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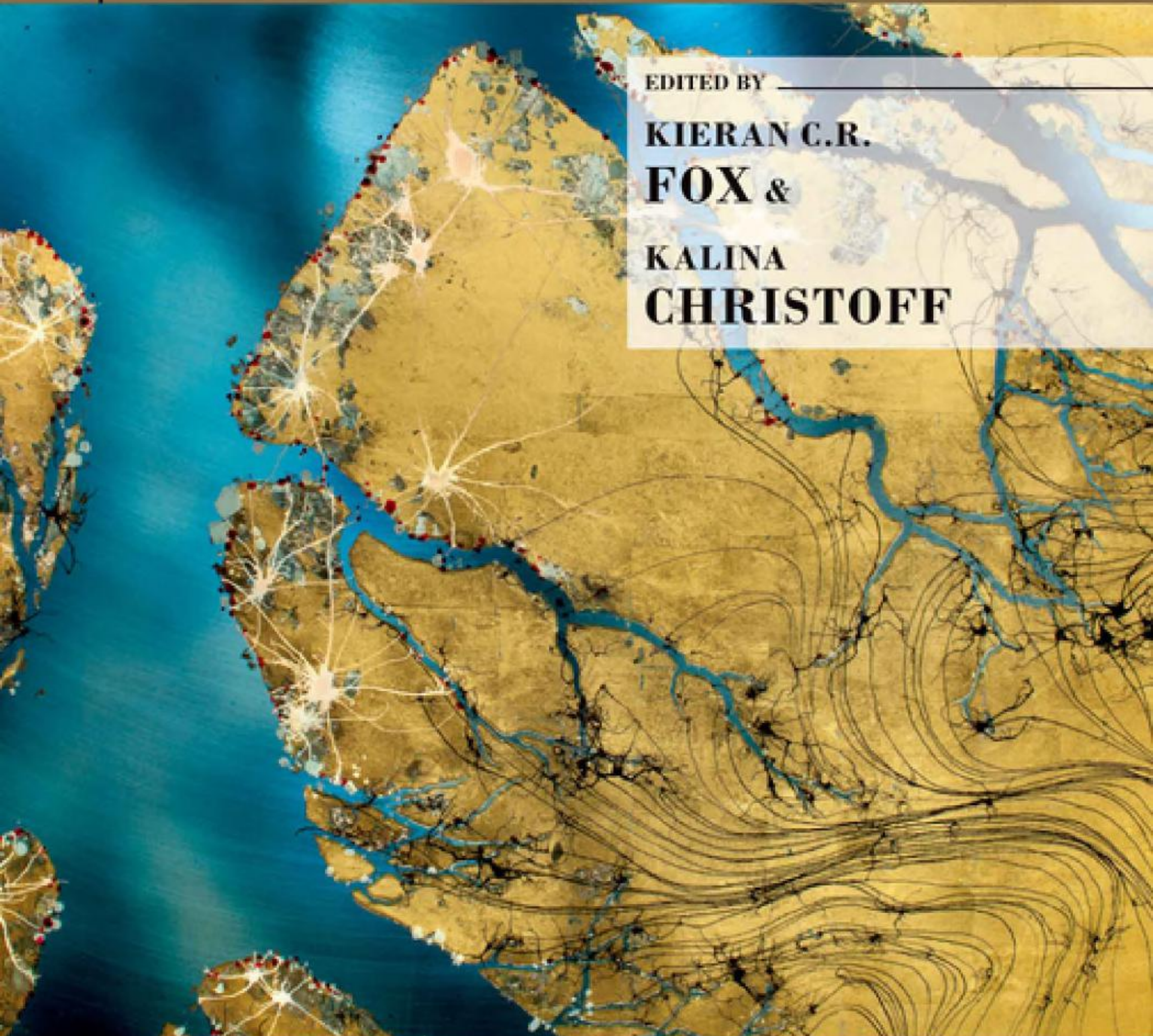

EDITED BY

KIERAN C.R. FOX &

KALINA CHRISTOFF

The Oxford Handbook *of* SPONTANEOUS THOUGHT

MIND-WANDERING, CREATIVITY, AND DREAMING

The Oxford Handbook of Spontaneous Thought

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Published in the United States of America by Oxford University Press
198 Madison Avenue, New York, NY 10016, United States of America.

Library of Congress Cataloging-in-Publication Data
Names: Fox, Kieran C. R., editor. | Christoff, Kalina, editor.
Title: The Oxford handbook of spontaneous thought : mind-wandering, creativity, and dreaming /
edited by Kieran C. R. Fox and Kalina Christoff.
Description: New York, NY : Oxford University Press, [2018] |
Series: Oxford library of psychology | Includes index.
Identifiers: LCCN 2017035192 | ISBN 9780190464745 (hardcover : alk. paper) | ISBN 9780190464769 (epub)
Subjects: LCSH: Creative thinking. | Thought and thinking. | Cognition.
Classification: LCC BF408 .O94 2018 | DDC 154.3—dc23
LC record available at https://lccn.loc.gov/2017035192

9 8 7 6 5 4 3 2 1

Printed by Sheridan Books, Inc., United States of America

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Kieran C. R. Fox studied neuroscience, philosophy, and world religions during his undergraduate degree at McGill University. He used functional neuroimaging to study the cognitive neuroscience of meditation and spontaneous thought during his Master's and PhD at the University of British Columbia, working with Dr. Kalina Christoff. Currently, he is using intracranial electroencephalography to pursue these lines of research in the Department of Neurology at Stanford University, working with Dr. Josef Parvizi.

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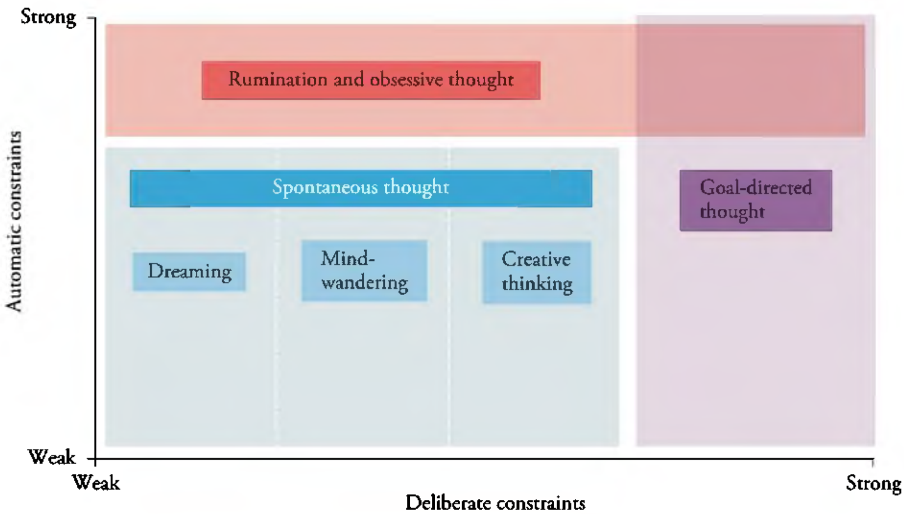

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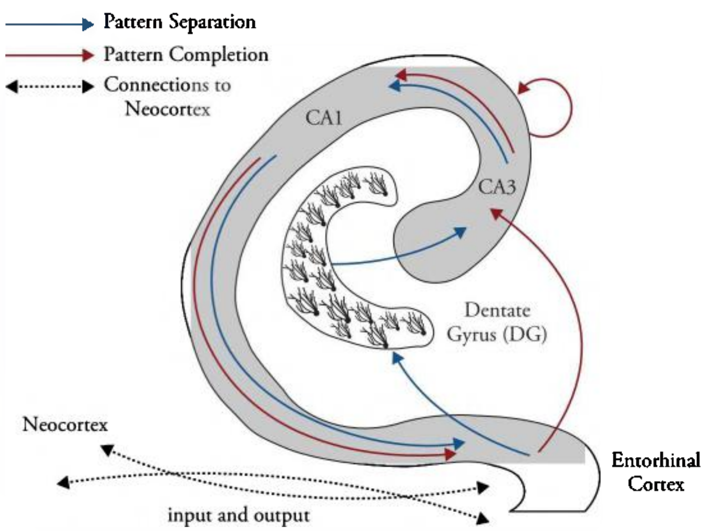

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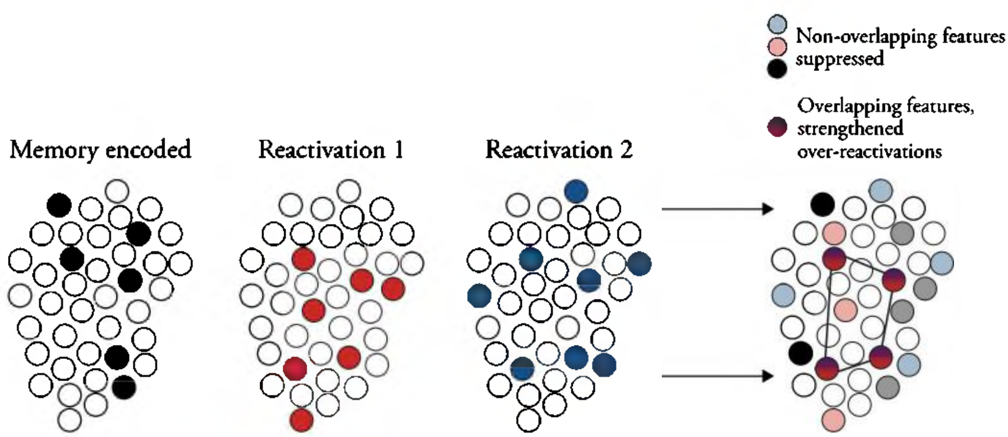

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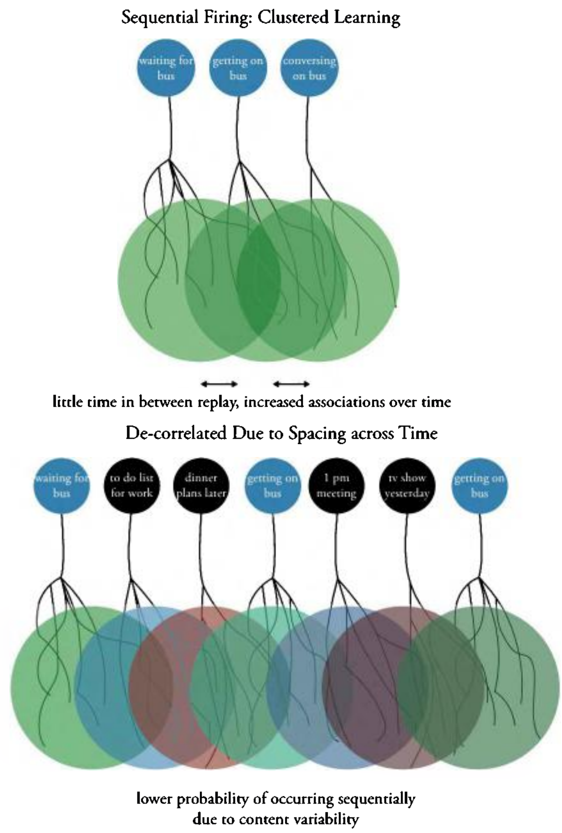

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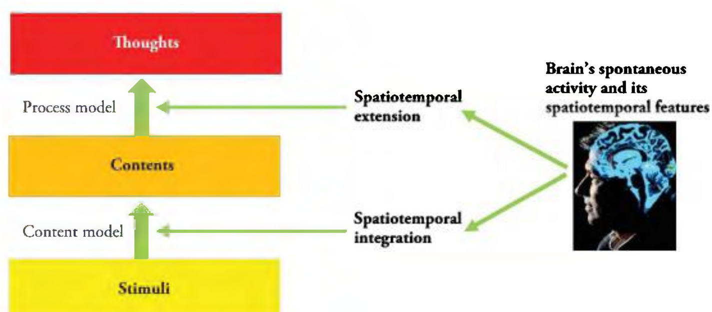

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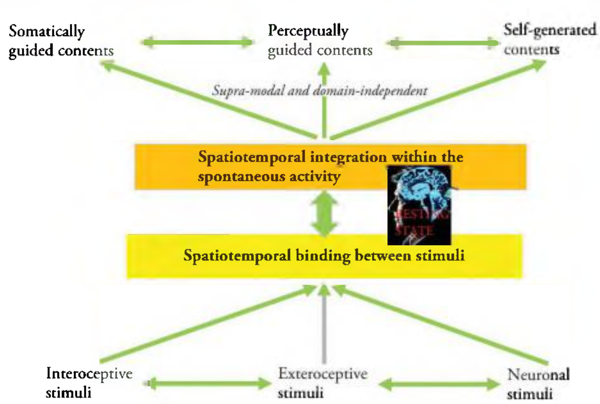

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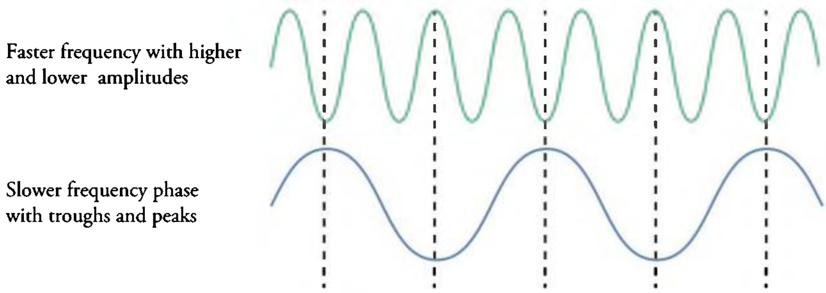

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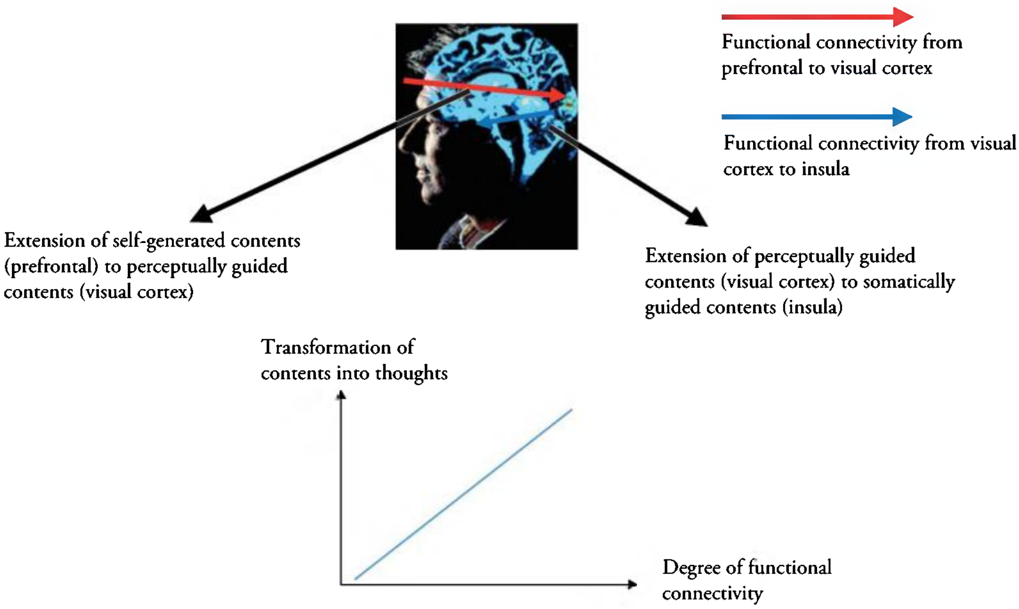

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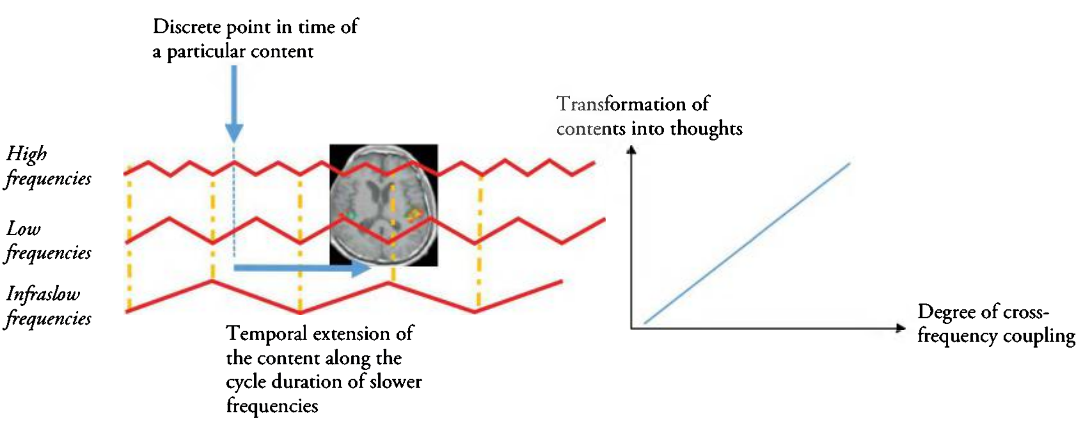

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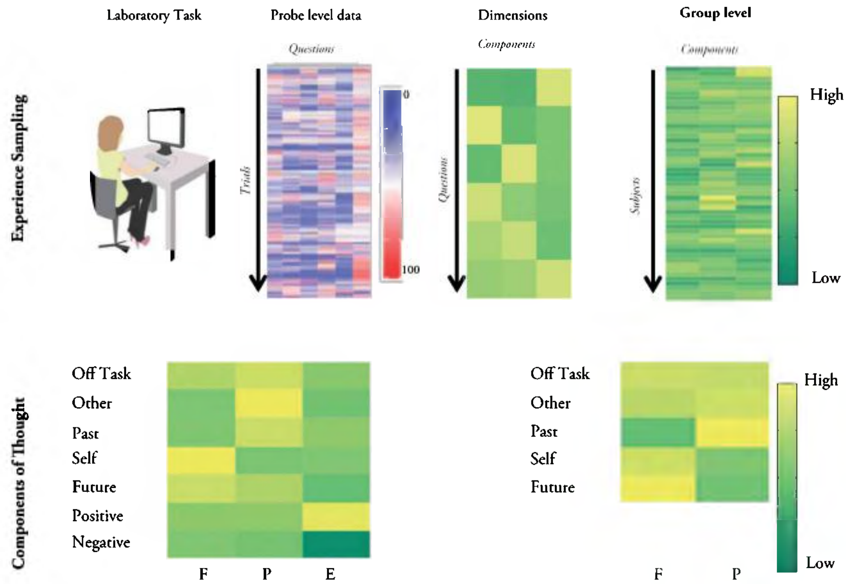

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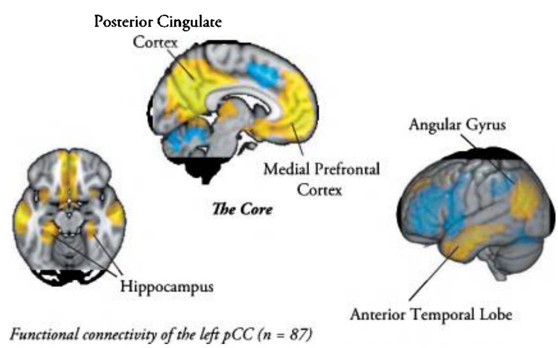

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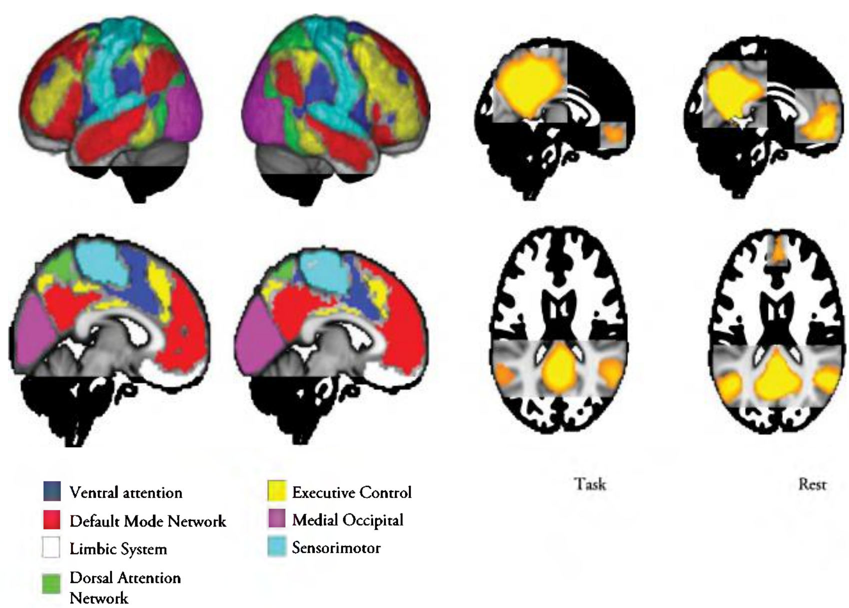

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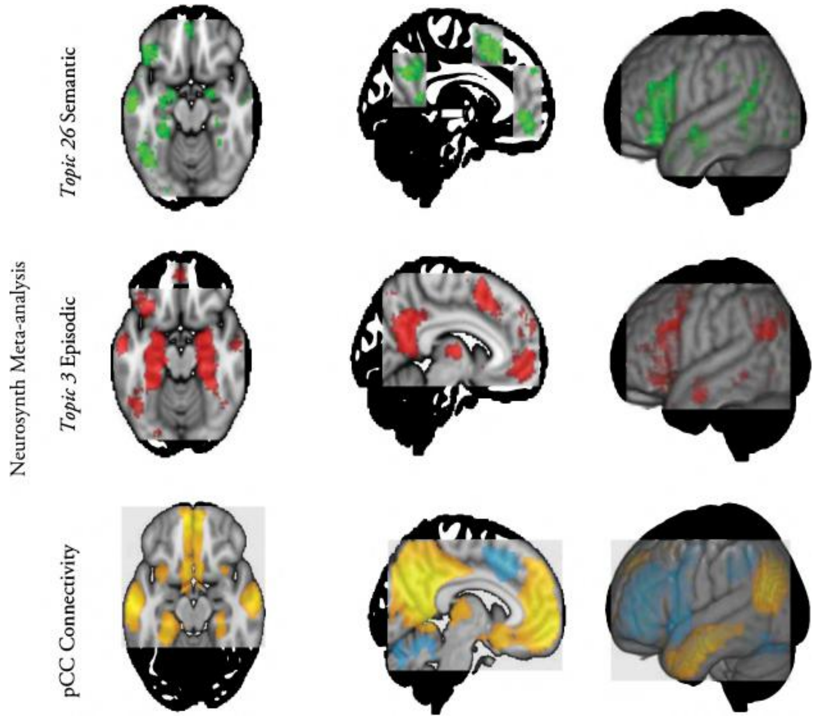

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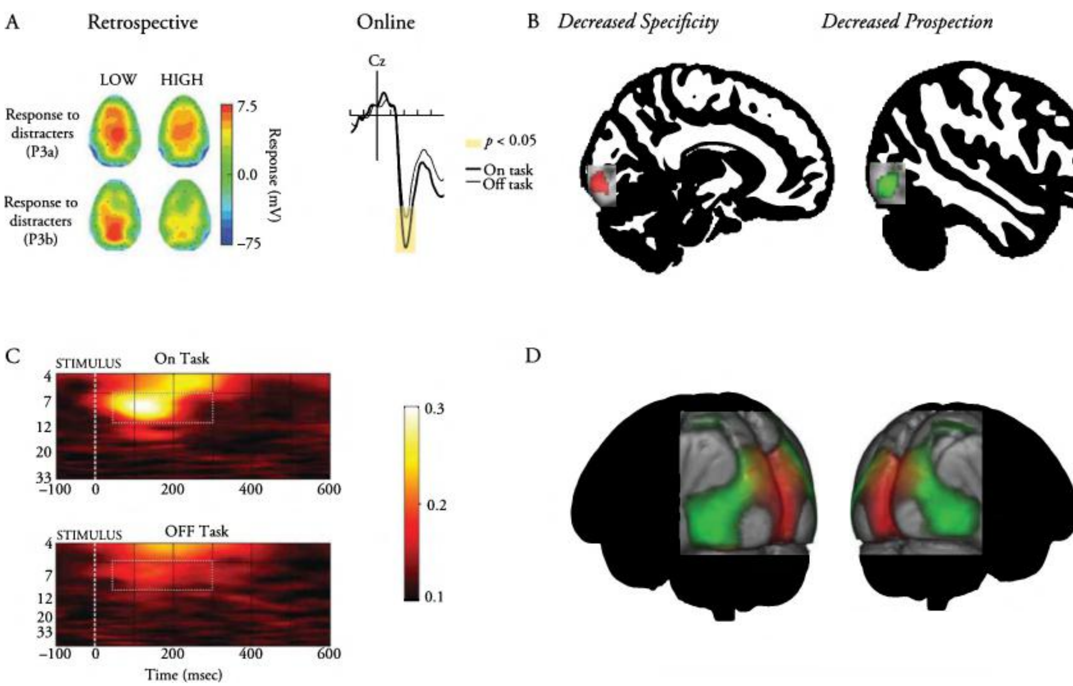

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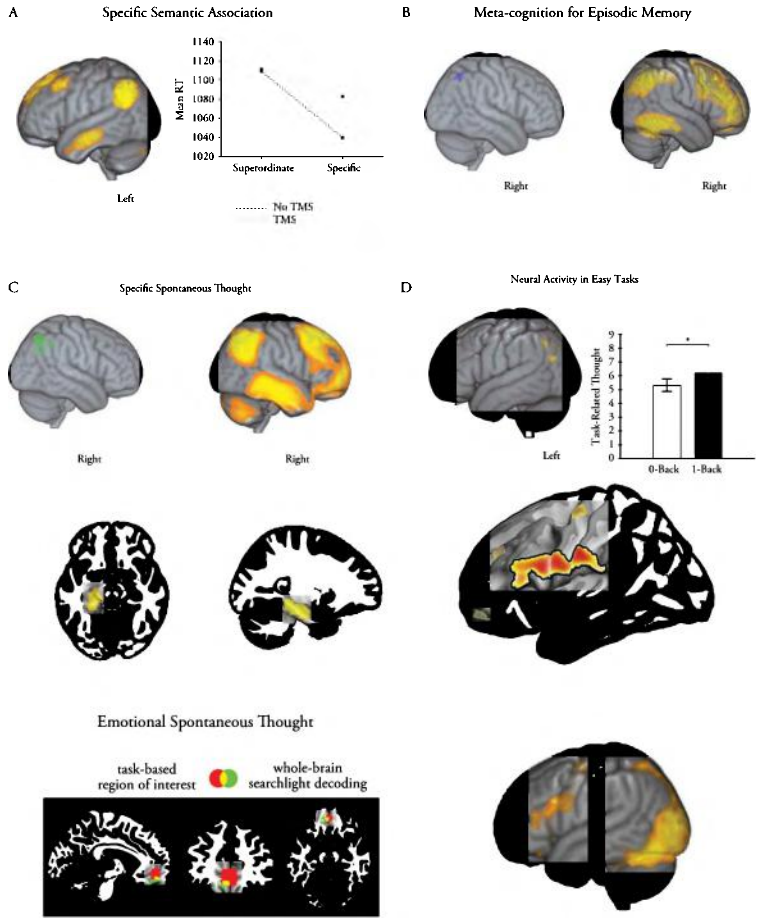

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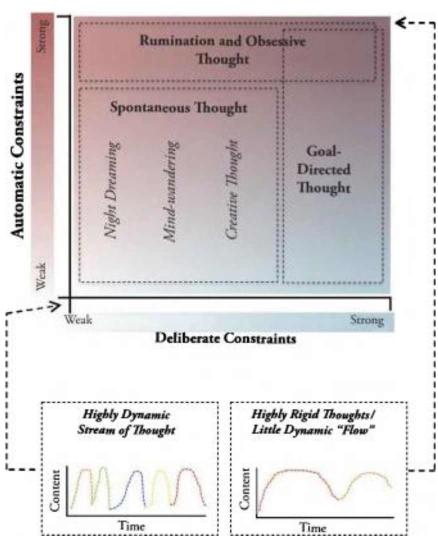
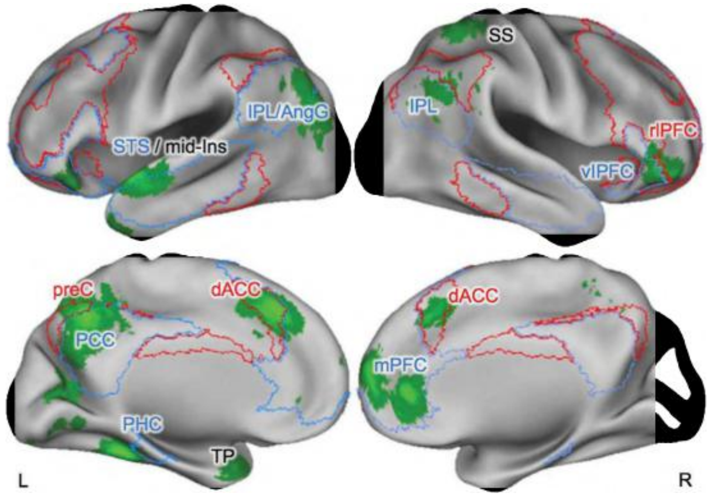


Figure 13.1. A dynamic model of spontaneous thought. Spontaneous thought spans a conceptual space, inclusive of night dreaming, mind-wandering, and creative thought, that is relatively free from two kinds of constraints: (1) deliberate constraints (x-axis), and (2) automatic constraints (y-axis). According to this model, adapted and extended from Christoff and colleagues (2016), ruminative and obsessive thought are not truly spontaneous in nature due to strong bottom-up, "automatic" constraints that bias their content. The dynamics of thought—the way thoughts unfold and flow over time—represent an important element of this model. As shown in the bottom left box, thoughts that are free from both kinds of constraints should transition relatively quickly and span different phenomenological content (represented by different colors). Conversely, excessively constrained thoughts should have longer durations with similar content (bottom right box).



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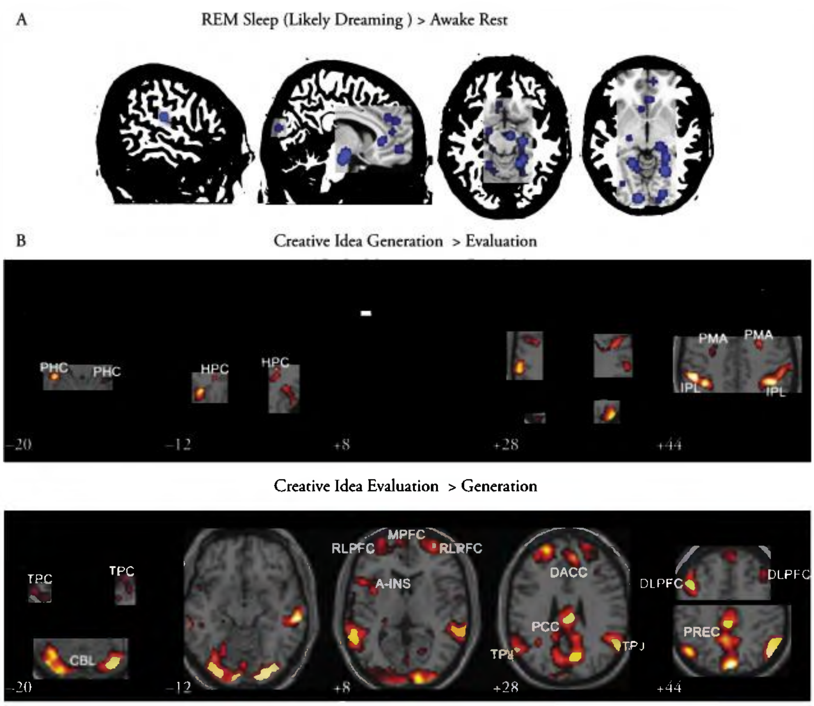


Figure 13.4. Neural underpinnings of night dreaming and creative thought. (A) A meta-analysis of neuroimaging studies on REM sleep (a sleep stage characterized by dreaming) reveals greater activity in a number of brain regions compared to awake rest. Among others, these include medial temporal and medial prefrontal regions within the default network, and visual cortex. (B) Creative thinking is associated with distinct temporal activity dynamics. The medial temporal lobe becomes engaged to a greater degree early in the creative process while generating a creative idea. Other regions within the default network, as well as key frontoparietal control network regions, become engaged to a greater degree during later stages of creative thinking, when evaluating creative ideas. A-INS = anterior insula; dACC = dorsal anterior cingulate cortex; DLPFC = dorsal lateral prefrontal cortex; CBL = cerebellum; HPC = hippocampus; IPL = inferior parietal lobule; MPFC = medial prefrontal cortex; PHC = parahippocampus; PMA = premotor area (PMA); PCC = posterior cingulate cortex; PREC = precuneus; TPC = temporopolar cortex; TPJ = temporoparietal junction. Figures adapted from Fox et al., 2015 (A), and Ellamil et al., 2011 (B).

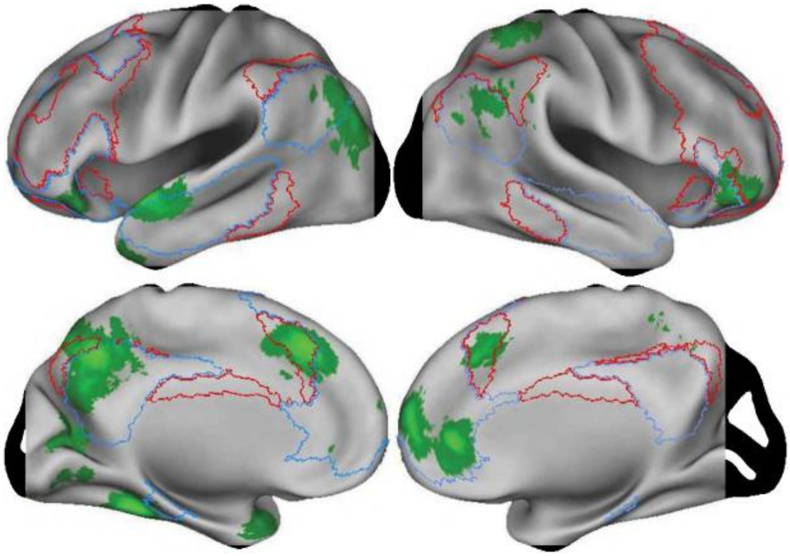
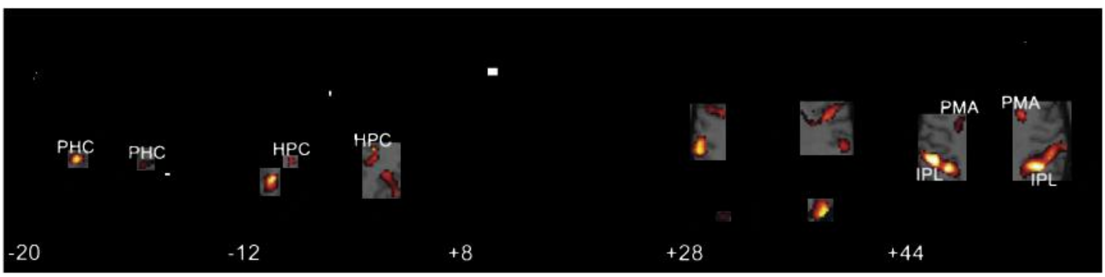


Figure 14.1. Meta-analysis of brain areas consistently recruited by self-generated forms of thought. Meta-analytic clusters indicating brain regions consistently recruited across various forms of spontaneous and self-generated thought. Outline of the frontoparietal (red) and default (blue) networks are shown for comparison. Reproduced with permission from Fox et al. (2015).



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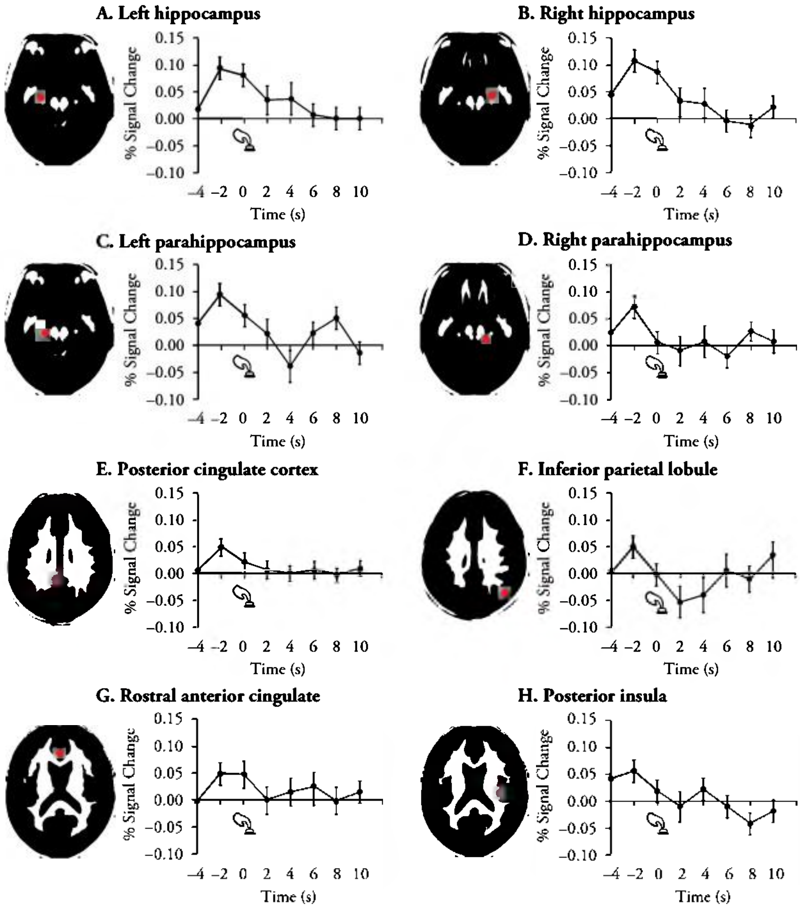

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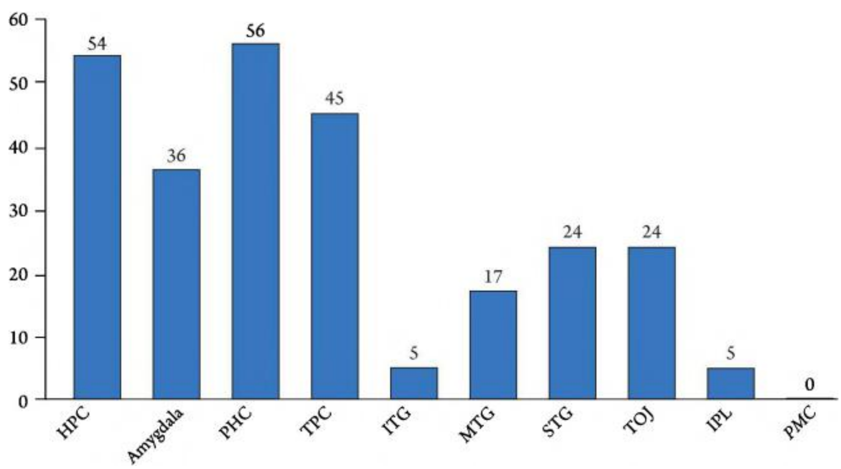

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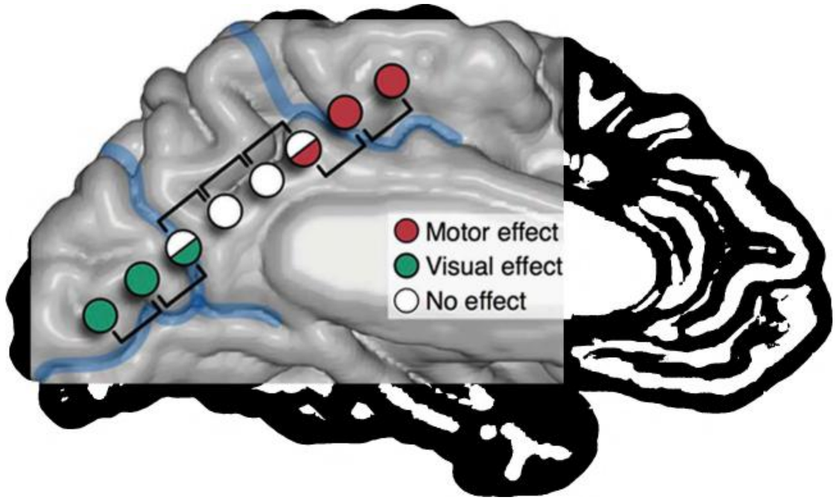

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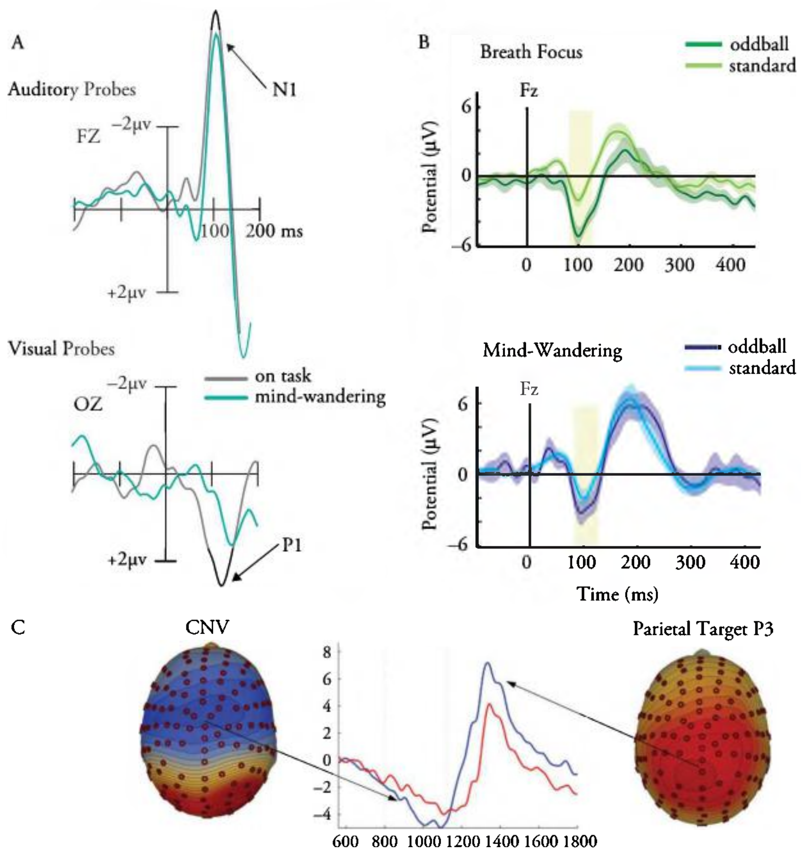

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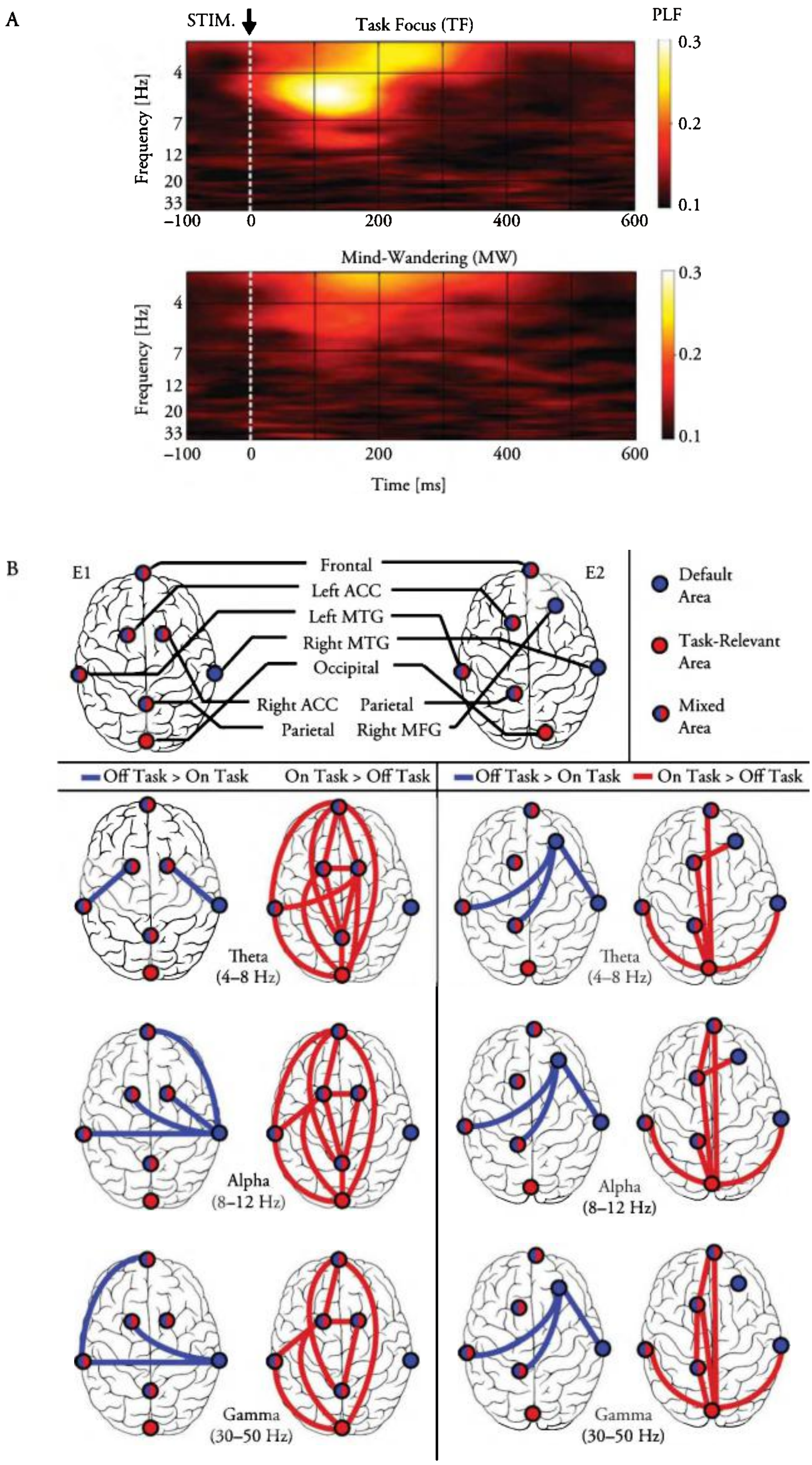

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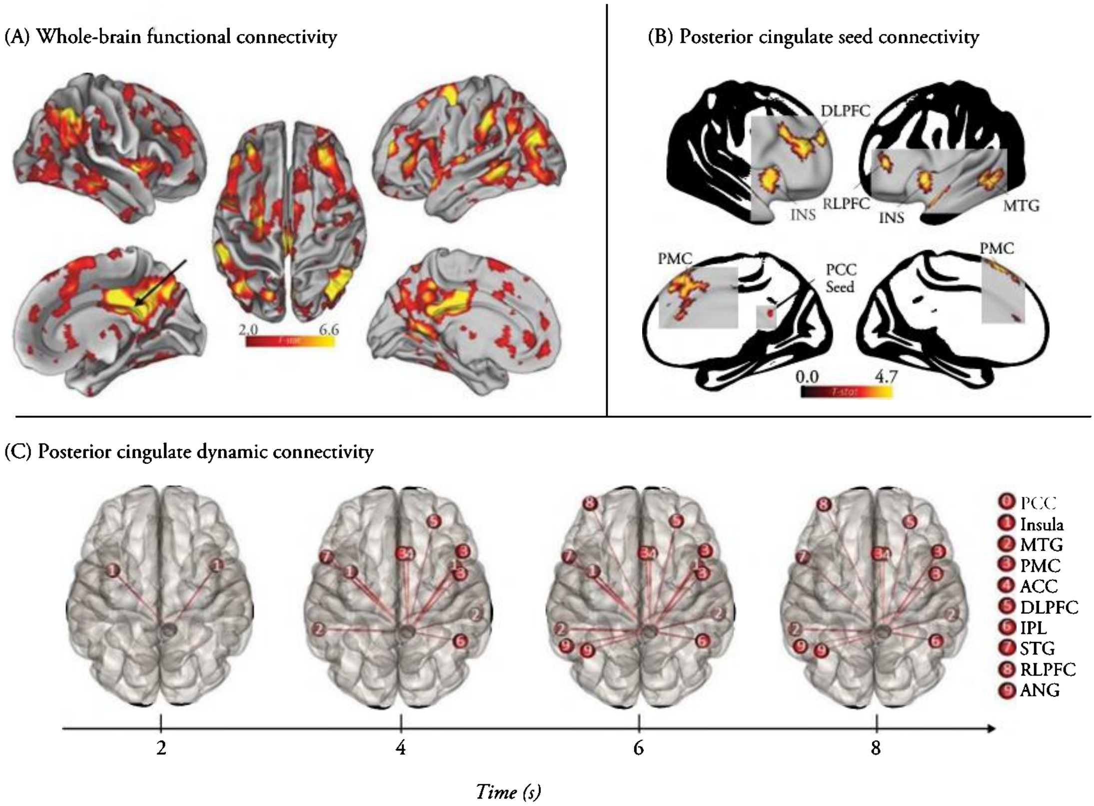

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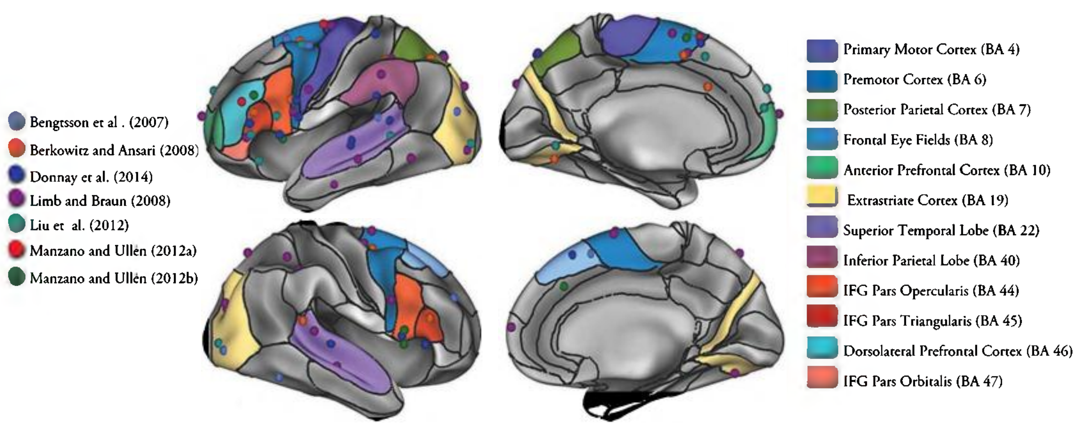

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Figure 25.1. Examples of traditional Chinese and realistic old landscape paintings. Adapted with permission from Wang et al. (2015).

Figure 25.2. The aesthetic triad. According to this framework, aesthetic experiences are an emergent property of the interaction of the sensory-motor, emotion-valuation, and knowledge-meaning neural systems. Reprinted, with permission, from *Trends in Cognitive Sciences* 18 ©2014 by Cell Press.

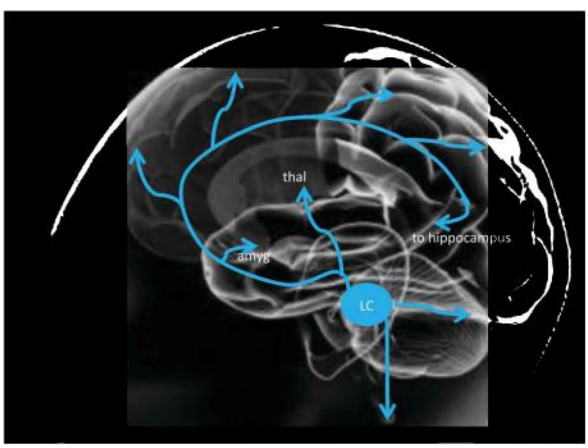

Figure 26.1. Noradrenergic pathways. The locus coeruleus (LC) projects posteriorly to the cerebellum and up to the thalamus (thal) and amygdala (amyg), as well as throughout the neocortex along a pericingular tract, also terminating posteriorly at the hippocampus (Heimer, 1995). The descending fibers to the spinal cord are also shown. Not shown is the lateral tegmental noradrenergic system, which also projects to the amygdala and down to the spinal cord. Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284–304). New York: Oxford University Press.

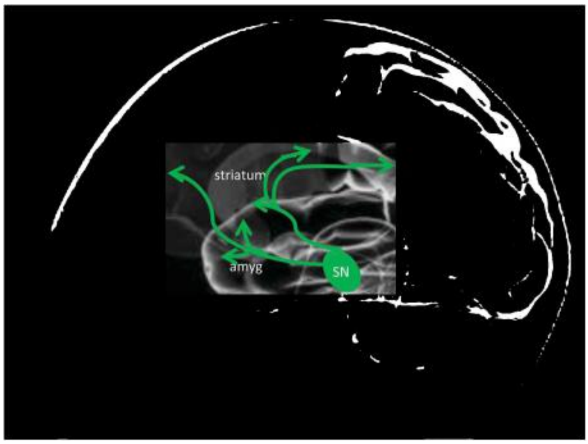

Figure 26.2. Dopaminergic pathways. Projections from the substantia nigra (SN) to the striatum are demonstrated, as are projections from the ventral tegmental area (VTA) to the amygdala (amyg), ventral striatum, and frontal cortex (Heimer, 1995). Not shown are the tuberoinfundibular and posterior hypothalamic dopaminergic systems. Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284–304). New York: Oxford University Press.

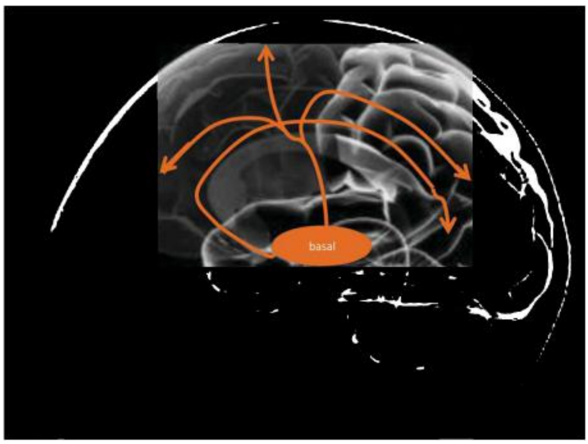

Figure 26.3. Cholinergic pathways. Cortical projections from the basal forebrain are demonstrated to the cingulate and pericingulate cortex, as well as the mesial frontal cortex along a mesial pericingular tract, and laterally through the external capsule and claustrum to the capsular region and lateral neocortex (Selden et al., 1998). Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284-304). New York: Oxford University Press.

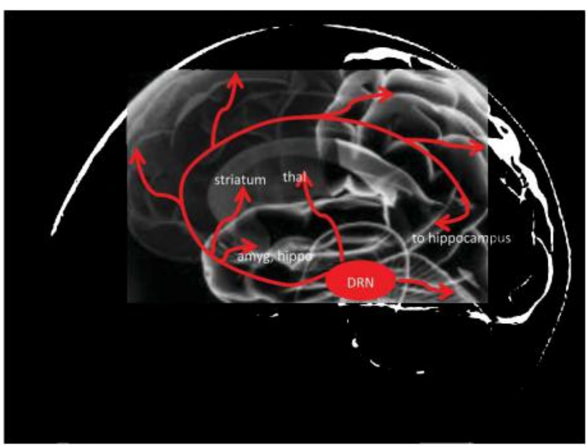

Figure 26.4. Serotonergic pathways. The dorsal raphe nuclei (DRN) project posteriorly to the cerebellum and intracerebellar nuclei, and up to the thalamus (thal), with projections also to the amygdala (amyg), hippocampus (hippo), hypothalamus, olfactory and entorhinal cortices, then to the ventral striatum, as well as throughout the neocortex along a pericingular tract, also terminating posteriorly at the hippocampus (Heimer, 1995). Not shown are the caudal raphe nuclei, which also project to the cerebellum and intracerebellar nuclei, and down to the spinal cord. Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284–304). New York: Oxford University Press.

Stage	Sub stages[1]	EEG Signature	EEG Signature Waveform
Wake	1	Alpha wave train	
	2	Alpha wave intermittent (>50%)	
NREM 1	3	Alpha wave intermittent (<50%)	
	4	EEG flattening (<20 µV)	
	5	Theta ripples	
	6	Vertex sharp wave (<200 µV)	
	7	> 1 Vertex sharp wave (<200 µV)	
	8	Incomplete spindle	
NREM 2	9	Complete Spindle	
NREM 3–4		Delta	
REM		Theta	

Figure 28.1. Main electrophysiological correlates of each sleep stage. NREM 1 substages are included, as is eyes-closed waking rest, for comparison. Note the easily differentiable EEG signature accompanying each sleep stage. Reproduced from Stenstrom, Fox, et al. (2012).

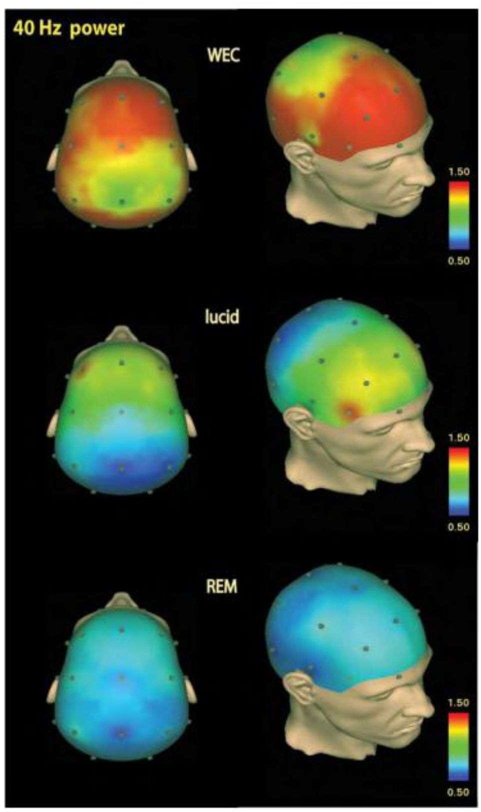

Figure 29.1. Standardized current source density power (CSD) in a waking participant with eyes closed (top), during a lucid dream (middle), and during ordinary REM sleep (bottom). Topographical images are based on movement-free EEG episodes and were corrected for eye movements. WEC refers to waking with eyes closed. Darker color corresponds to higher 40 Hz activity. For a full color picture, see Voss et al., 2009. Source: Voss et al. (2009).

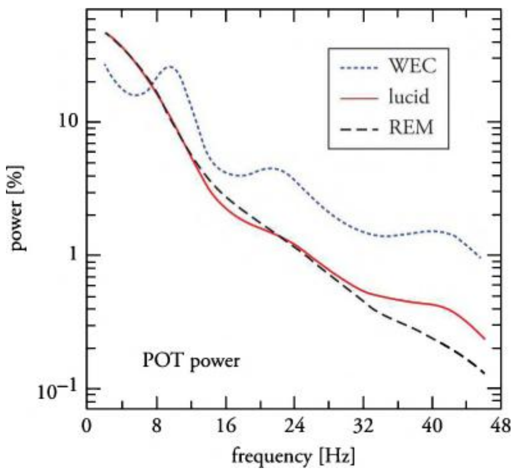

Figure 29.2. EEG Power (POT = scalp potential) in the analyzed frequencies from 1 to 48 Hz, averaged over three lucid dreams and for all electrode recording sites, corrected for eye movements (Gratton et al. 1983). Blue line: Waking, eyes closed (WEC), lying down. Red line: lucid dream sleep. Black line: non-lucid REM sleep. Source: Voss et al. (2009).

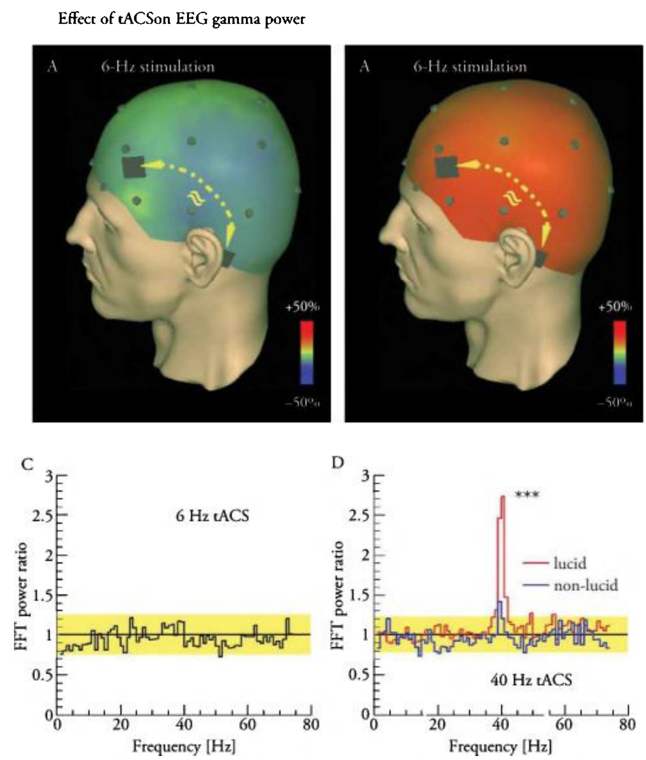

Figure 29.3. Effect of transcranial alternating current stimulation (tACS) on EEG gamma power (37–43 Hz). tACS electrodes were placed bilaterally at frontal and temporal positions (black rectangles) and current was flowing back and forth between these electrodes. EEG electrode placements are indicated as dark dots. (A) Stimulation with 6 Hz resulted in no change in lower gamma activity around 40 Hz (37–43 Hz). (B) Stimulation with 40 Hz led to a strong increase in lower gamma activity around 40 Hz. (C) Grand average Fast Fourier Transform (FFT) power ratios of activity during versus activity prior to stimulation for the 6-Hz stimulation condition. Yellow shading represents mean values ± 2 standard errors (s.e.). Any excursions outside of this range would be considered significant at least at the $p < .05$ level. However, with 6 Hz, we see no significant stimulation-induced increase in 6 Hz activity. Grand average FFT power ratios of activity during versus activity prior to stimulation for the 40-Hz stimulation condition. Yellow shading represents mean values ± 2 standard errors (s.e.). Note that lucid dreams (red line) are accompanied by a significantly larger increase in the 40 Hz frequency band than non-lucid dreams (blue line) (independent two-sided t tests between lucid and non-lucid dreams during stimulation with 40 Hz: $t_{40Hz} = 5.01$, df = 35, $p < 0.001$). Source: Voss & Hobson (2015).

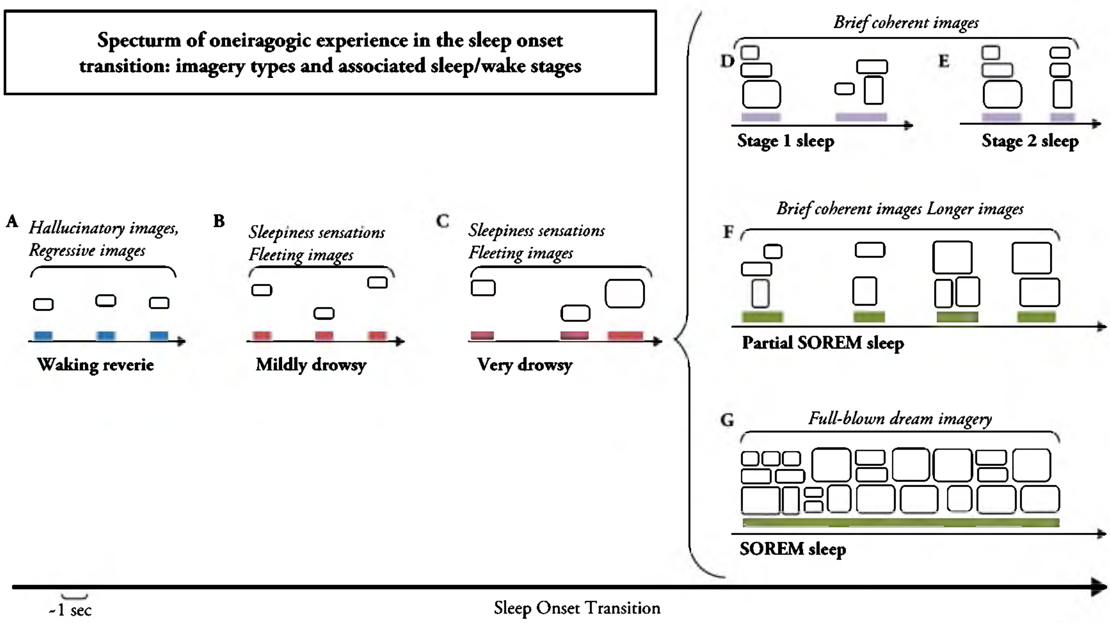

Figure 30.1. Some varieties of experience falling on the oneiragogic spectrum (i.e., the phenomenological events characterizing the sleep-onset transition). Experiences of increasing complexity are proposed to occur during passage through different sleep-onset states, as described in the text. The briefest and least complex events are presumed to occur during microsleeps that may occur during (A) waking reverie (blue bars) or (B) mildly or (C) very drowsy wakefulness (red bars) and more complex events during (D) Stage 1 and (E) Stage 2 NREM sleep (purple bars). Longer images and full-fledged dreaming occurs during either (F) Partial SOREM sleep, when only some signs of REM sleep (e.g., muscle atonia, alpha EEG reduction) are visible (green bars), or (G) SOREM sleep, when all basic signs of REM sleep are visible. SOREM events are very prevalent, occurring under various situations of sleep disruption, including especially combinations of low NREM and high REM propensity.

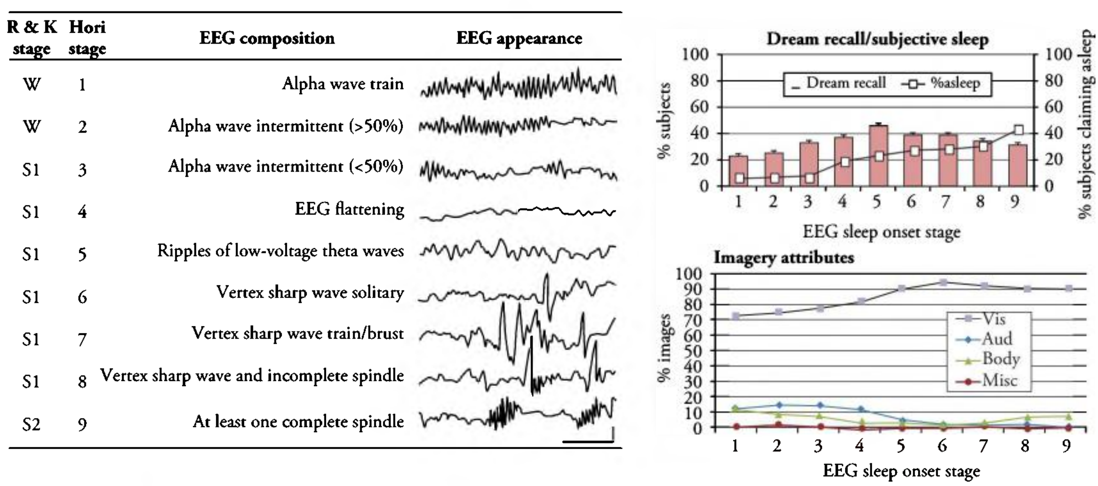

Figure 30.2. Left panel: definitions of Hori sleep-onset substages (Hori stage) in relation to standard Rechtschaffen and Kales sleep/wake stages (R&K stage). Right panel: Percentages of subjects reporting dreams and claiming to be asleep (upper panel) and sensory attributes of reported imagery for 9 EEG-defined sleep-onset substages. Note that visual imagery can occur in the earliest substages. W = wake; S1 = stage 1; S2 = stage 2. Source: Hori, Hayashi, & Morikawa, (1994).

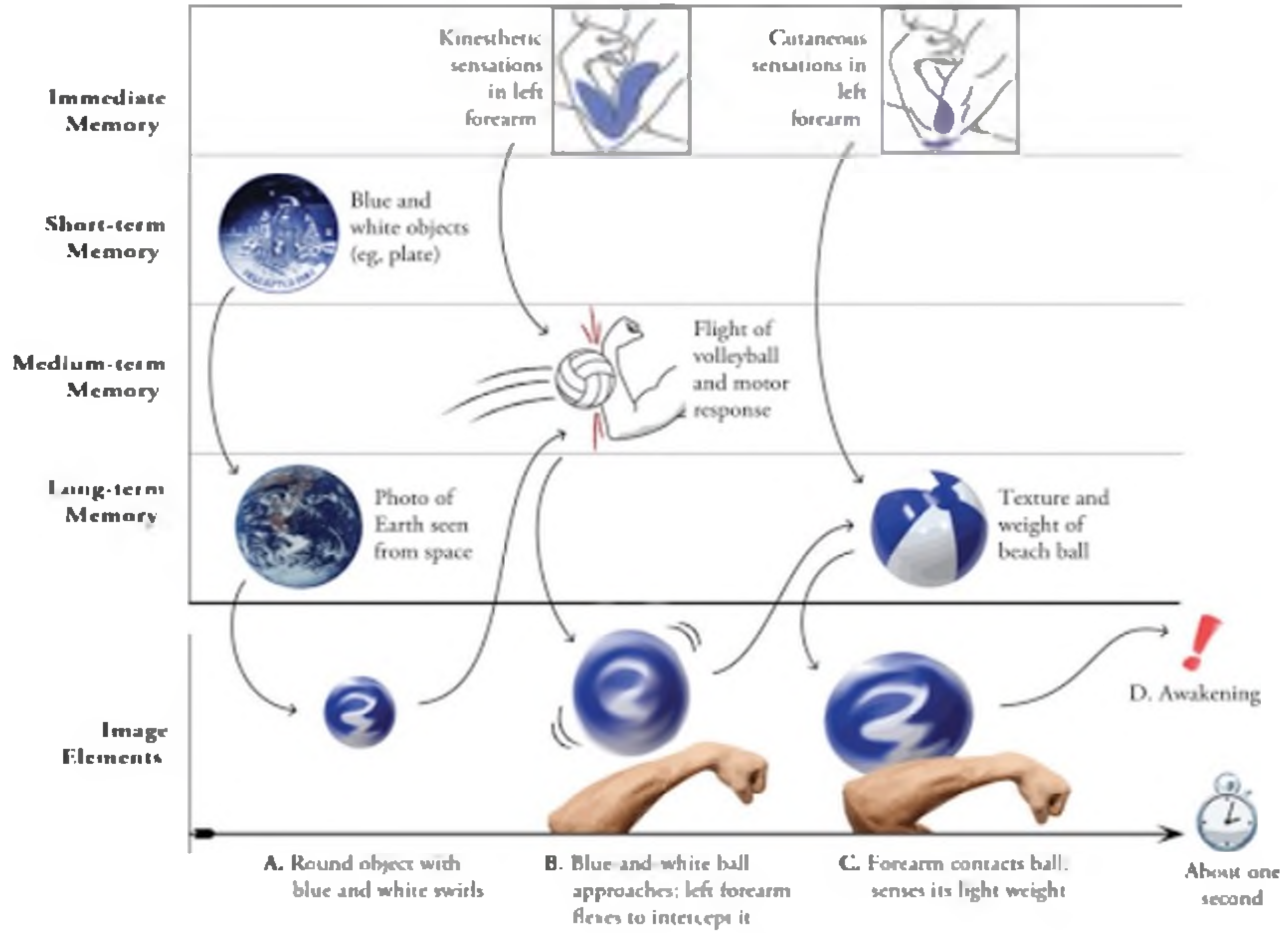

Image: I see a small blue-and-white object far off to my left. Its colors are very bright and form a swirled pattern. It suddenly and unexpectedly flies toward me, horizontally but with a slight arc. It was as if someone had thrown it at me. Close to me it is about the size of a basketball. I make a quick, reflexive movement with my left arm as if to strike or intercept it. For an instant I feel a sensation on the upper part of the elbow and forearm as the ball makes contact with me From this I perceive that the ball is much lighter and thinner in consistency than I had expected–like a beach ball. Though I expect it to bounce, it stays in my arm as if I had caught it there. However, I wake up abruptly at the moment of contact, before anything else can happen. I was surprised by the image.

Figure 30.5. Multi-temporal description of memory sources associated to a single, one-second microdream (right panel) and hypothetical model of their combination during image formation. Four categories of memory elements (*y*-axis) combine to produce elements of the microdream as they unfold chronologically. Arrows indicate possible causal influences among elements via a process referred to as *transformative priming*. The image is proposed to unfold in three steps: (1) a combination of several short-term and one long-term memory elements to produce a round, blue-and-white object seen at a distance; (2) combination of the prior result with immediate memory impressions (kinesthetic) and one medium-term memory (flight of ball, motor response) to produce a transformed image of an approaching ball and reflex motor response; (3) combination of the prior result with further immediate memory impressions (cutaneous), and a long-term memory element (beach ball) to produce a transformed image of object contact with cutaneous feedback. Elements are thought to transform subsequent elements as they trigger ("prime") them—but all very quickly and at a preconscious level. The result is a continuous, de novo integration of memory elements that reflects features from all of the contributing memories but which expunges other features. In the present case, the primary memory element—a reflex arm movement—is modified by several secondary elements: features such as color, trajectory, weight, and texture are changed, but only slightly. Transformative priming may sustain the spatiotemporal coherence of the imagery sequence, may account for its persistently novel character, and may explain why larger episodic memories are typically not represented. Source: Nielsen (2017; 1995).

Figure 31.1. A representation of sleep paralysis experience. The sleeper is awakened suddenly and sees a menacing shadowy creature on top of him. He experiences the sensation of being pushed into the bed, while the bed itself is swirling in a sort of a tornado. The two faces of the dreamer represent the "double" consciousness during sleep paralysis: he is simultaneously terrified of the supernatural attacker and also knows that if he does not resist the experience and allows himself to drift back into sleep he may have a lucid dream (this lucid consciousness is represented as a sleeping face with a detailed brain, denoting vibrant possibilities of lucidity). Artist: Benjamen Samaha, Montreal, Canada, 2016. Reproduced with the artist's permission.

Figure 31.2. Henry Fuseli, *The Nightmare* (1781). Detroit Institute of Art. Public Domain image: https://commons.wikimedia.org/w/index.php?curid=15453518

Figure 31.3. Takehara Shunsen, *Yamachichi* (1841). Public domain image: https://commons.wikimedia.org/w/index.php?curid=2074508

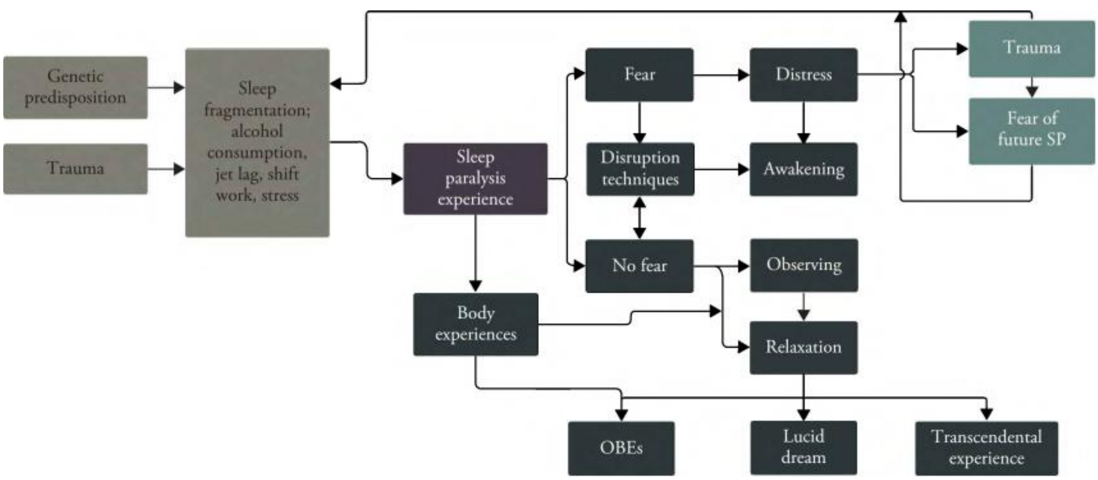

Figure 31.4. Predisposing, precipitating factors and experience and outcome of sleep paralysis episodes. Note: OBE = out-of-body experience; SP = sleep paralysis.

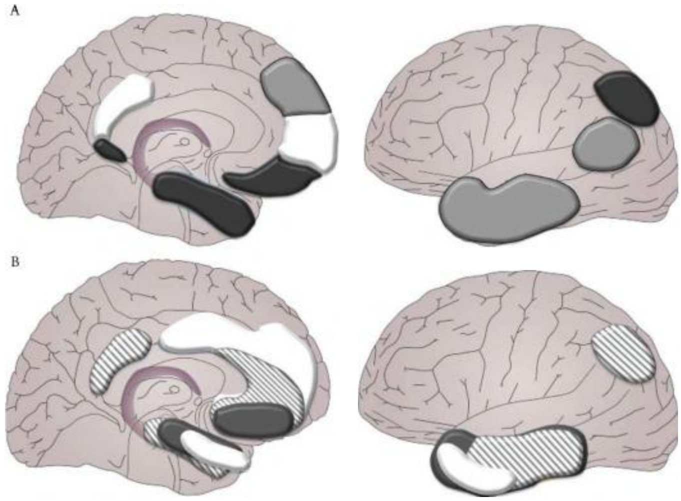

Figure 35.1. (A) The default network. The MTL subsystem (dark grey) encompasses the hippocampal formation, parahippocampal cortex, retrosplenial cortex, ventromedial prefrontal cortex, and posterior inferior parietal lobule, whereas the dmPFC subsystem (light grey) comprises the dorsomedial prefrontal cortex, temporoparietal junction, lateral temporal cortex, and temporal pole. The midline core (white) refers to the anterior medial prefrontal cortex, and the posterior cingulate cortex. Regional anatomical boundaries are approximate. Abbreviations: dmPFC = dorsomedial prefrontal cortex; MTL = medial temporal lobe. (B) Characteristic patterns of atrophy in Alzheimer's disease, semantic dementia, and behavioral variant FTD. Patients with Alzheimer's disease (diagonal stripes) show hippocampal, medial temporal and retrosplenial cortex involvement, spreading to lateral parietal and medial prefrontal regions with disease progression. In semantic dementia (dark grey), the typical pattern of atrophy is lateralized (generally left greater than right hemisphere), targeting the anterior temporal lobes and temporal pole, including the hippocampal formation and amygdala, and spreading to ventromedial prefrontal cortical regions as the disease progresses. Patients with behavioural variant FTD (white) show bilateral atrophy in mesial and orbital frontal regions, extending to the temporal pole and hippocampal formation as the disease progresses. Regional anatomical boundaries are approximate. Abbreviation: FTD = frontotemporal dementia. Figure and legend adapted with permission from *Nature Reviews Neurology* (Irish, Piguet, et al., 2012).

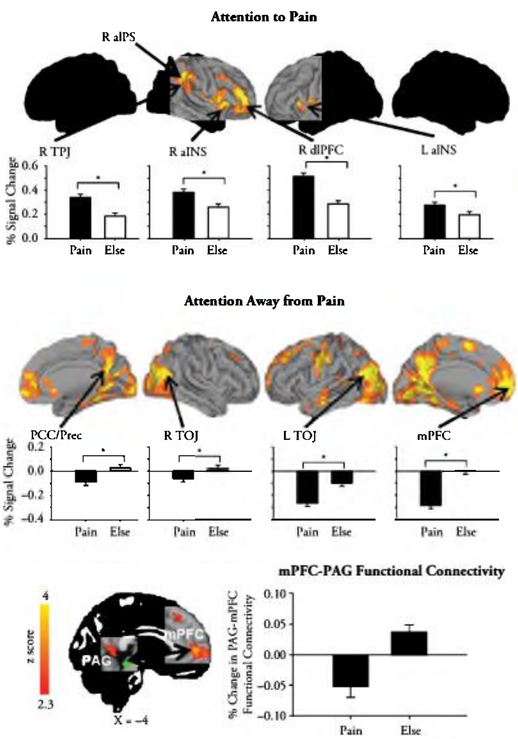

Figure 37.1. Brain dynamics of self-reported attention to and spontaneous mind-wandering from pain. Brain regions within salience and frontoparietal networks show increased activation during attention to pain, compared to attention away from pain (top). During attention away from compared to toward pain, brain regions in the default mode network show decreased deactivation (middle) and the periaqueductal gray shows increased functional connectivity with the medial prefrontal node of the default mode network. aINS = anterior insula; aIPS = anterior intraparietal sulcus; mPFC = medial prefrontal cortex; dmPFC = dorsomedial prefrontal cortex; dlPFC = dorsolateral prefrontal cortex; MTL = medial temporal lobe; mPFC = medial prefrontal cortex; PAG = periaqueductal gray; PCC = posterior cingulate cortex; Prec = precuneus; TOJ = temporo-occipital junction; TPJ = temporoparietal junction. Adapted with permission from Kucyi et al. (2013).

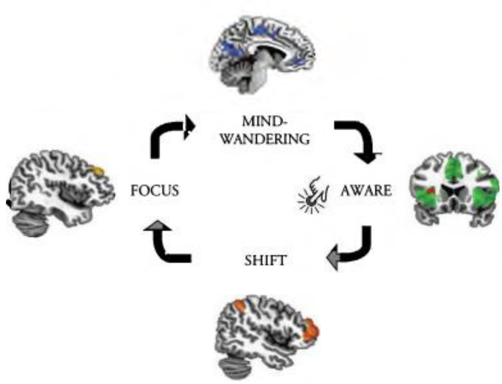

Figure 39.2. Brain networks involved in FA meditation. Using a button-press from the participant to mark the moment of awareness, four brief cognitive phases were defined around this time point, and neural activity was analyzed accordingly. These results show activity during the FOCUS, AWARE, and SHIFT phases compared to the MW phase; MW activity is compared to SHIFT activity. Mind-wandering was associated with default mode regions (blue), awareness of mind-wandering was associated with the salience network (green; red shows activations due to a motor control for the button press), and shifting and maintaining attention was associated with the executive network (orange, light orange). Image modified with permission from Hasenkamp (2014).

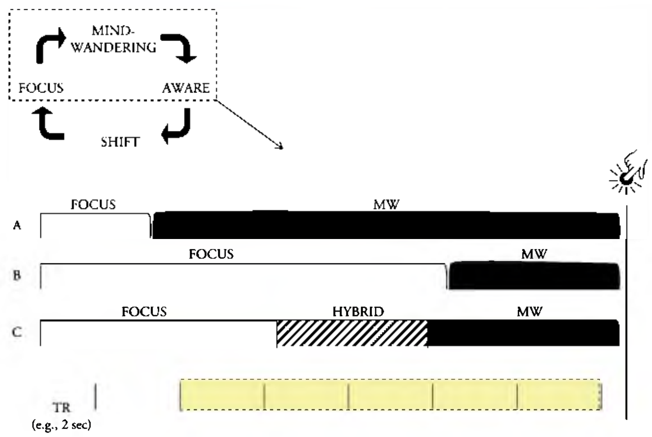

Figure 39.3. Defining the temporal window of analysis. This schematic depicts three hypothetical cognitive scenarios and related window of analysis for a neuroimaging study of self-caught mind-wandering. Tick marks denote TRs (the fMRI scanner's sampling rate, here 2 seconds each), and the yellow bar represents an analytical window of 10 seconds prior to the button press. (A) A scenario where the window of analysis is accurate and only includes mind-wandering states. (B) A scenario where the window is too long, and includes contaminating focused states. (C) A graded transition between focused attention and mind-wandering, showing a hybrid state where some portion of the attention remains on the object for a time, but spontaneous thought still occurs. In this case, the window contains all three mental states, again confounding the analysis.

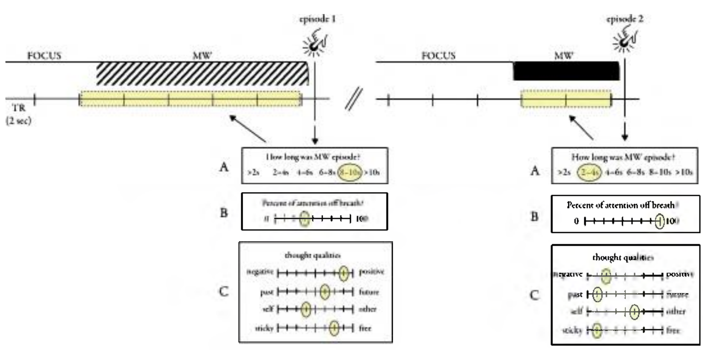

Figure 39.4. Possible characterization of individual thought episodes through first-person reports during FA meditation. This schematic shows two temporally and phenomenally different episodes of mind-wandering that could occur during the course of FA meditation. In this kind of design, each time the practitioner becomes aware of mind-wandering, she would press a button, and then provide subjective report on any number of variables, including (A) the estimated duration of the episode (based on units of analysis, such as TRs); (B) percentage of off-task attention; and (C) various dimensions of thought content. These and other measures could be gathered alone or in combination, depending on the research question. Subjective data could then be used to drive analyses of physiological correlates by providing both temporal and phenomenological constraints. For example, the window of analysis for mind-wandering could be customized for each episode, as shown by the yellow bars. Other approaches could combine episodes with similar characterizations (e.g., percent attention, thought content, etc.) to determine specific neural correlates.

Figure 40.1. Bruce McCandless II, floating alone in the darkness of space. Source: NASA.

Figure 40.4. REST chamber, University of British Columbia. Photo by Peter Suedfeld.

Figure 40.5. REST flotation tank. Reproduced by permission of Float On LLC, Portland, OR.

Figure 40.6. Art from the flotation tank. Created by Cori Kindred and reproduced by permission of the publisher and copyright holder, Float On.

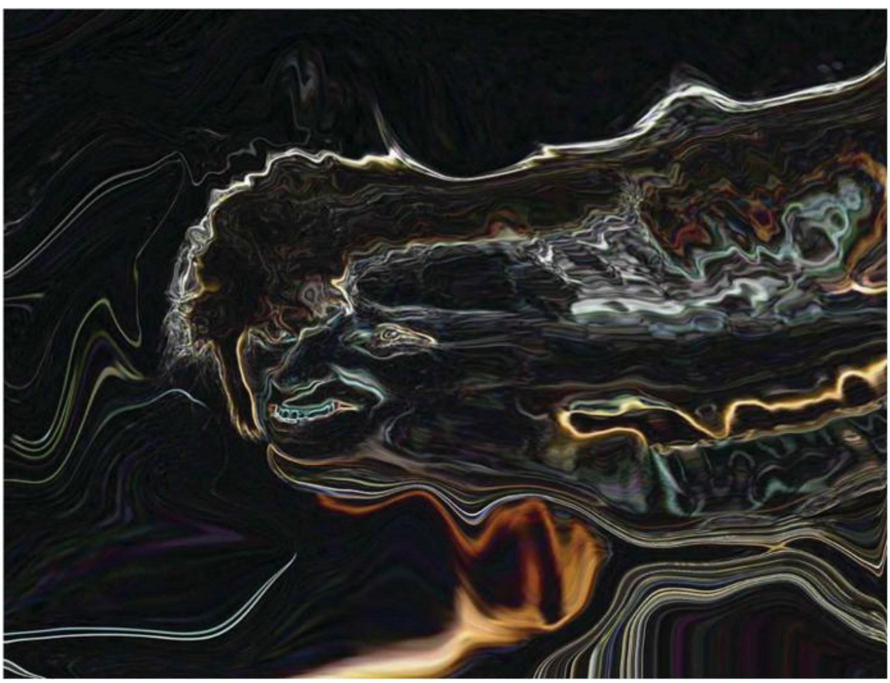

Figure 40.7. "Lady Darkness": Art from Dark Therapy.

PART I

Introduction and Overview

CHAPTER

1

Introduction: Toward an Interdisciplinary Science of Spontaneous Thought

Kieran C. R. Fox *and* Kalina Christoff

Abstract

Enormous questions still loom for the emerging science of spontaneous thought: What, exactly, is spontaneous thought? Why does the human brain engage in spontaneous forms of thinking, and when is this most likely to occur? And perhaps the question most interesting and accessible from a scientific perspective: How does the brain generate, elaborate, and evaluate its own spontaneous creations? The central aim of this volume is to bring together views from neuroscience, psychology, philosophy, phenomenology, history, education, contemplative traditions, and clinical practice in order to begin to address the ubiquitous but poorly understood mental phenomena collectively known as "spontaneous thought." Perhaps no other mental experience is so familiar in daily life, and yet so difficult to understand and explain scientifically. The present volume represents the first effort to bring such highly diverse perspectives to bear on answering the what, when, why, and how of spontaneous thought.

Key Words: mind-wandering, creativity, dreaming, daydreaming, spontaneous thought, self-generated thought

Where Do Spontaneous Thoughts Come From?

It may be surprising that the seemingly straightforward answers "from the mind" or "from the brain" are in fact an incredibly recent, modern understanding of the origins of spontaneous thought. For nearly all of human history, our thoughts—especially the most sudden, insightful, and important—were almost universally ascribed to divine or other external sources. Cultures around the world believed that dreams were messages sent from the gods (Kracke, 1991); inventions like writing and agriculture were credited to ancient culture heroes and tutelary deities long lost in the mists of legend (Chang, 1983); and the belief that artistic creativity was inspired by the Muses (Murray, 1989) held sway for two millennia (McMahon, 2013). Even the original sense of the word *inspiration* was that the divine had been "breathed into" a mere mortal, accounting for the new idea or insight. There were of course exceptions—Aristotle, for instance, put forward the naturalistic hypothesis that dreams were created by the mind of the dreamer (Gallop, 1996)—but nowhere, it seems, was there a widespread belief in the spontaneity, originality, and creativity of the unaided human mind.

We still sometimes worship our great intellectual innovators—artists, scientists, philosophers—as semi-divine figures. But somewhere, somehow, our perspective changed and we began to see ourselves as the authors of our own thoughts, however inexplicable their origins might seem. Perhaps the beginnings of this shift in perspective are echoed in the ancient myth of Prometheus, who "stole and gave to mortals" the "fount of the arts, the light of fire"—in other words, the power of conjuring up novel thoughts (Griffith, 1983). Although this internalization of thought's origins began long ago, only in the past few centuries have human beings truly taken responsibility for their own mental content, and finally localized thought to the central nervous system—laying the foundations for a protoscience of spontaneous thought.

This shift has broadly answered the *who* and the *where* of spontaneous thought: we are the source of our thoughts, and these thoughts seem to be constructed in our heads. But enormous questions still loom: *What*, exactly, is spontaneous thought? *Why* does the brain engage in spontaneous forms of thinking, and *when* is this most likely to occur? And perhaps the most interesting and accessible question from a scientific perspective: *How* does the brain generate, elaborate, and evaluate its own spontaneous creations? Each chapter that follows aims to provide at least preliminary answers to these perplexing questions.

The central aim of this volume is to bring together views from neuroscience, psychology, philosophy, phenomenology, history, education, contemplative traditions, and clinical practice in order to begin to address the ubiquitous but poorly understood mental phenomena that we collectively call "spontaneous thought." Perhaps no other mental experience is so familiar to us in daily life, and yet so difficult to understand and explain scientifically. The present volume represents the first effort to bring such highly diverse perspectives to bear on answering the what, when, why, and how of spontaneous thought.

Although "spontaneous thought" as a term has been used throughout the last decade in both the psychological (Klinger, 2008) and neuroscientific literature (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Christoff, Ream, & Gabrieli, 2004; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015), recent years have marked tremendous progress in our theoretical understanding of what spontaneous thought is and what phenomena it encompasses. Spontaneous thought can be defined as thought that arises relatively freely due to an absence of strong constraints on its contents or on the transitions from one mental state to another (Christoff et al., 2016). In other words, spontaneous thought moves freely as it unfolds (Figure 1.1).

There are two general ways in which thought can be constrained (Figure 1.1). One type of constraint is flexible and deliberate, and is implemented through cognitive control. Another type of constraint is automatic in nature. Automatic constraints can be thought of as a family of mechanisms that operate outside of cognitive control to hold attention on a restricted set of information. Examples of automatic constraints are emotional significance and habits, both of which can constrain our thoughts without any effort or intention on our part (Christoff et al., 2016; Fox, Kang, Lifshitz, & Christoff, 2016; Todd, Cunningham, Anderson, & Thompson, 2012).

Spontaneous thought can also be understood as a broader family of mental phenomena, including our daytime fantasies and mind-wandering (Christoff, 2012; Fox et al., 2015); the flashes of insight and inspiration familiar to the artist, scientist, and inventor (Beaty, Benedek, Silvia, & Schacter, 2016; Kounios & Beeman, 2014; Zabelina & Andrews-Hanna, 2016); and the nighttime visions we call dreams (Christoff et al., 2016; Domhoff & Fox, 2015; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013). There is a dark side to spontaneous

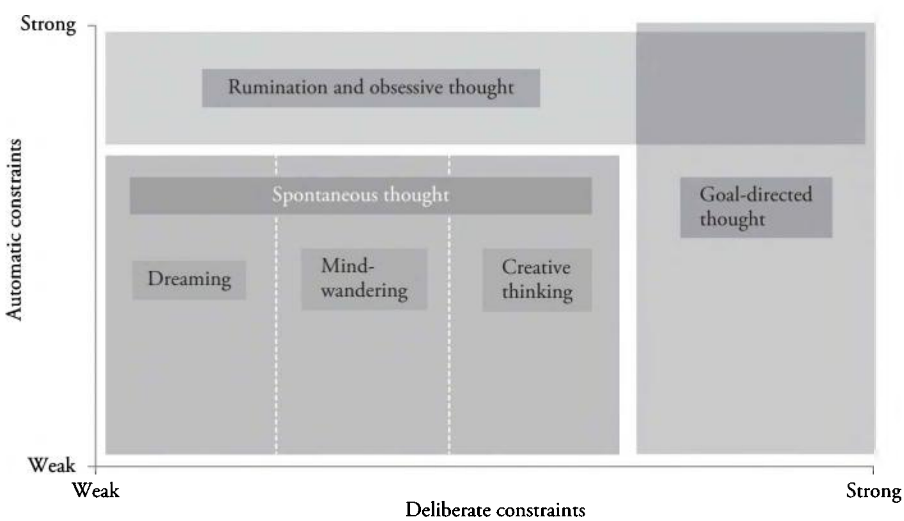

Figure 1.1. (See Color Insert) Conceptual space relating different types of thought and their constraints. Reproduced, with permission, from Christoff et al. (2016).

thought as well—the illumination of which is yet another major goal of this volume. Repetitive depressive rumination, uncontrollable thoughts in obsessive-compulsive disorder, the involuntary and lifelike re-experiencing of post-traumatic stress disorder—all these, we suggest, can be considered dysfunctional forms of spontaneous thought, and need to be understood in relation to our natural and healthy propensity toward novel, variable, imaginative thought (Christoff et al., 2016; see also Mills et al., Chapter 2 in this volume).

Spontaneous should in no way suggest *random* or *meaningless*. Another key aim of this volume is to highlight the ample evidence in favor of the idea that goal-related and "top-down" processing often co-occurs with and can sometimes guide spontaneous thought (Fox & Christoff, 2014; Fox et al., 2016; Klinger & Cox, 2011; Seli, Risko, Smilek, & Schacter, 2016). Although the cause and meaning of specific thoughts or dreams often elude us, the rare but sensational occurrences of transgressive thoughts or highly bizarre and emotional dreams tend to obscure just how mundane (but, quite possibly, useful) most of our self-generated mental content really is (Domhoff, 2003; Fox et al., 2013; Klinger, 2008). The degree to which mental processes that are ostensibly spontaneous and beyond our control appear to be planned, relevant, and insightful with respect to our personal goals and concerns is striking—and, we believe, deserving of further exploration.

These ubiquitous spontaneous mental phenomena raise some intriguing questions: Can we engage in planning and other executive processes in the absence of conscious awareness? To what extent are "we" in control of our own minds? The true qualities and content of spontaneous thought also fly in the face of many culturally sanctioned but unwarranted beliefs about the inexplicability of our fantasy lives, the randomness and meaninglessness of dreams, or the disorderliness of creative thoughts and insights in artists and scientists. A closer look at psychological, neuroscientific, and philosophical work shows not only the co-occurrence of cognitive processes like planning, mentalizing, and metacognition with various forms of spontaneous thought (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fox & Christoff, 2014; Fox et al., 2015; Seli et al., 2016), but also a compelling correspondence between the content of one's spontaneous thoughts and the content and concerns of one's daily life (Klinger, 2008). *The Oxford Handbook of Spontaneous Thought* is the first volume of its kind to bring together experts from so many diverse fields to explore these phenomena, and should therefore be of interest to psychologists, neuroscientists, philosophers, clinicians, educators, and artists alike—indeed, to anyone intrigued by the incredibly rich life of the mind.

Overview of the *Handbook*

This *Handbook* is divided into seven separate but closely interrelated parts. This introductory chapter comprises Part I, providing an overview of spontaneous thought in general and the many chapters of this book in particular.

Part II dives right into fundamental theoretical issues surrounding the definition and investigation of spontaneous thought. In Chapter 2, Caitlin Mills, Arianne Herrera-Bennett, Myrthe Faber, and Kalina Christoff ask why the mind wanders at all, and propose the default variability hypothesis: the idea that by default, spontaneous thought tends to exhibit high variability of content over time—variability that serves as an adaptive mechanism that enhances episodic memory efficiency and facilitates semantic knowledge optimization. Chandra Sripada, in Chapter 3, puts forward a theoretical framework within which spontaneous and deliberate thought can be compared, respectively, with "exploration" of the environment in search of new resources versus "exploitation" of the resources we already have at hand. In Chapter 4, Carey Morewedge and Daniella Kupor provide an overview of people's metacognitive appraisals of the meaning and relevance of spontaneous thoughts, with the surprising conclusion that people tend to attribute *more* importance to thought whose origin is mysterious—perhaps hearkening back to the ancient human view of the origins of thought discussed at the outset of this chapter. Dylan Stan and Kalina Christoff, in Chapter 5, propose that a key quality of mind-wandering is an accompanying subjective experience of *ease*, or low motivational intensity. In Chapter 6, Georg Northoff proposes a novel theory aiming to explain how spontaneous brain activity generates and constitutes subjectively experienced spontaneous thought. Finally, in Chapter 7, Jonathan Smallwood, Daniel Margulies, Boris Bernhardt, and Elizabeth Jeffries present their component process framework of spontaneous thought, explaining how different types of thought can arise through the interaction of specific underlying neurocognitive processes.

Part III explores broader philosophical, evolutionary, and historical perspectives on spontaneous thought. In Chapter 8, Zachary Irving and Evan Thompson provide an in-depth introduction to the philosophy of mind-wandering, reviewing several psychological and philosophical accounts and providing a new view of their own. Thomas Metzinger, in Chapter 9, addresses the question, "Why is mind-wandering interesting for philosophers?" In Chapter 10, Dean Keith Simonton relates the spontaneity of human thought to other spontaneous generative processes, highlighting the connections with "selectionist" views of evolution and creativity. John Antrobus, in Chapter 11, offers an analysis of how the brain in both waking and sleeping can so effortlessly produce a constant stream of visual imagery and thoughts—and what use they might have. Rounding out Part III, Alex Soojung-Kim Pang, in Chapter 12, explores how spontaneous thought was viewed in the past, how it was used by creative people to further their endeavors, and how deep historical research could lead to an understanding of the role of spontaneous thought in the history of ideas.

Part IV focuses on mind-wandering and daydreaming. In Chapter 13, Jessica Andrews-Hanna, Zachary Irving, Kieran Fox, Nathan Spreng, and Kalina Christoff present an interdisciplinary overview of the rapidly evolving neuroscience of spontaneous thought. Investigating what we have learned from intracranial electrophysiology in humans, Kieran Fox, in Chapter 14, then synthesizes the available evidence on how and where self-generated thought is initiated within the brain. In Chapter 15, Arnaud D'Argembeau provides a detailed discussion of the link between mind-wandering and self-referential thinking, and their common neural basis. David Stawarczyk, in Chapter 16, provides a detailed overview of the phenomenological properties of all kinds of mind-wandering and daydreaming, covering both the historical trajectory of these investigations and the present state of research. In Chapter 17, Eric Klinger, Igor Marchetti, and Ernst Koster discuss the critical importance of goal pursuit to spontaneous thought, elaborating on how these thoughts are adaptive in everyday life but can go awry in a variety of clinical conditions. Claire Zedelius and Jonathan Schooler, in Chapter 18, provide a fine-grained view of the many different kinds of mind-wandering and the evidence that they have distinctive effects on task performance, mood, and creativity. In Chapter 19, Julia Kam and Todd Handy comprehensively review the evidence from human electrophysiology that mind-wandering involves a decoupling of attention from the external world. Finally, Jeffrey Wammes, Paul Seli, and Daniel Smilek, in Chapter 20, review what we know about mind-wandering in educational settings, and how excessive, unintentional mind-wandering in the classroom impacts learning and academic performance.

Part V covers creativity and insight, and their relation to other forms of spontaneous thought. Roger Beaty and Rex Jung, in Chapter 21, offer an overview of how large-scale brain networks interact during creative thinking and creative performance. In Chapter 22, Mathias Benedek and Emanuel Jauk offer detailed empirical evidence for a "dual-process" model of creative cognition, wherein the flexible switching between controlled and spontaneous cognition is critical to an optimal creative process. Charles Dobson, an artist as well as a professor of fine arts, offers in Chapter 23 an insider's view of what he calls "flip-flop thinking," and outlines his firsthand experiences of what helps (and what hurts) the creative process. In Chapter 24, John Vervaeke, Leo Ferraro, and Arianne Herrera-Bennett develop an intriguing account of the "flow" state as a form of spontaneous thought characterized by a cascade of successive insights and learning experiences. Oshin Vartanian, in Chapter 25, delves into how self-referential thoughts can be elicited by aesthetic appreciation of artworks, such as paintings. Finally, in Chapter 26, David Beversdorf provides an extensive review of the neurochemical basis of flexible and creative thinking.

Spontaneous thought does not cease when we close our eyes and turn out the lights. Part VI explores the many normal, extraordinary, and sometimes pathological varieties of spontaneous thought that take place throughout the sleep cycle, and how these are related to memory consolidation and involuntary memory retrieval. In Chapter 27, G. William Domhoff provides an overview of the neural basis of dreaming and REM sleep, while Chapter 28, by Kieran Fox and Manesh Girn, provides a comprehensive review of what is known about the neural correlates of all sleep stages throughout the sleep cycle. In Chapter 29, Jennifer Windt and Ursula Voss provide an in-depth treatment of the phenomenon of lucid dreaming, bringing psychological, philosophical, and neuroscientific perspectives to bear to better explain this remarkable mental state. Tore Nielsen, in Chapter 30, explores the fascinating topic of "microdreaming" and hypnagogic imagery as a paradigm for a fine-scaled neurophenomenological approach to inner experience. In Chapter 31, Elizaveta Solomonova offers an interdisciplinary look at the little-known phenomenon of sleep paralysis, and the spontaneous visions and emotions that accompany it. Erin Wamsley, in Chapter 32, explores how spontaneous thought in both waking and sleep can be seen as an expression of memory consolidation and recombination, and John Mace, in Chapter 33, provides a comprehensive overview of involuntary memories—how often they occur, how they can chain together, how they differ from voluntarily recalled information, and what their function might be.

Part VII takes us to the fringes and also the cutting edge of research on spontaneous thought: its relationship to clinical conditions and altered states of consciousness. Dylan Stan and Kalina Christoff begin, in Chapter 34, by outlining the many potential clinical benefits and risks of spontaneous thought. In Chapter 35, Claire O'Callaghan and Muireann Irish describe the neural underpinnings of how spontaneous thought changes in relation to aging and dementia syndromes. Elizabeth DuPre and Nathan Spreng, in Chapter 36, explore the relationships between depression, rumination, and spontaneous thought. In Chapter 37, Aaron Kucyi explores the intriguing relationships between mind-wandering and both chronic and acute pain, and how these interactions are mediated by large-scale brain networks. Halvor Eifring, in Chapter 38, investigates how religious and contemplative traditions around the world have tended to see mind-wandering as an obstacle, while at the same time viewing spiritual attainment and liberation as a spontaneous process of transformation that cannot be actuated deliberately. In Chapter 39, Wendy Hasenkamp outlines how meditation and mindfulness practices can provide a window into the rapid fluctuations of mind-wandering. Peter Suedfeld, Dennis Rank, and Marek Malůš offer in Chapter 40 an account of spontaneous thought in extreme and unusual environments, exploring rarely seen records of the thoughts and experiences of polar explorers, astronauts, and those undergoing severe sensory deprivation. Finally, Michael Lifshitz, Eli Sheiner, and Laurence Kirmayer detail in Chapter 41 how the powerful unconstrained cognition brought on by psychedelic substances can be guided by culture and context.

All told, these chapters provide the most comprehensive overview of the wide-ranging field of spontaneous thought to date—and there could be no better guides to this realm than the 64 outstanding scientists, historians, philosophers, and artists who have come together to write them.

Spontaneous forms of thought enable us to transcend not only the here and now of perceptual experience, but also the bonds of our deliberately controlled and goal-directed cognition; they allow the space for us to be other than who we are, and for our minds to think beyond the limitations of our current viewpoints and beliefs. In studying such an abstruse and seemingly impractical subject, we need always to remember that our capacity for spontaneity, originality, and creativity defines us as a species—and as individuals.

The painting adorning the cover of this *Handbook* is by artist and neuroscientist Greg Dunn, who draws inspiration for his work from the ancient *sumi-e* tradition of ink wash painting still practiced in Japan. The essence of *sumi-e*, which has deep roots in Taoism and Zen Buddhism, is to combine discipline with spontaneity, to evoke a complex essence with simplicity—to bring order, so to speak, out of chaos, and to give rise to a creation that is coherent and integrated, yet natural and unforced (Cheng, 1994; Van Briessen, 2011; Watts, 1957). We could think of no better artist to provide a visual overture to the multifaceted exploration of these same themes throughout the pages of this book.

Philosopher Alan Watts eloquently captured the tension and interplay between spontaneity and purpose when he wrote, "spontaneity is not by any means a blind, disorderly urge, a mere power of caprice. A philosophy restricted [by] conventional language has no way of conceiving an intelligence which does not work according to plan, according to a one-at-a-time order of thought. Yet the concrete evidence of such an intelligence is right to hand . . ." (Watts, 1957, p. 17). We hope the chapters that follow help to illuminate this elusive wisdom of spontaneous thought in all its many manifestations.

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PART II

Theoretical Perspectives

CHAPTER

2

Why the Mind Wanders: How Spontaneous Thought's Default Variability May Support Episodic Efficiency and Semantic Optimization

Caitlin Mills, Arianne Herrera-Bennett, Myrthe Faber, *and* Kalina Christoff

Abstract

This chapter offers a functional account of why the mind—when free from the demands of a task or the constraints of heightened emotions—tends to wander from one topic to another, in a ceaseless and seemingly random fashion. We propose the *default variability hypothesis*, which builds on William James's phenomenological account of thought as a form of mental locomotion, as well as on recent advances in cognitive neuroscience and computational modeling. Specifically, the *default variability hypothesis* proposes that the default mode of mental content production yields the frequent arising of new mental states that have heightened variability of content over time. This heightened variability in the default mode of mental content production may be an adaptive mechanism that (1) enhances episodic memory efficiency through de-correlating individual episodic memories from one another via temporally spaced reactivations, and (2) facilitates semantic knowledge optimization by providing optimal conditions for interleaved learning.

Key Words: mind-wandering, default variability hypothesis, episodic memory, semantic memory, learning, neuroscience

Why doesn't the mind grind to a halt when we are not doing anything? Why does it keep moving instead? And why does this movement tend to proceed in a seemingly haphazard manner, with thoughts jumping from one topic to another, often distant, seemingly unrelated topic—creating a variability in thought content to which the mind seems to default?

More than 100 years ago, William James described thought as a form of mental locomotion. Here we build on James's phenomenological account and on recent advances in cognitive neuroscience and computational modeling to offer a functional account of why the mind, when free from the demands of a task or the constraints of heightened emotions, ceaselessly moves from one topic to the next. We introduce the *default variability hypothesis*, which highlights the continuous change and heightened variability of the contents of spontaneous thought as they unfold over time. The default variability hypothesis proposes that our default mode of mental content production, with its continuous change and heightened variability over time, may be an adaptive mechanism that (1) enhances episodic storage efficiency by helping de-correlate individual episodic memories from one another via temporally spaced reactivations, and (2) facilitates semantic knowledge optimization by providing optimal conditions for interleaved learning.

Overview of the Default Variability Hypothesis

People report highly variable moment-to-moment experiences during "resting states" that facilitate spontaneous thought (Hurlburt, Alderson-Day, Fernyhough, & Kühn, 2015). For example, a thought about the scallops one had for dinner the day before might be followed by a memory of a bus ride taken a week ago, followed by an image of a sunny beach. The mental states that form our thought flow need not be events that have actually occurred (Addis, Wong, & Schacter, 2008; Schacter, Addis, & Buckner, 2007). In addition to conjuring up veridical episodic events, details from the past can also be recombined in novel ways to produce episodic mental simulations and other mental states that become part of the stream of thought.

We operationalize content variability as the extent to which consecutive mental states in the stream of thought are episodically and/or semantically distinct from each other. The greater the semantic/episodic distance between consecutive mental states, the more variable thought content would be over time. We propose that a default mode of variability in thought contents serves two purposes: to facilitate efficient encoding of separate episodic events (the *episodic efficiency hypothesis*), and to support the integration and transformation of episodic memories into semantic knowledge (the *semantic optimization hypothesis*).

In what follows, we elucidate the two sub-hypotheses that together make up the default variability hypothesis. We draw on the episodic and semantic memory formation and consolidation literature to explain how these processes are inextricably connected to spontaneous thought's default variability. Finally, we integrate our hypothesis into existing accounts of mind-wandering, and offer some suggestions for empirically testing each sub-hypothesis.

Episodic Efficiency Hypothesis

We propose that a default mode of content variability in the stream of thought improves episodic memory efficiency by optimizing the distinctiveness of different episodic memories. In this section, we give a brief description of two pivotal episodic memory mechanisms—pattern separation and pattern completion—followed by an account of how the content variability of spontaneous thought may lead to increased episodic memory efficiency. We propose that this process is twofold: First, pattern separation processes produce separable (i.e., distinct) episodic memories, through de-correlating (i.e., making distinct) the corresponding activation patterns in the hippocampus and neocortex. A default content variability in spontaneous thought may directly support pattern separation processes via mental simulations (reactivations or novel recombinations) that adaptively separate the memories over time by providing dissimilarities in consecutive representations over time. Second, pattern completion may help strengthen representations of the separately encoded memories through multiple, similar re-instantiations of the same memories (which could be triggered by either external or internal cues).

Pattern Separation

Pattern separation is a process through which distinct representations of episodic experiences, and their contextual properties, are indexed in the hippocampus as separate and discrete events (Rolls, 2016). Pattern separation plays a vital role in episodic memory storage and retrieval by helping us create distinct neural representations for individual episodic events. Here, we propose that a fundamental function of a default variability in mental contents over time is to support pattern separation by helping de-correlate distinct memories from one another.

At the neural level, pattern separation is considered to be dependent on hippocampal processes (Leutgeb, Leutgeb, Moser, & Moser, 2007; Rolls, 2016; Yassa & Reagh, 2013). It begins with input from the entorhinal cortex (see Figure 2.1), which feeds into the granule cells of the dentate gyrus (DG) by way of the perforant path (Witter, 1993, 2007). The DG cells are proposed to serve as a modifiable network that ultimately produces sparse, orthogonalized outputs to Cornu Amonis region 3 (CA3). DG granule cells exhibit unique functional properties: They have relatively sparse firing rates, yet exert a strong influence on CA3 cells (Jung & McNaughton, 1993; Leutgeb et al., 2007). Moreover, only a very small number of connections are received at each CA3 cell. For example, it is presumed that the small number of connections (approximately 46 mossy fiber connections to each CA3 cell) creates a randomizing effect (i.e., for any given event, a random set of CA3 neurons is activated). In other words, there is an extremely low probability that any two CA3 neurons would receive input from a similar set of DG cells (Kesner, 2007). As a result, event (i.e., episodic) representations should be as highly differentiated as possible from one another (Rolls, 1989, 1989; Rolls & Kesner,

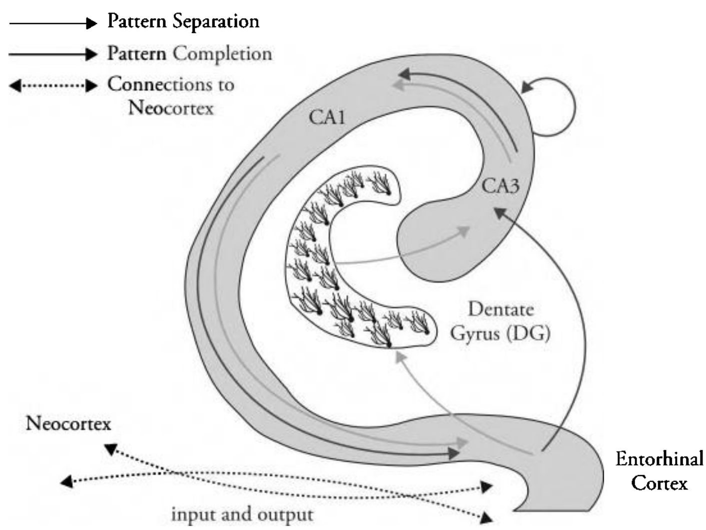

Figure 2.1. Diagram representing the pathways for pattern completion and pattern separation from the cortex to the medial temporal lobe (and back to the cortex). (See Color Insert)

2006; Rolls & Treves, 1990), which affords optimal storage capacity of distinct event representations (Hunsaker & Kesner, 2013; Myers & Scharfman, 2009, 2011; Treves & Rolls, 1992, 1994).

The mechanisms in pattern separation ultimately contribute to the *orthogonalization* of episodic memory representations, characterized by reduced overlap or redundancy between distinct event representations. Sometimes referred to as *dilution* or *diluted connectivity*, orthogonalization is characterized by low levels of correlation between different encoded episodic memories and a low number of synaptic connections between each of the CA3 neurons themselves—as little as one connection between any pair of randomly connected CA3 neurons within the network (Rolls, 2013). Supporting evidence comes from both rodent and human studies suggesting that the DG and CA3 can update the de-correlated network after exposure to even slight deviations in previously encountered contexts or stimulus (Bakker, Kirwan, Miller, & Stark, 2008; Gilbert, Kesner, & Lee, 2001; Leutgeb et al., 2007). For example, novelty is associated with increased firing rates from certain inhibitory neurons in the DG (Nitz & McNaughton, 2004), which may serve as a filtering mechanism for determining when new events should be encoded as such (Jones & McHugh, 2011).

From Pattern Separation in the Hippocampus to Neocortical Competition

Although the exact neural details of pattern separation are still a subject of debate, one thing is clear: the ability to separate different episodic memory patterns requires an efficient storage mechanism. In addition to the sparse encoding in the DG and CA3, efficient storage capacity is also proposed to be achieved through hippocampo-cortical interactions, according to *the hippocampal indexing theory* (Teyler & DiScenna, 1986). While individual memory traces are indexed separately in the hippocampus, additional details of the memory are thought to be stored elsewhere in the cortex. Yassa and Reagh (2013) have described this process by comparing the neocortex to a library where information is stored, and the hippocampus as the librarian who can refer to where the information is stored.

Based on this idea, the *competitive trace theory* (Yassa & Reagh, 2013) makes a specific prediction about the benefits of episodic memory reactivation. According to this theory, certain episodic features of a memory are preserved through multiple reactivations of this memory over time (Figure 2.2). Every reactivation causes a trace to be re-encoded in the DG, so that this trace does not completely overlap with the traces created by other reactivations or by the original event. Across multiple reactivations over time, some features of the memory will overlap (i.e., will be the same), while others will not (i.e., they will differ; Figure 2.2). Over time, overlapping features are strengthened with respect to their corresponding hippocampal and neocortical representations, which results in their higher fidelity during retrieval. On the other hand, non-overlapping features compete for representation in the cortex (unlike overlapping features), and mutually inhibit

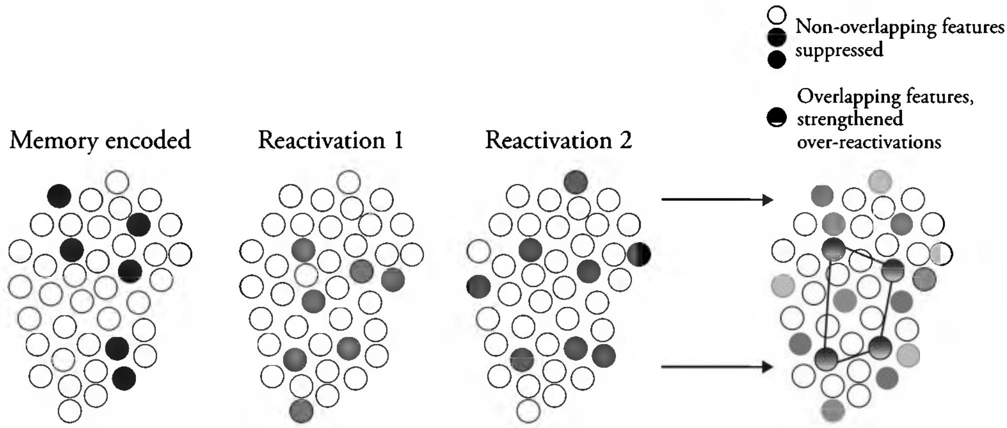

Figure 2.2. Graphic illustration of how overlapping features are preserved and non-overlapping features are suppressed. (See Color Insert)

one another through anti-Hebbian learning (i.e., active neurons initiate inhibitory competition, and weakly activated neurons are subsequently inhibited). Therefore, non-overlapping features—which are presumably likely to be the less common and less important features of the memory—will have a reduced likelihood of being retrieved.

The idea that both the hippocampus and neocortex are involved in pattern separation is important for considering how temporally variable mental simulations (reactivations and novel recombinations) can aid in efficient separation. The neocortex, where much of the episodic memory information is stored, is associatively modifiable through competitive learning so that given some input, competition is generated among neural representations (i.e., multiple representations of a memory receive some level of activation, resulting in a competition between them to win total activation, resulting in an action potential). The "winner" of the competition then becomes activated, thus strengthening the association between the input and particular neural activations in the neocortex. Indeed, the mossy fiber system in the DG and its connections to CA3 also exhibit an associative Hebbian learning network (Treves & Rolls, 1994), where concurrent presynaptic activity and postsynaptic action potentials result in a strengthened connection and increased synaptic efficiency (Treves & Rolls, 1994). In turn, this type of synaptic strengthening supports the sparse coding in the DG and CA3, which may be a sufficient mechanism for orthogonalization in the hippocampus.

The idea that memories can become de-correlated over time in the neocortex also bears relation to other proposed mechanisms. For example, Hulbert and Norman (2015) propose a process similar to pattern separation, called differentiation, in which episodic memories can become de-correlated through competitive learning in the hippocampus and cortical regions. Their explanation distinguishes between pattern separation, which is asserted to be automatic, and differentiation, which is driven by competition (in the neocortex) after pattern separation has already occurred (in the hippocampus). Hulbert and Norman (2015) present functional magnetic resonance imaging (fMRI) evidence that a reduction in similarity in the hippocampus between memories is correlated with retrieval-induced facilitation, which is the opposite of retrieval-induced forgetting (e.g., impaired memory for related items). This pattern of results supports the idea that when memories are differentiated from one another, they do not hinder retrieval due to similarity. Further support also comes from Favila et al. (2016), who showed that reducing the similarity between memories can be an adaptive process: learning serves to reduce the amount of overlap in hippocampal representations of highly similar stimuli, which in turn prevents interference during subsequent retrieval.

Role of Content Variability

How does the content variability inherent to spontaneous thought contribute to episodic memory separation? At a basic level, spontaneous reactivations can provide the foundation for initiating competition between multiple instantiations of a given memory, ultimately preserving the important (i.e., recurring) features of the memory; that is, since each spontaneous thought is re-encoded as a new memory trace (Yassa & Reagh, 2013), competition is generated among the non-overlapping features in the new and previously encoded memories. The idea here is that essential overlapping features that are present in both (or more) versions of the encoded memory will be strengthened and retained for later recall due to spontaneous reactivations. At the same time, spontaneous reactivations are unlikely to be veridical instantiations of the memory. Therefore, the non-overlapping, and perhaps irrelevant, features of that memory will be inhibited and potentially lost over time. See Figure 2.2 for a graphical example.

A second proposed role of content variability is that memories can become de-correlated through continual shifts in mental content, where memory reactivations are not temporally or spatially bound from one spontaneous thought to the next (see Figure 2.3 for an example). The variability of content over time acts to provide a time buffer between overlapping memories. Enough time can pass between similar memory traces, such that activation from one memory can die down before other related memories are activated, thus avoiding the "fire together, wire together" association rule originally proposed by Hebb.

We argue therefore that default content variability plays a functional role in organizing episodic memories by optimizing de-correlated memories in the hippocampus and neocortex. Although the flow of mental states during spontaneous thought may seem randomly disjointed, spontaneous thoughts are often tied to recent memories, past events, or

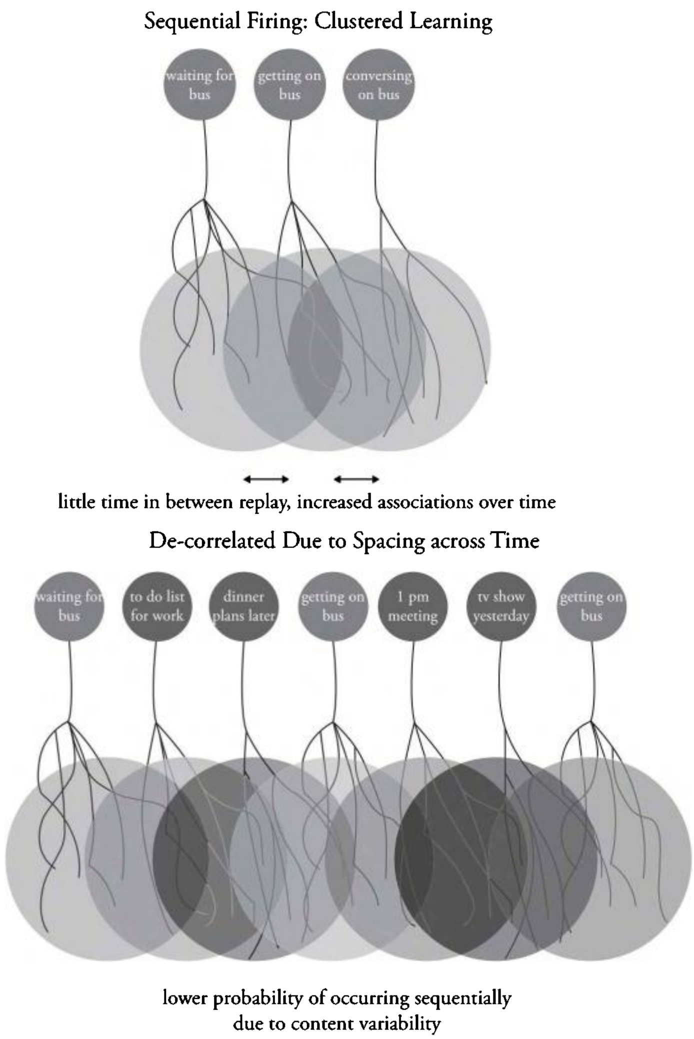

Figure 2.3. Examples of low variability in thought (top), corresponding to clustered learning, and highly variable thought content (bottom), corresponding to de-correlated memories via temporally spaced memories in spontaneous thoughts. (See Color Insert)

future plans (Baird, Smallwood, & Schooler, 2011; Klinger & Cox, 2004). Thus, spontaneous mental simulations may play a critical role in separating episodic memories that are important to one's life, such as episodic experiences that need to be distinguished from others and should not be grouped with them due to factors such as temporal contiguity.

Pattern Completion

Pattern completion is a process through which completion of a whole memory of an event or experience is generated from recall of any of its parts. In other words, partial or degraded cues can trigger the respective stored event representation, which then serves to reactivate the original episodic memory and its accompanying features, including the context in which it was originally experienced (Marr, 1971). The phenomenological qualities of the original event—including even elements such as the emotional tone of the initial experience—can be recaptured and reinstated, and in this sense vividly *re-experienced* by the individual. As such, pattern completion is central to the notion of episodic memory retrieval, in that it supports not only the recall of the information surrounding a given event, but also taps into the fundamental conscious feeling of reliving a moment as a specific, rich, and unique subjective episode (Nadel & Moscovitch, 1997; Teyler & Rudy, 2007). Pattern completion therefore elicits a sense of autonoetic consciousness (e.g., the ability to mentally put ourselves in other situations—past, present, and imagined—and reflect on them), a hallmark of episodic awareness (James, 1890; Tulving, 2002), which is necessary for episodic memory retrieval.

At the neural level, the hippocampus and the surrounding structures of the medial temporal lobe (MTL) are considered to be among the key neural substrates underlying the reinstatement of episodic memories (see Figure 2.1). While pattern separation is thought to be mediated by the DG, areas CA1 and CA3 have been implicated as more central components of pattern completion. Incoming information stems from the entorhinal cortex, and perforant path projections onto CA3 cells initiate retrieval in CA3 (without passing through the DG). The process of pattern completion itself is principally subserved by the CA3 auto-associative network architecture (a network that can essentially retrieve a memory from partial information about the memory itself; Marr, 1971). This auto-associative CA3 architecture is considered to operate as a single attractor network (Rolls, 2013). Because of that, a retrieval cue need not be very strong in order to produce accurate recall—the retrieval process itself is taken over by the CA3 recurrent auto-associative system (Rolls, 2013; Treves & Rolls, 1992).

Completion is then carried out via CA3 projections to CA1 neurons, which then results in divergent back-projections from CA1 to the entorhinal cortex and subsequent neocortical areas. These back-projections occur through a Hebbian-like competitive learning network (i.e., associative learning, where similar firing patterns result in strengthened connections), so that inputs from CA3 generate competition among the cells in CA1. Subsequently, cells with the strongest activation in CA1 instigate a winner-take-all effect, thereby strengthening that specific pattern and suppressing shared activation among other memory representations that were not completed. Thus, an anti-Hebbian effect takes place when the active neurons initiate inhibitory competition, thereby depressing activations from weakly activated neurons.

CA1 projections act as efficient retrieval cues (even partial or degraded), ultimately eliciting activity in those areas of the cerebral cortex that initially supplied input to the hippocampus. In other words, those areas of the brain that served to generate the initial episodic experience are again recruited upon retrieval. In this way, pattern completion can be conceptualized as "a reverse hierarchical series of pattern association networks implemented by the hippocampo-cortical back-projections, each one of which performs some pattern generalization, to retrieve a complete pattern of cortical firing in higher-order cortical areas" (Rolls, 2013, p. 1).

Pattern Completion as a Source of Continuously Generated Mental Content

In addition to strengthening the existing memories, we also propose that pattern completion might serve as a source of the ceaseless change in mental content (i.e., the frequent generation of new mental states). Indeed, a similar idea was proposed earlier by O'Neill, Pleydell-Bouverie, Dupret, and Csicsvari (2010), where pattern completion in the CA3 was suggested to be well suited for promoting reactivation during rest. Further, there is evidence that spontaneous reactivation of a memory can be triggered by partial cues from the memory's retrieval context, as evidenced by qualitative overlap between thought content and its cue (Berntsen, 1996; Berntsen & Hall, 2004).

We therefore consider the possibility that memories recalled during pattern completion might provide partial or degraded cues that may then serve to trigger further pattern completions, thus facilitating a continuous change in mental contents. For example, one might see a chocolate cupcake. Chocolate may then become a cue to complete a memory of a birthday party with chocolate cake. The cue of birthday might lead to completing a memory of the Ninja Turtles, and green may serve as a cue to remember a favorite green shirt. This continuous cue provision and pattern completion tendency may help us understand why the mind keeps moving, with novel mental contents emerging repeatedly.

If, as we propose here, there is a bias for consecutive spontaneous mental simulations to be decorrelated via pattern separation processes, these partial cues are likely to trigger patterns that are at least somewhat dissimilar to the immediately preceding pattern that was triggered. This might be one reason that spontaneous thought exhibits a heightened variability over time, while at the same time allowing for thematic relationships or other partial associations to be present among consecutive mental states. In turn, the completed patterns may also work together with pattern separation processes to further differentiate episodic events by strengthening the hippocampal-neocortical representations of an episodic memory when it is reactivated.

Cascades of thought might spontaneously arise within the hippocampus and propagate throughout the brain (Ellamil et al., 2016). Some of these thoughts may end up being experienced consciously, whereas others may fail to reach awareness. This account is consistent with the notion of thoughts shifting in and out of the foreground of one's focus of attention, and the accompanying subjective experience of competing or coexisting streams of thought. It also speaks to the ease with which we experience a high level of content variability from one moment to the next, a large proportion of which may unfold spontaneously from partial cues in the internal or external environment.

Semantic Optimization Hypothesis

How do we transform our fragmented episodic experiences into a meaningful understanding of our world—or what scientists call "semantic knowledge"? Prominent consolidation models, such as the *standard consolidation theory* (Scoville & Milner, 1957; Squire, 1992; Squire & Alvarez, 1995; Squire & Zola, 1998) and the *multiple trace theory* (Nadel & Moscovitch, 1997)—although not in full theoretical agreement—share a central assumption with regard to this episodic-to-semantic transformation: at the neural level, episodic memories for events are primarily hippocampus-dependent, whereas semantic memories rely primarily on neocortical substrates. Here, we propose that default variability not only supports the organization of episodic memory in the hippocampus and neocortex, but also supports the organization of semantic memory by providing the conditions necessary for efficient episodic-to-semantic transformation.

The creation of semantic knowledge out of episodic experiences is a gradual process that occurs across multiple instantiations (McClelland, McNaughton, & O'Reilly, 1995). Variability across instantiations plays an important role in semantic knowledge acquisition. A combination of similarity and dissimilarity across representations facilitate the extraction of regularities and the development of categorization (Gelman & Markman, 1986; Sloutsky, 2003). Similarity (i.e., overlapping features that should be extracted for meaning-making) provides evidence for regularities within a category, whereas dissimilarity (i.e., specific differences in individual events) provides contrasting evidence that helps identify category boundaries. Moreover, the experience of repeated events in various contexts aids the encoding of relationships between its typical elements (Avrahami & Kareev, 1994). Over multiple subsequent exposures, these event elements are stored together in one schema, affording economical representations of semantic concepts (Nadel, Hupbach, Gomez, & Newman-Smith, 2012). As part of the default variability hypothesis, we propose that spontaneous thought's heightened content variability serves to support and optimize semantic abstraction by providing multiple mental simulations that are both similar and dissimilar in nature. A default mode of content variability in spontaneous thought may therefore provide a mechanism for generating contextually variable episodic simulations (both veridical and novel recombinations). The similarity in consecutive mental simulations can provide the basis for abstracting general meaning and overarching categories through multiple exposures, while the dissimilarities can help ensure that one specific instance is not overlearned (e.g., if you only saw one breed of dog, you may not realize that another breed is also a dog).

Aside from the variability of consecutive representations, gradual exposure is also considered to play a critical role. Gradual exposure, also referred to as *interleaved learning*, affords optimal semantic abstraction (McClelland et al., 1995). Based on evidence from connectionist models, interleaved learning is theorized to critically support the progressive refinement of stable representations at the conceptual level. Semantic representations resulting from interleaved learning are optimally flexible in assuming and reflecting "the aggregate influence of the entire ensemble of patterns" elicited across events, while simultaneously being resilient to large modifications due to exposure to a single episodic trial (e.g., catastrophic interference; McClelland et al., 1995, p. 429).

Accuracy in neocortical conceptual representation formation is argued to be a function of both sample size (i.e., number of experiences being aggregated across) and learning rate, whereby a slower rate allows for a greater number of interleaved samples to be factored into each computed estimate (White, 1989). For example, after enough gradual exposure to the meaning of "cat," a child would be less susceptible to fundamental misunderstandings of the cat category (e.g., classifying a small dog as a cat). However, if a child is shown 50 pictures of cats in one day, he or she may confuse a small dog for a cat one week later. Interleaved learning is assumed to operate by "basically causing the network to take a running average over a larger number of recent examples" (McClelland et al., 1995, p. 437). We propose that a default content variability in spontaneous thought serves as a mechanism for increasing the opportunities for interleaved episodic-to-semantic transformation. By combining spontaneous reactivations that are highly variable from moment to moment, but also have recurring themes over time (e.g., particular things that are relevant to goals or current concerns), spontaneous thought may optimize the conditions for episodic-to-semantic abstraction and semantic memory organization overall.

Another important property of interleaved learning is that it can deter *catastrophic interference* (the loss of previously learned information due to the introduction of new information; McCloskey & Cohen, 1989). As commonly portrayed through the *AB-AC paradigm* (for more details, see McClelland, McNaughton, & O'Reilly, 1995), newly learned associations (*AC*) can exhibit retroactive interference upon a previously acquired set of associations (*AB*). In this example, *AC* can interfere with the ability to recall *AB* later—because *AC* has "replaced" our concept of the *AB* association. Avoiding catastrophic interference means that we can actually distinguish *AB* and *AC* as different instances in an overarching category, rather than letting exposure to one harm the memory of the other.

If "what one learns about something is stored in the connection weights among the units activated in representing it" (McClelland et al., 1995, p. 433), then abstraction or generalization is only possible to the extent to which conceptual pattern representations overlap (Hinton, Mcclelland, & Rumelhart, 1986). Therefore, it is imperative that a system is not only capable of—but also capitalizes upon—the ability to extract shared properties among concepts, while simultaneously minimizing catastrophic interference. McClelland, McNaughton, and O'Reilly (1995) aptly highlight the existence of two independent yet complementary learning systems that meet both these needs: rapid acquisition at the hippocampal level (pattern separation and completion), paired with gradual interleaved learning consolidation at the neocortical level.

Taken together, we propose that the content variability that characterizes spontaneous thought supports episodic-to-semantic transformation and semantic memory organization by providing both increased variability and frequency over time in a set of samples—novel combinations of elements and reinstatements of episodic memories in new contexts—which facilitates rapid extraction of regularities and allows for generalization across them. In this way, spontaneous thought's default variability plays a critical role in optimizing the efficient abstraction and organization of semantic memory.

Other Potential Benefits of Spontaneous Thought

Novel Association Formation

Another key prediction of the semantic optimization hypothesis is that novel association formations can arise out of MTL activity. Fox, Andrews-Hanna, and Christoff's (2016) expanded account of the *hippocampal indexing theory* (Teyler & DiScenna, 1986; Teyler & Rudy, 2007) suggests that the generation of novel thought is supported by the same mechanisms involved in the spontaneous reactivation of memory traces. This is consistent with the idea that the organization of memory traces in MTL regions is considered *associative* (Moscovitch, 1995). In other words, immediate temporal contiguity or simultaneity will largely dictate which combinations of cues and ensuing memory reactivations will arise together.

In this way, novel thought patterns that are constructive or generative in nature can be potentially facilitated by spontaneous mental simulations, whereby randomization of emergent thought patterns might in part promote more flexible, as opposed to fixated, thinking (Fox, Kang, Lifshitz, & Christoff, 2016). In fact, it has been shown that noise or variability in attractor networks is indeed beneficial for decision-making and memory, because it causes them to be non-deterministic, which in turn can cultivate new problem solutions and creativity (Deco, Rolls, & Romo, 2009; Rolls, 2013, 2014). Furthermore, spontaneous thought has also been recognized as supporting many constructive cognitive functions (Fox & Christoff, 2014; Fox, Kang, et al., 2016; McMillan, Kaufman, & Singer, 2013; Smallwood & Andrews-Hanna, 2013), including generation of creative solutions and ideas to present problems (Baird et al., 2012; Campbell, 1960; Simonton, 1999), simulated thinking (Rice & Redcay, 2015; Spiers & Maguire, 2006), and coordination and planning of future goals (Smallwood & Andrews-Hanna, 2013; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010).

According to the default variability hypothesis, mind-wandering and spontaneous thought activity can be considered a mechanism involved in not only consolidating past episodes, but also processing ongoing current concerns and upcoming future events, a system that is expected and theorized to continuously update and integrate new information into existing semantic knowledge.

Reconciling Existing Mind-Wandering Frameworks

Several theories of spontaneous thought and mind-wandering have been proposed, yet there is a lack of consensus about functional role(s) and underlying mechanisms. Smallwood (2013) recently attempted to differentiate two accounts: the first explained *why* the spontaneous *onset* of unconstrained self-generated mental activity arises (deemed "occurrence" hypotheses), while the second explained *how* the *continuity* of internal thought is maintained once initiated (i.e., "process" accounts).

Although his process-occurrence model certainly helps unify the various accounts under one framework, it falls short of providing a functional reason for why the mind evolved to wander. Instead, Smallwood suggests that the *prospective consolidation hypothesis* might be a possible explanation for the source and function of internally generated thought (Smallwood, 2013). The prospective consolidation hypothesis suggests that "a core function of the hippocampal-cortical system is to use remnants of past experiences to make predictions about upcoming events" (Buckner, 2010, p. 42). Our hypothesis extends this idea to also include the reactivation of past and current information. Specifically, the default variability hypothesis provides further insight into the question of why we have evolved to produce spontaneous thought marked by heightened variability of content over time. First and foremost, we propose a functional account for why spontaneous thought is such a prevalent and ongoing experience in daily waking life, and the mechanisms that support this ongoing mental activity. Second, we suggest that from one moment to the next, high levels of content variability—thoughts that seem unrelated to each, or only loosely related—are capable of arising quickly, ranging and shifting between past and current episodic reactivations to future-related simulated events. Finally, the current account takes a step away from the traditional task-centric literature, and suggests that this ongoing mental activity persists in both the presence and absence of external input.

As such, the content of spontaneous thought itself may be partially determined by simple random probability of thought-pattern reactivation, as determined by any incoming externally or internally generated partial cues, paired with the effect of constraints acting upon the cognitive system within each given moment (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). These constraints might be a function of salience, whether personal or perceptual in nature (e.g., the *current concerns hypothesis*; Klinger & Cox, 2004), the effect of attentional control (e.g., the *executive failure hypothesis*; McVay & Kane, 2009), a result of one's capacity to identify the contents of one's consciousness (e.g., the *meta-awareness hypothesis*; Schooler, 2002), or most likely the outcome of a combination of all of those, functioning to different degrees. In this way, it can be expected that mental contents are constantly emerging from within hippocampal structures, whereby the extent to which they are transformed into thoughts and unfold throughout the rest of the brain (and the extent to which they are likely to be experienced consciously) is determined by the level and specificity of those constraints.

Conclusion

Our minds frequently tend to "wander" about, shaping a spontaneous thought flow marked by heightened content variability over time. Since the signature of free movement and content variability are likely to come at a considerable metabolic cost (Laughlin, de Ruyter van Steveninck, & Anderson, 1998; Plaçais & Preat, 2013), there is likely some evolutionary advantage of the dynamic nature of human thought. Thus, this chapter has attempted to introduce an account of the neural and cognitive evolutionary benefits of spontaneous thought and its inherent content variability.

Specifically, the default variability hypothesis proposes that mind-wandering is characterized by content variability and continuous movement that support both efficient episodic storage (episodic efficiency hypothesis) and semantic knowledge abstraction (semantic optimization hypothesis). The episodic efficiency hypothesis suggests that the reactivations and recombinations underlying content variability play a critical role in pattern separation by helping to de-correlate memories in the hippocampus and neocortex. Pattern completion, on the other hand, is proposed to strengthen the separated episodic memory representations, while also being a potential source of continuous mental content, where one activated memory serves as a partial cue for the next. In addition, the semantic optimization hypothesis maintains that content variability supports episodic-to-semantic abstraction through multiple mental simulations that are both similar and dissimilar: The similarities provide the opportunity for repeated exposures so that concepts and categories can be strengthened over multiple exposures, while the dissimilarities mitigate the danger of overlearning a single instance. Through mental simulations, stemming from novel recombinations as well as reactivations, semantic abstraction is optimized due to increased variability and frequency over time in a set of samples containing similar yet dissociable information.

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CHAPTER

3

An Exploration/Exploitation Trade-off Between Mind-Wandering and Goal-Directed Thinking

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Abstract

Agents invariably face trade-offs between exploration, which increases informational stores and potentially opens up new opportunities, and exploitation, which utilizes existing informational stores to take advantage of known opportunities. This exploration/exploitation trade-off has been extensively studied in computer science and has been productively applied to multiple cognitive domains. In this chapter, this framework is extended to the ubiquitous alternation between two modes of serial thought: mind-wandering and goal-directed thought. The exploration/exploitation framework provides a new perspective on the functionality of mind-wandering and its pattern of regular switching with goal-directed thought. It also raises new hypotheses about the regulation of mind-wandering across time and differences in the propensity to mind-wander across individuals.

Key Words: mind-wandering, goal-directed thought, serial thought, exploration, exploitation

> [W]hilst we are awake, there will always be a train of ideas succeeding one another in our minds. [W]hen the mind with great earnestness, and of choice, fixes its view on any idea . . . and will not be called off by the ordinary solicitation of other ideas, it is that we call . . . "study." [W]hen ideas float in our mind without any reflection or regard of the understanding, it is that which the French call reverie . . ..
>
> —*John Locke (1689, II, 19 §1)*

Theorists in psychology and neuroscience often distinguish two modes of serial thinking. The first, which is here dubbed *goal-directed thinking*, is a voluntary, focused, purposeful mode. It depends on working memory (Baddeley, 1996, 2012) and cognitive control (Botvinick & Cohen, 2014; Miller, 2000) and is similar to what cognitive psychologists call "system 2" thinking (Evans, 2008). It is engaged during tasks that involve top-down control, vigilant attention, planning, problem-solving, and deliberative decision-making, among others. The second mode is *mind-wandering* (Callard, Smallwood, Golchert, & Margulies, 2013; Smallwood & Schooler, 2015), and it has been a topic of increasing investigation in the last decade. In this mode of thinking, individual thoughts spontaneously pop into mind, transitions between them are unpredictable, and the ongoing stream is discursive (Irving, 2015).

These two modes of serial thought appear to be competitive. As Locke noted, the modes of thought alternate with each other; episodes of one mode are displaced by episodes of the other with a complex pattern of switching. In this chapter, I develop a high-level theory that provides a unified understanding of these two modes of serial thought and the regulation of transitions between the two. The approach is rooted in the exploration/exploitation trade-off that was first described in theoretical models of learning (see Sutton & Barto, 1998 for a discussion) but is increasingly recognized as an important topic in psychology, neuroscience, and psychiatry. The model highlights the distinctive functionality of each mode of thought. It also sheds light on how the balance between the two modes of thought is tuned across time and varies across individuals.

The Exploration/Exploitation Framework

Consider a rabbit in a large patch with numerous bushes spread throughout, which vary considerably in the quantity of berries they have. The rabbit starts at one of the bushes and knows how many berries it offers, but it is unaware of the quantity of berries at any of the other bushes. At each moment in time, the rabbit faces a choice: continue to feed from the current bush, depleting it further (exploit), or visit other bushes to get a better sense of where they are and how many berries they have (explore).

In most environments, the optimal strategy will involve some combination of these. If the rabbit exclusively exploits, it might miss significant opportunities. For example, it might happen to be in a particularly barren region of the patch where berries are hard to come by, while abundant berries are available if it shifts to another corner of the patch. If the rabbit exclusively explores, it will build up better and better estimates of where the berries are distributed in the patch. But there are likely to be diminishing returns in making the estimates increasingly precise, not to mention that these precise estimates will be useless if the rabbit starves to death before they can be used.

In short, the problem faced by the rabbit pits two kinds of competing actions against each other. At an abstract level, they can be differentiated in terms of the kinds of search processes that they employ. Exploration involves wider, more open-ended search, the main purpose of which is to increase the agent's information about the properties of the search space (e.g., its size, structure, distribution of rewards, what actions are available). Exploitation employs a narrower, more goal-directed search strategy. Exploration and exploitation also differ in the types of uncertainty involved during search. In exploration, uncertainty tends to take the form of "unknown unknowns." For example, key parameters about the search space—its size, the magnitude and distribution of rewards, and so on—either lack adequate prior estimates or the confidence intervals around them are large. In exploitation, in contrast, uncertainty tends to take the form of "known unknowns" (i.e., uncertainty for which at least minimally reliable probability estimates are available).

While exploration and exploitation are sometimes presented in terms of a sharp dichotomy between two "pure" types of action, the preceding characterization suggests a continuum. Across various different domains, agents face trade-offs between actions that are relatively more exploratory versus actions that are relatively more exploitative. Exploration and exploitation are thus not defined in absolute terms, but rather should be understood comparatively and relative to a particular context.

The exploration/exploitation framework has been usefully applied to a number of real-world domains. Early theoretical work focused on reinforcement learning problems faced by animals and humans (Kaelbling, 1996; Sutton & Barto, 1998). Applied work examined foraging problems (Krebs, 1978), visual search (Wolfe, Cave, & Franzel, 1989), memory search (Hills, Jones, & Todd, 2012), and attention (Aston-Jones & Cohen, 2005; Usher, Cohen, Servan-Schreiber, Rajkowski, & Aston-Jones, 1999), among other topics (see Cohen, McClure, & Yu, 2007; Hills, Todd, Lazer, Redish, & Couzin, 2015). In what follows, the exploration/exploitation framework is extended to another domain: goal-directed thinking, mind-wandering, and their transitions (see also Mittner, Hawkins, Boekel, & Forstmann, 2016; Smallwood et al., 2012).

Applying the Exploration/Exploitation Framework to Serial Thought

Mind-Wandering Is an Exploratory Process

Recent studies suggest that we spend an enormous portion of our waking lives mind-wandering (Kane et al., 2007; Killingsworth & Gilbert, 2010; Klinger & Cox, 1987). What might be the purpose of this activity? While there are different perspectives on this question, an emerging view, supported by multiple lines of evidence, is that mind-wandering facilitates pattern learning and creativity. I review theoretical and empirical evidence for this "deep learning" approach to mind-wandering in detail elsewhere (Sripada, 2016) so here I will be brief.

During mind-wandering, various kinds of thoughts are called to mind, and much of the content is quasi-perceptual and imagistic: autobiographical memories of remote events, replays of more recent events, prospections into the near and distant future (Delamillieure et al., 2010; Klinger & Cox, 1987). The transitions between individual thoughts are discursive. There are often thematic continuities (Bar, Aminoff, Mason, & Fenske, 2007) between adjacent thought items but also substantial discontinuities. This kind of meandering thought stream is ideal for identifying interesting patterns and relationships. Thoughts are juxtaposed next to others in unpredictable and partially random ways, thus enabling implicit learning systems to "observe" these novel thought streams—in the same way they would observe actual unfolding events in the world—and to extract new patterns, generalizations, interpretations, and insights.

Several lines of evidence support the view that mind-wandering facilitates pattern learning and creativity. In early work, Jerome L. Singer and colleagues (Singer & Antrobus, 1963; Singer, 1974; Singer & Schonbar, 1961) found that a higher propensity to daydream was predictive of higher levels of creativity. Behavioral studies manipulated the quantity of mind-wandering during a specific interval of time and found that participants who mind-wandered more scored higher on measures of creativity (Baird et al., 2012). Studies using functional magnetic resonance imaging (fMRI) found greater activation in the default mode network (DMN), which has been associated with mind-wandering (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Andrews-Hanna, Smallwood, & Spreng, 2014), predicted better mnemonic functioning (Wig et al., 2008), greater depth of social understanding (Yang, Bossmann, Schiffhauer, Jordan, & Immordino-Yang, 2012), and greater creativity (Wang et al., 2009).

If the preceding picture that mind-wandering facilitates pattern learning and creativity is correct, then mind-wandering is naturally understood as an exploratory process. It involves a wide, discursive search through a vast space of memories, prospections, and other thought items. The search yields information gain through extraction of hidden patterns and production of creative insights.

Goal-Directed Thought Is an Exploitative Process

Relative to mind-wandering, goal-directed thinking is naturally understood as a more exploitative process, one that implements a narrow, targeted search strategy. The hallmark of goal-directed thinking is the coordinated use of attention, working memory, and cognitive control for the purposes of achieving a specific goal (Baddeley, 1996, 2012; Botvinick & Cohen, 2014; Evans, 2008; Miller, 2000). The coordination of these elements is achieved by task sets, which are conceptualized as explicitly encoded instructions activated by specific task contexts (Dosenbach et al., 2006; Hazeltine & Schumacher, 2016).

Consider a specific example: mental arithmetic. Here the overall goal is to get the solution of a math problem, and instructions specify the steps that need to be undertaken (e.g., start at the right column and sum the digits; if the sum is greater than 10, then carry the one; move one column to the left, etc.). Each element of the unfolding sequence of thought is constrained by the task instructions. If attention is spontaneously redirected to something salient in the environment, cognitive control processes redirect attention and resume the sequence of steps (Miller, 2000).

Notice that, unlike mind-wandering, goal-directed thinking is not open-ended or discursive. Rather, this mode of thought is aimed at achieving a specific goal and is constrained by explicit instructions. This form of thinking is thus unlikely to uncover novel patterns or to produce creative insights.

There Is a Trade-off Between Goal-Directed Thinking and Mind-Wandering

In the quote at the head of this chapter, Locke notes that goal-directed thinking (what he called "study") and mind-wandering (what he calls "reverie") typically alternate; that is, they are not usually co-present, but rather follow each other in succession. One could interpret this observation as an instance of a broader thesis that goal-directed thinking and mind-wandering exhibit a competitive relationship: Engaging in one tends to interfere with the other.

Behavioral studies provide one line of evidence in favor of this thesis. A number of studies have examined mind-wandering during prolonged, relatively monotonous tasks. These studies reliably find that measures of task performance, such as accuracy, reaction time, and reaction variability, significantly deteriorate during intervals when participants are engaged in mind-wandering (McVay & Kane, 2009; Schooler, Reichle, & Halpern, 2004; Smallwood, Brown, Baird, Mrazek, et al., 2012; Smallwood, McSpadden, Luus, & Schooler, 2008; Smallwood, McSpadden, & Schooler, 2007).

There is also support for competition between goal-directed thinking and mind-wandering from neuroimaging. Goal-directed thinking is associated with activity in a frontal and parietal network of regions encompassing dorsal lateral prefrontal cortex (dlPFC), superior parietal cortex, frontal eye fields, anterior insula, and supplementary motor cortex. These regions are reliably activated in a broad array of otherwise diverse cognitively demanding tasks (Cabeza & Nyberg, 2000) and thus have been dubbed variously: general demand cortex (Duncan & Owen, 2000), the task-positive network (M. D. Fox et al., 2005), and the cognitive control network (Cole & Schneider, 2007).

Mind-wandering, in contrast, is associated with preferential activity in the DMN (Andrews-Hanna et al., 2010, 2014), a network of midline, lateral parietal, and medial and lateral temporal brain regions. Regions of this network are associated with internally directed attention, representations of self, and episodic memory, among other functions (Buckner, Andrews-Hanna, & Schacter, 2008; Buckner & Carroll, 2007).

During tasks, the neural regions that subserve goal-directed thinking on the one hand, and the DMN on the other, exhibit a robust reciprocal relationship: while the task stimulus is present, the former regions are activated and the DMN is deactivated, while the reverse is true during rest intervals (Mazoyer et al., 2001; Raichle et al., 2001; Shulman et al., 1997). Additionally, tasks that are more cognitively demanding are associated with more activation in the regions subserving goal-directed thinking, more deactivation in the DMN, and reduced mind-wandering (McKiernan, D'Angelo, Kaufman, & Binder, 2006; McKiernan, Kaufman, Kucera-Thompson, & Binder, 2003). This has led to the suggestion that the DMN is being adaptively downregulated during cognitively demanding tasks to facilitate task performance (McKiernan et al., 2006).

The preceding neural evidence suggests reliable antagonism between the neural regions supporting goal-directed thinking and mind-wandering. There is a complication, however. Some theorists propose that during mind-wandering, there is significant activation in specific regions that are often associated with goal-directed thinking, for example dlPFC (K. C. R. Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Smallwood, Brown, Baird, & Schooler, 2012; Teasdale et al., 1995).

Findings such as these, however, can be reconciled with the hypothesis of antagonism between goal-directed thinking and mind-wandering. The key is to recognize that antagonism is being proposed at the level of overall brain-wide neural signatures: stronger presence of one signature is reliably associated with reduced presence of the other signature. Such antagonism between aggregate signatures is compatible with the respective signatures exhibiting overlap at one or more specific nodes. So even if dlPFC (as well as certain other "executive" regions) are activated during goal-directed thinking as well as during mind-wandering, the overall signatures of the former and latter are still quite distinct, and these signatures remain reciprocally related.

An exploration/exploitation trade-off exists when there is a relatively exploratory course of action, a relatively exploitative course of action, and there is a trade-off between doing one and the other. The evidence reviewed in the preceding subsection builds a case that mind-wandering and goal-directed thinking are, respectively, relatively exploratory and relatively exploitative. The behavioral and neural evidence reviewed in the present subsection suggests there is a trade-off between the two modes of thought, that is, engaging in one generally entails forgoing the other

Management of the Exploration/Exploitation Trade-off in Serial Thought

If the alternation between mind-wandering and goal-directed thinking is an instance of an exploration/exploitation trade-off, then this raises a question: How are the transitions between the two managed? It is plausible that there are mechanisms that balance the two modes of thought and produce an adaptive distribution between them.

There are important theoretical results about how to optimally solve exploration/exploitation trade-offs (Gittens, 1979). However, these solutions tend to be computationally intensive and rely on assumptions that are unlikely to hold in many real-world circumstances. Thus it is plausible that exploration/exploitation trade-offs that arise in the kinds of problems faced by humans and other animals are usually solved by various kinds of simplifying shortcuts (Cohen et al., 2007). Here, three regulatory strategies are proposed that might potentially play a role in adaptive transitions between goal-directed and mind-wandering modes of serial thought. Note that these aren't strategies that people consciously and intentionally implement. Rather, it is proposed that mental systems can be thought of "as if" they execute these strategies—the strategies are, in effect, built into the procedures implemented by these mental systems.

The Default Strategy

Goal-directed thought is useful in certain specific kinds of situations where sequencing and guidance of thought by task sets are required.

These situations will (typically) arise intermittently with long intervening periods where goal-directed thought is not needed. Given this pattern, a reasonable way to handle the allocation between goal-directed thought and mind-wandering is to treat mind-wandering as a kind of default state: it is what the person will do so long as goal-directed thought is not required. When necessary, this default state of mind-wandering can be interrupted for brief bursts of goal-directed thought, after which the default state automatically resumes.

Evidence for the default strategy comes from the neuroimaging studies described earlier. There it was noted that during cognitively demanding tasks, the regions supporting goal-directed thinking are activated, while the DMN, which supports mind-wandering, is deactivated. However, as soon as a rest interval is provided, the DMN is immediately activated and remains so for the duration of the rest. Experience sampling studies show that during these rest intervals, participants experience streams of autobiographical memories and prospective thoughts characteristic of mind-wandering (Delamillieure et al., 2010). Notice that the experimenter does not have to tell participants that they should mind-wander as soon as the task ends. Nor are children explicitly socialized or trained to do this. Rather, the tendency to engage in mind-wandering whenever not engaged in a cognitively demanding task seems to be universal, automatic, and unlearned, which is precisely what is predicted by the view that a default strategy is being utilized.

The Oscillation Strategy

Earlier it was noted that it is almost never a sound strategy to engage exclusively in exploration or exclusively in exploitation. An agent that only exploits will fail to develop informational stores that may lead to still greater rewards. An agent that only explores will fail to seize on known opportunities, and if the relevant opportunities consist of food or shelter, the agent may even perish. It is thus adaptive to engage in some balance between exploration and exploitation.

Now consider a second agent (that lives for many years) that balances the total amount of time spent in each mode in the following way: the agent engages exclusively in exploration during the first half of its lifetime and exclusively in exploitation during the second half of its lifetime. This is a maladaptive allocation for nearly the same reasons that applied to the first agent that engages in exclusive exploration or exclusive exploitation (i.e., over each half of its life, this second agent either fails to build up informational stores or fails to seize known opportunities). The example illustrates that an adaptive allocation between exploration and exploitation not only balances the total time spent in each, but also maintains this balance within some appropriately short unit of time. Moreover, it is clear that this relevant unit of time is much shorter than a lifetime, and it plausibly might even be as short as minutes and hours.

One efficient way to ensure that an agent achieves a balance between exploration and exploitation across some relatively short unit of time is to have an inner "drive" to engage in each, where the drive exhibits temporal oscillation within the relevant unit of time. Interestingly, there is some evidence that goal-directed thought and mind-wandering do exhibit the kinds of temporal oscillations that are predicted by this type of model.

In everyday experience, we are familiar with attention fluctuating over time on timescales of seconds to minutes. For example, a person attentively reads a dense academic article for a minute or so, her mind wanders away from the article for a minute, she returns to attentive reading of the article, and the cycle continues. A useful method for quantitatively measuring these ongoing cycles of attention is reaction time variability (RTV), which is a measure of the instability of reaction time across time within the same individual. During episodes of goal-directed thought, RTV is lower as the focus of attention is on the task at hand. During episodes of mind-wandering, RTV increases as attention turns away from the task and toward the ongoing discursive stream of memories and prospections (Allan Cheyne, Solman, Carriere, & Smilek, 2009; Mooneyham & Schooler, 2013; Smallwood et al., 2008).

Given this link between RTV and modes of serial thought, it is noteworthy that a number of recent studies find that RTV is not constant across time, but itself exhibits a somewhat fluctuating pattern. Individuals typically experience short epochs (lasting tens of seconds) of low RTV, reflecting higher levels of attention, interspersed with epochs of high RTV, reflecting lower levels of attention (Esterman, Noonan, Rosenberg, & Degutis, 2013; Esterman, Rosenberg, & Noonan, 2014). This observation suggests that there are regular ongoing oscillatory shifts between goal-directed thought and mind-wandering.

Other studies shed light on the mechanistic basis of these oscillatory shifts. Usher and colleagues

(Usher et al., 1999) trained Cynomolgus monkeys to perform an extended visual discrimination task and divided the train of responses into epochs of good and bad performance. They measured neurons in the locus coeruleus (LC), a midbrain nucleus that is the principal site of norepinephrine synthesis and has projections throughout the prefrontal cortex, among other brain regions. They found that modes of LC activity mediated shifts between epochs of good and bad performance, with the "phasic mode" of LC activity (low baseline and high task-evoked LC output) associated with good epochs, and the "tonic mode" of LC activity (high baseline and low task-evoked LC output) associated with bad epochs. They speculated that the LC plays a role in managing the exploration/exploitation trade-off, with the tonic LC mode characterized by less attention to task and greater exploration (see also Aston-Jones & Cohen, 2005; Cohen et al., 2007; McClure, Gilzenrat, & Cohen, 2006).

Pupillary diameter has been shown to reliably reflect phasic versus tonic modes of LC activity (Aston-Jones & Cohen, 2005). Smallwood and colleagues took advantage of this relationship to study attention fluctuation and mind-wandering in human participants performing an extended continuous performance task (Smallwood, Brown, Baird, Mrazek, et al., 2012). They found that epochs of poor performance were characterized by increased mind-wandering (as measured by experience sampling) as well as pupillary signatures of the tonic LC mode. (Of note, pupillary findings are more difficult to interpret when time-on-task is taken into account, especially in demanding vigilance tasks that minimize breaks between trials. These tasks often find lower pupillary baselines as time-on-task increases (Brink, Murphy, & Nieuwenhuis, 2016; Grandchamp, Braboszcz, & Delorme, 2014; Hopstaken, van der Linden, Bakker, & Kompier, 2015; Van Orden, Jung, & Makeig, 2000), and the role of the LC in producing these effects remains poorly understood.)

Putting together the preceding lines of evidence, the overall picture looks like this: The LC serves as something like an internal pacemaker, shifting back and forth over timescales of seconds to minutes (extending perhaps to hours, though this has been less studied) between two modes: (1) an exploitative mode, characterized by a high degree of task-directed attention and good task performance; and (2) an exploratory mode, characterized by a lower degree of task-directed attention, high levels of mind-wandering, and poor task performance. According to the "oscillation strategy" model, this pattern of oscillatory fluctuation produces balanced sampling of both exploration and exploitation strategies across relatively short intervals of time.

Recently, Mittner and colleagues proposed an alternative model that links phasic versus tonic modes of LC functioning to modes of serial thought, but their model differs from the present one in many respects (Mittner et al., 2016). For example, they link the exploitative phasic LC mode with both goal-directed thinking and mind-wandering, while the exploratory tonic LC mode is linked with a third "off-focus" state that mediates transitions between the two. A comprehensive discussion of their model, and evidence for and against it, is beyond the scope of this chapter. But their work illustrates the fruitfulness of the exploration/exploitation framework for spurring novel hypotheses about regulation of serial thinking.

The Fatigue Strategy

It is plausible that goal-directed thinking and mind-wandering exhibit different profiles of marginal utility with time. Goal-directed thinking is likely to exhibit diminishing marginal utility over relatively short stretches of time (i.e., minutes and hours). This is because this mode of thinking is usually initiated to achieve some well-defined specific goal, perhaps deliberating on a set of options or trying to solve some specific problem (e.g., figuring out the shortest route between two locations). After a certain amount of time, additional efforts in deliberating or explicit problem-solving are unlikely to yield additional gains; the person is better off stopping and moving forward with action.

Mind-wandering, in contrast, is likely to exhibit relatively constant value over time. Earlier, mind-wandering was interpreted in terms of a wide search process that operates over a vast space of episodic memories, prospections, and so on. The search process yields information gains through pattern learning and generation of creative insights. Given the vastness of the search space over which mind-wandering operates, there is no obvious reason that its usefulness should decline over relatively short stretches of time (i.e., minutes to hours).

Let us assume that this picture is correct, and that the two modes of serial thought differ in terms of marginal utility with time. It follows that to maximize utility, it would be adaptive to have a time-on-task dependent signal that limits the duration in which one engages in goal-directed thinking. This signal should gradually build with time, so that it becomes harder to continue with goal-directed thinking as the signal becomes stronger. Such a signal would tend to motivate the person away from goal-directed thought after a prolonged interval. Given the default strategy noted earlier, the person would naturally resume mind-wandering once goal-directed thinking had ceased.

It is possible that cognitive fatigue plays precisely the role of the time-on-task dependent signal just proposed (for a related suggestion, see Carruthers, 2015; Irving, 2016). Consistent with the proposed model, cognitive fatigue does in fact occur in a wide variety of tasks that engage goal-directed thinking, including tasks involving inhibitory control, vigilant attention, decision-making, and planning (Hagger, Wood, Stiff, & Chatzisarantis, 2010; See, Howe, Warm, & Dember, 1995; van der Linden, Frese, & Meijman, 2003). In contrast, mind-wandering is described as feeling automatic and effortless, and it is not accompanied by cognitive fatigue (McVay & Kane, 2010).

The model of cognitive fatigue being proposed here has clear similarities to a model by Kurzban and colleagues, which appeals to the idea that engaging in cognitive processes for certain tasks incurs opportunity costs (Kurzban, Duckworth, Kable, & Myers, 2013). There is a critical difference, however. Kurzban and colleagues propose that "controlled cognition" (what is here being called goal-directed thinking) depends on a "prefrontal executive network," which constitutes a versatile cognitive resource that can be used for multiple purposes. The function of cognitive fatigue, on their view, is not to get a person to disengage from goal-directed thinking. Rather, it is to get the person to switch from using goal-directed thinking for one specific task and instead deploy it for another specific task. In short, the model from Kurzban and colleagues treats cognitive fatigue during goal-directed thinking as a signal that represents the opportunity cost of *alternative tasks* that one could instead be doing. In contrast, on the model being presently proposed, cognitive fatigue during goal-directed thinking represents the opportunity cost of *an alternative mode of serial thought* that one could instead be engaged in, an exploratory mode of thought that delivers a more or less stable quantity of utility irrespective of duration.

The two models of cognitive fatigue—Kurzban and colleagues' model and the one being presently proposed—make different predictions about what happens when a person engages in goal-directed thinking for a prolonged period of time (assume that he or she is performing a single task, say a difficult planning problem). Kurzban and colleagues' model says the buildup of cognitive fatigue will motivate the person to disengage from the current task and instead take up any of a number of sufficiently distinct tasks that also engage goal-directed thought, say a task requiring vigilant attention. In contrast, the model being presently proposed says that the buildup of cognitive fatigue will motivate the person to disengage from goal-directed thought and instead take up mind-wandering, a mode of serial thought that is distinctive in being effortless and non-fatiguing. While direct head-to-head comparisons of the predictions of the two models are lacking, ordinary experience seems much more supportive of the second model.

Individual Differences: Mind Wandering and Attention Deficit Hyperactivity Disorder

So far, the exploration/exploitation trade-off has been used to try to provide deeper understanding of the trade-off between mind-wandering and goal-directed thinking, and the mechanisms by which the trade-off is managed across time in the same individual. In this section, the focus will be on individual differences, that is, ways in which the trade-off might be managed in systematically different ways in different persons. In particular, the case of attention deficit hyperactivity disorder (ADHD) is examined in detail as a way of shedding light on the broader issue of individual differences.

ADHD is the most common psychiatric disorder of childhood, affecting roughly 5%–8% of youth (Polanczyk & Rohde, 2007), and involves inattention, hyperactivity, and impulsivity (American Psychiatric Association & DSM-5 Task Force, 2013). Recently, Hauser and colleagues proposed an intriguing model in which ADHD is caused by a pervasive increase in exploration relative to exploitation (Hauser, Fiore, Moutoussis, & Dolan, 2016). Their model builds on the observation that individuals with ADHD exhibit alterations in catecholamine neurotransmitter systems (including the norepinephrine system discussed earlier), which are hypothesized to play a role in managing the balance between exploration and exploitation (Aston-Jones & Cohen, 2005; McClure et al., 2006). They propose that one of the ways that increased exploration in ADHD manifests is through the decision temperature variable, which governs the stochasticity of choice. More specifically, agents usually select actions that have highest expected utility based on their current (potentially incorrect) estimates. But as the decision temperature setting goes higher, agents increasingly deviate from responding in line with their current utility estimates and instead randomly select alternative actions, which constitutes an exploratory strategy.

Hauser and colleagues' model focuses on greater exploration in ADHD primarily in the domains of decision-making and action. It is notable, however, that individuals with ADHD also exhibit a greater propensity to mind-wander (G. A. Shaw & Giambra, 1993; Franklin et al., 2014; Seli, Smallwood, Cheyne, & Smilek, 2015). This observation suggests an extension to their model: In addition to a greater propensity for exploration in decision and action, individuals with ADHD might also have a greater propensity for exploration in serial thought.

What are the neurocognitive mechanisms that lead to greater exploration and mind-wandering in ADHD? Interestingly, certain lines of research link increased mind-wandering in ADHD to alterations in some of the strategies discussed earlier for management of the exploration/exploitation trade-off in serial thought. For example, consider the oscillation strategy. Several studies have measured changes in RTV during the course of an extended task (note: fluctuations in RTV over long intervals of time might themselves be regarded as "low frequency" aspects of RTV). These studies find that individuals with ADHD have more pronounced fluctuations in RTV compared to healthy individuals (Castellanos et al., 2005; Di Martino et al., 2008; Tamm et al., 2012). Recall that high RTV during an interval of time is thought to reflect the occurrence of mind-wandering during that interval. The more pronounced fluctuations in RTV across time in ADHD could potentially reflect an increased tendency to regularly punctuate episodes of goal-directed thought with bouts of mind-wandering, which would produce more frequent back-and-forth switching and thus more variation in RTV.

Other studies suggest an alteration in the fatigue strategy in ADHD. Many studies have documented that nearly all individuals show diminished performance with prolonged engagement in cognitively demanding tasks, which is plausibly thought to reflect the buildup of cognitive fatigue (Hagger et al., 2010; See et al., 1995; van der Linden et al., 2003). In individuals with ADHD, this decline in performance with time-on-task appears to be more pronounced (Bioulac et al., 2012; Börger et al., 1999; Tucha et al., 2015). This could reflect exaggerated operation of the fatigue strategy, which leads to more rapid disengagement from goal-directed thinking and the resumption of the default state of mind-wandering.

Another mechanism that might lead to greater exploration generally, and mind-wandering specifically, in ADHD is brain immaturity. Theorists have noted that the exploration/exploitation trade-off tends to be biased toward exploration during youth (Eliassen, Jørgensen, Mangel, & Giske, 2007; Mata, Wilke, & Czienskowski, 2013), which is reflected in a greater tendency to explore objects and places and to engage in pretend play. Interestingly, the brains of individuals with ADHD have reliably been found to be less developmentally mature than neurotypical individuals (Castellanos & Lee, 2002; P. Shaw et al., 2006, 2007, 2012, 2013). Studies of the development of functional networks in the brain, in particular, have shown that relative immaturity is especially prominent in (1) the networks supporting goal-directed thinking; (2) the DMN, which supports mind-wandering; and (3) interconnections between the two (Kessler, Angstadt, & Sripada, 2016; Sripada, Kessler, & Angstadt, 2014). These observations suggest a neurodevelopmental mechanism for greater exploration in ADHD: individuals with ADHD exhibit lower levels of brain maturation relative to healthy age-matched controls, resulting in the preservation of a relatively more youthful and more exploratory cognitive style.

Conclusion

The trade-off between exploration and exploitation has been extensively studied in computer science and has been usefully applied to multiple cognitive domains, including learning, visual search, memory search, and decision-making. In this chapter, this framework was extended to the ubiquitous alternation between mind-wandering and goal-directed thought. The exploration/exploitation framework potentially helps illuminate the default nature of mind-wandering, the fluctuation of attention over timescales of seconds to minutes, the increase in cognitive fatigue with time-on-task, and the greater propensity to mind-wander in youth and in those with ADHD.

Acknowledgments

Thanks to Kalina Christoff, Kieran Fox, and Zac Irving for providing extensive written comments that greatly improved this chapter.

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CHAPTER

4

When the Absence of Reasoning Breeds Meaning: Metacognitive Appraisals of Spontaneous Thought

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Abstract

Intuitions, attitudes, images, mind-wandering, dreams, and religious messages are just a few of the many kinds of uncontrolled thoughts that intrude on consciousness spontaneously without a clear reason. Logic suggests that people might thus interpret spontaneous thoughts as meaningless and be uninfluenced by them. By contrast, our survey of this literature indicates that the lack of an obvious external source or motive leads people to attribute considerable meaning and importance to spontaneous thoughts. Spontaneous thoughts are perceived to provide meaningful insight into the self, others, and the world. As a result of these metacognitive appraisals, spontaneous thoughts substantially affect the beliefs, attitudes, decisions, and behavior of the thinker. We present illustrative examples of the metacognitive appraisals by which people attribute meaning to spontaneous secular and religious thoughts, and the influence of these thoughts on judgment and decision-making, attitude formation and change, dream interpretation, and prayer discernment.

Key Words: spontaneous thought, mind-wandering, decision-making, attribution, metacognition

At times you have to leave the city of your comfort and go into the wilderness of your intuition. What you'll discover will be wonderful. What you'll discover is yourself.

—*Alan Alda, Commencement Speech at Connecticut College (1980)*

Spontaneous thoughts are uncontrolled thoughts, generated for reasons and by processes inaccessible to the thinker (e.g., Marchetti, Koster, Klinger, & Alloy, 2016; Miller, 1962). As such, people might justifiably view spontaneous thoughts to be random and meaningless byproducts of their past or present circumstances. The literature that we survey suggests the opposite. Precisely because their origin is ambiguous, people attribute considerable meaning to spontaneous thoughts, including attitudes, dreams, intuitions, intrusive thoughts and memories, mind-wandering, and prayers. People perceive spontaneous thoughts to provide important insights about the self, others, and their world. As a consequence of the meaning imbued through these metacognitive appraisals, spontaneous thoughts can profoundly influence behaviors, including beliefs, attitudes, and decisions. We present a synopsis of this literature and illustrative examples in domains including judgment and decision-making, attitude formation and change, dream interpretation, and prayer.

Spontaneous Thoughts Are Attributed Peculiar Meaning

Spontaneous thoughts have long been attributed considerable meaning across a wide swath of religions, secular cognition, and scientific theory. Religious and mythological texts from antiquity relate many cases in which spontaneous thoughts in the form of dreams and visions were imbued with divine commands and revelations. Early biblical passages describe many instances in which God communicates God's actions or will to believers and heathens through spontaneous visions and dreams. In contemporary religions, such as among Evangelical Christians, believers find meaning similar to that found by their ancient counterparts in their dreams and the spontaneous thoughts that occur to them during prayer (Luhrmann, 2012).

Secular literature and popular culture abound with similar examples of influential spontaneous thoughts. Famous cases include people tortured by intrusive thoughts (e.g., Dostoyevsky, 1866/2011; Homer, 8th century BCE; Poe, 1976). Achilles was so tortured by intrusive thoughts of his deceased friend Patroclus that he could not sleep (Homer, 8th century BCE). Mercutio and Lady Macbeth were similarly haunted with nightmares of past battles and murder, respectively (Shakespeare, 1595/1985; 1623/2001). Modern literature is full of cases in which people are well guided by their intuition (e.g., "trust your gut"). Agatha Christie lauded the utility of trusting intuition in her famous mystery novels (Christie, 1930/2011), for instance, as did Madeleine L'Engle in her popular fantasy novels for children (e.g., 1973).

Early and recent clinical, cognitive, and social psychological theories and methods reflect a similar view of the importance attributed to dreams and spontaneous thoughts. Early psychoanalytic traditions viewed dreams as a "royal road" to the unconscious motives and emotions that guide behavior (e.g., Freud, 1900/1953). More recent psychological theories and practices place considerable value on the elicitation of spontaneous thought because those thoughts are perceived to provide access into unconscious processes (e.g., Gawronski & De Hoouwer, 2014; Mihura, Meyer, Dumitrascu, Bombel, 2013; Murray, 1943; Schafer, 1954), are purported to reflect the undistorted preferences of the thinker (e.g., Dijksterhuis, Bos, Nordgren, & Van Baaren, 2006; Wilson & Schooler, 1991), and may be less affected by self-presentational concerns and experimental demand than similar deliberate forms of cognition (Nosek, 2007; cf. Fiedler & Bluemke, 2005). For instance, the first thought that occurs spontaneously in response to the prompt "African American" might reveal which of several concepts related to that stimulus is most chronically accessible (Bargh & Chartrand, 2014), and spontaneous methods of attitude elicitation such as the implicit association test (IAT) may reveal more negative associations with "African American" than a typical person might be willing to explicitly reveal (Gawronski & De Hoouwer, 2014).

In this section, we review evidence suggesting that both laypeople and scientists often attribute greater meaning to spontaneous thoughts in the form of intuitions, attitudes, counterfactuals, intrusive thoughts, dreams, and prayers than to similar forms of deliberate cognition. Indeed, people perceive that the spontaneity of a thought signals its truth-value and accuracy (e.g., Topolinski & Reber, 2010), or the quality of a decision (e.g., Kupor, Tormala, Norton, & Rucker, 2014). People even attribute greater meaning to spontaneous thoughts than more deliberative or effortful thinking when the content of spontaneous and deliberate cognitions is similar (Morewedge, Giblin, & Norton, 2014; Morewedge & Norton, 2009).

Spontaneous Thoughts Are Meaningful Mental Events

Although it would be reasonable to believe that random thoughts are less meaningful than thoughts with an apparent cause, secular laypeople, religious congregants, and scientists in many cases attribute meaning to thoughts precisely because they occurred spontaneously. Features of spontaneous thoughts, such as their high processing fluency, certainly can contribute to the meaning they are attributed. However, the spontaneity of a thought itself may be taken as a signal of its importance, whether the thinker is examining her thoughts for traces of a divine origin, inferring if an action is morally praiseworthy or blameworthy, or determining her attitude toward a new stimulus or recent decision.

Approximately one-third to one-half of thought is spontaneous (Klinger & Cox, 1987), and people derive significant meaning from the occurrence of their spontaneous thoughts. Indeed, people explicitly attribute meaning to thoughts to the extent that they are perceived to be spontaneous. In one study we conducted, research participants ($N = 198$) appraised 13 categories of thought on the extent to which each provided insight into the self, and the extent to which they tend to occur spontaneously versus deliberately: intuition, deliberation, dreaming, Freudian slips, thoughts under hypnosis, mind-wandering, logical thoughts, problem-solving, random thoughts, rumination, spontaneous thoughts, and thoughts while under the influence of a truth serum. The greater the extent to which each of those categories of thought was perceived to be spontaneous linearly predicted the extent to which it was perceived to reveal meaningful insight into the mind of the thinker (Morewedge et al., 2014; Figure 4.1).

The spontaneity of a thought may imbue it with meaning by signaling its truth-value. "Ah-ha" moments, solutions to problems that appear to the thinker through sudden insight, are perceived to provide true insight to the extent that they are perceived to have been surprising. These solutions benefit from their high fluency (i.e., ease of cognitive processing), which can lead them to be evaluated more positively (Zajonc, 1968). However, spontaneous insights must be distinctive in their prominence or suddenness to be perceived as more creative and truer than alternative solutions (Pronin, 2013; Topolinski & Reber, 2010). Manipulating fluency through the figure–ground contrast of font and background colors, Reber and Schwartz (1999) found that people perceived high-fluency statements to be truer than low-fluency statements, but only when the high-fluency statements immediately followed low-fluency statements. When a high-fluency statement was embedded in a block of other high-fluency statements, its fluency was insufficiently surprising to increase its perceived truth-value.

For some, the spontaneity of a thought during prayer is taken as a possible signal of its divine truth—that it is the will of God. Evangelical Christians in the Vineyard tradition regularly engage in communication with God through prayer. The form of this communication often follows a question–response format. The person praying deliberately formulates a query or topic, and then waits for a response from God in the form of a spontaneous thought. This potentially divine thought is then examined by the individual and her religious community through a process of prayer discernment, with many thoughts classified as divine messages from God. One example of such a "discourse" is the individual picturing a person for whom she is concerned, and waiting until a word is spoken or appears in her mind across the picture. These spontaneous thoughts are often described as verbal or visual stimuli, such as a spoken word, written word, or image, which are often accompanied by a positive affective cue (Luhrmann, 2012).

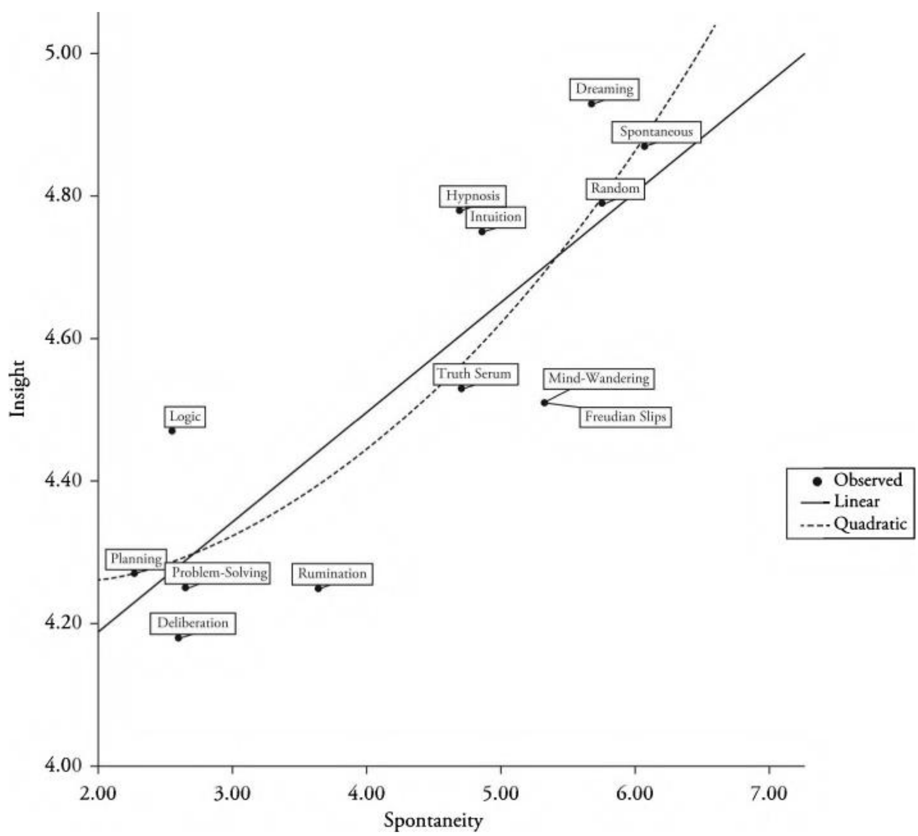

Figure 4.1. Greater perceived thought spontaneity increases perceived insight into the thinker's mind. Reprinted from Morewedge, Giblin, and Norton (2014).

Secular spontaneous beliefs and attitudes are often immediately accepted as true (e.g., Frederick, 2005; Morewedge & Kahneman, 2010). Rather than questioning why they occurred, people often engage in post hoc rationalization and a search for supporting arguments to justify these intuitive beliefs and attitudes. A sudden disgust response, for instance, can prompt the thinker to generate reasons justifying her initial feeling (e.g., Haidt, 2001). If a disgust response occurs when she is evaluating non-normative but harmless activities, such as homosexual sex, that explanatory process may lead her to then believe that the activity is immoral (e.g., Inbar, Pizarro, Knobe, & Bloom, 2009).

More generally, spontaneous affective reactions to stimuli cause people to immediately and unintentionally evaluate stimuli across a wide range of domains as good or bad. People interpret positive (or negative) affect as an indicator that their attitudes toward a focal stimulus must be positive (or negative; Chaiken, 1987; Zajonc, 1980). Such automatic evaluations occur even when people do not have a goal of evaluating the stimulus (Bargh, Chaiken, Raymond, & Hyme, 1996). As a result of these spontaneous thoughts, people's preferences, judgments, and attitudes can be formed before they are consciously aware of them (e.g., Loewenstein, Weber, Hsee, & Welch, 2001; Morewedge & Kahneman, 2010; Zajonc, 1980).

Spontaneous thoughts can also serve as meaningful signals about the quality of an activity or decision. If spontaneous thoughts arise that are unrelated to the focal activity in which the thinker is engaged, she may infer that she is unsatisfied with it (e.g., bored; Eastwood, Frischen, Fenske, & Smilek, 2012). If a moviegoer finds his mind wandering to other pleasant or entertaining events, he is more likely to infer that he is not enjoying the movie than that he has a poor attention span (Critcher & Gilovich, 2010; Eastwood et al., 2012). Indeed, people report being happier throughout the day when their mind is focused on the activity in which they are engaged than when their mind wanders elsewhere (Killingsworth & Gilbert, 2010; Smallwood & Schooler, 2015).

Counterfactual thoughts, a particular type of mind-wandering in which people imagine what could have been if events had unfolded differently, can signal dissatisfaction with a decision or outcome in the recent or distant past (e.g., Iyengar, Wells, & Schwartz, 2006). If a consumer thinks about a laptop other than the laptop he just purchased, he might infer that he isn't happy with the laptop that he bought (Mannetti, Pierro, & Kruglanski, 2007; Morewedge, 2016). Similarly, a student's counterfactual thoughts about how she might have performed better on a test are likely to indicate to her that she is unhappy with her test performance (Roese & Hur, 1997). Intriguingly, people also report being less attracted to their current or recent significant other if mind-wandering leads them to think of another person to whom they are sexually attracted than if the attractive other is identified through more deliberate reasoning processes (Morewedge et al., 2014).

Spontaneous Thought Content Is Important Thought Content

In many contexts, people perceive the content of spontaneous thoughts to provide more meaningful information about the self, other people, and their world, than the content of similar deliberative and effortful thinking. In other words, people attribute greater meaning and importance to the content of their intuitions, reflexive and implicit attitudes, spontaneous thoughts, and even their dreams, than to similar content arising from more deliberate forms of cognition.

INTUITION

People explicitly believe that intuition provides better solutions for some of their decisions than deliberate forms of thinking, as when choosing a spouse or dessert (Inbar, Cone, & Gilovich, 2010). People also apply this same belief to others' decisions. When an actor makes a fast decision about an easy choice set (e.g., a choice set in which products differ only in color), observers infer that the actor is a better decision-maker and are more willing to follow that actor's advice in the future. In contrast, when an actor makes a fast decision about a difficult choice set (e.g., a choice set in which products differ across multiple non-aligning attributes), observers infer that the actor is a poor decision-maker (Kupor, Tormala, Norton, & Rucker, 2014). Whether people make decisions for themselves or simply observe others' decisions, people explicitly believe that intuition can be a conduit to quality decisions.

These beliefs are not necessarily misguided. In some cases, intuition may be a better way to make decisions than deliberation (Dijksterhuis et al., 2006; Wilson & Schooler, 1991; cf. Payne, Samper, Bettman, & Luce, 2008). When making complex decisions involving multiple attributes, deliberation can lead people to place undue weight on a subset of attributes that happen to be salient at the time of judgment for idiosyncratic reasons. A chronic flaw in graduate admissions, for example, is the tendency to base admissions decisions on how candidates performed in their interview, rather than on more predictive and quantifiable measures of their performance, such as their GRE exam score (Dawes, 1979).

Even in cases where people believe deliberation is a better process by which to make decisions than intuition, people perceive decisions that they made through intuition to be as good or better than decisions that they made through deliberation. In an incentive-compatible experiment in which students received one of five posters for their dorm room, students predicted that they would like the poster that they chose more, and would be willing to forgo more money to keep their poster, if they selected a poster deliberately than if they selected a poster by letting their mind wander until a choice came to mind (Giblin, Morewedge, & Norton, 2013). In a second group of students who actually selected a poster (see Figure 4.2), both groups of participants reported liking their poster equally and were willing to forgo similar amounts of money to keep their poster. In addition, both groups liked and valued their poster considerably more than did students who were randomly assigned a poster.

People even prefer to rely on their intuition when compelling reasons suggest that their intuition is wrong (e.g., Denes-Raj & Epstein, 1994; Kirkpatrick & Epstein, 1992; Morewedge & Kahneman, 2010; Simmons & Nelson, 2006). One surprising example is ratio-bias. When people are given the chance to win money for drawing a red bean from a bowl, they intuit that they are more likely to win if they draw from a bowl that holds a larger number of red beans (e.g., 7 out of 100) rather than a bowl with a smaller number of beans with better odds (e.g., 1 out of 10). In other words, intuition suggests choosing the bowl with the most "chances" of winning, whereas rational deliberation suggests choosing the bowl with the most favorable ratio. Some people exhibit this ratio bias even when they are explicitly reminded that their odds are worse if they draw from the larger bowl (Peters et al., 2006).

People also believe that intuition reveals more about the mind and character of the thinker than more deliberate forms of cognition, whether the thinker is another person or the self. For example, a person who finds a cash-filled wallet and decides to keep it is judged to be more immoral if he quickly decides to keep the wallet than if he decides to keep it after deliberating. Conversely, a person who decides to return the wallet to its rightful owner is judged to be more moral if he quickly decides to return the wallet than if he returns it after deliberating (Critcher, Inbar, & Pizarro, 2013).

People similarly derive more self-insight from their own intuitive than deliberative decision-making, even when the decision they are making is how to categorize other people. In an illustrative

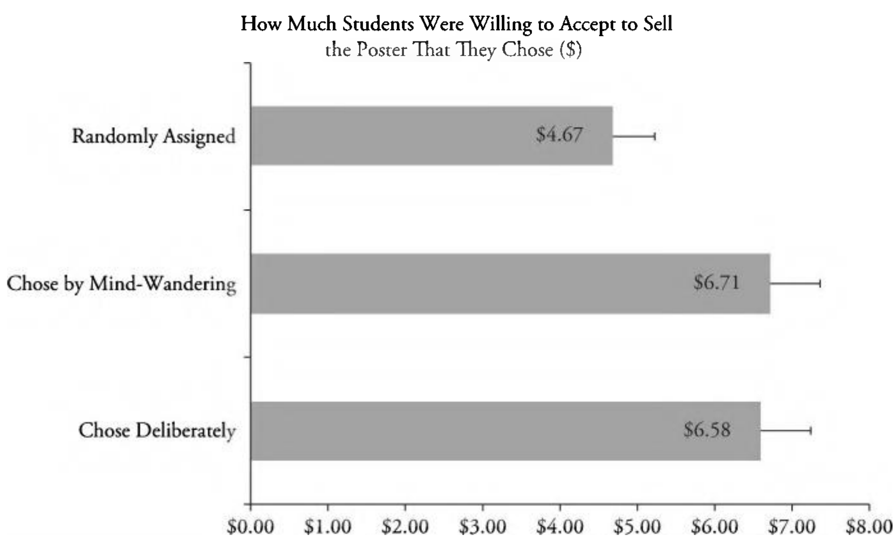

Figure 4.2. How much real money participants were willing to forgo ($USD) to keep a poster they received through random assignment, spontaneous selection process (i.e., mind-wandering), or a deliberate selection process. Adapted from Giblin, Morewedge, and Norton (2013).

experiment, research participants were shown four people and were asked to generate one word to describe each person (Morewedge et al., 2014). Participants who generated these descriptions intuitively (i.e., who used the first word that came to mind to describe each person) inferred that they gained greater self-insight from the descriptions that they generated than did participants who generated these descriptions in a more deliberate manner (i.e., who used the word they thought most logical to describe each person). In short, intuition is often perceived to provide more valuable insight into the self and others than similar deliberate forms of judgment and decision-making.

ATTITUDES

The spontaneous thoughts elicited by a persuasive message are a primary determinant of attitude formation and change (Greenwald, 1968). Rather than shaping people's attitudes directly, persuasive messages shape attitudes through the thoughts people have in response to the persuasive message. Consider a voter who hears Donald Trump advocate the construction of a wall between the United States and Mexico (e.g., "It's gonna be a great wall . . .. This will be a wall with a big, very beautiful door because we want the legals to come back into the country"; Jerde, 2015). The voter is likely to be more persuaded by the content of her spontaneous reactions to the proposal (e.g., "That's inhumane and absurd!" or "That will save American jobs!") than by the proposal itself. Repeated exposure to persuasive information can increase persuasion by inducing increasingly favorable cognitive responses (due to mere exposure). On the other hand, excessive repeated exposure can decrease persuasion by inducing unfavorable cognitive responses (because of repetition-induced tedium; Cacioppo & Petty, 1979; Calder & Sternthal, 1980). The thoughts that people have in response to a persuasive communication often determine whether the communication successfully instills or changes attitudes.

People also derive significant meaning from the content of others' spontaneous implicit evaluative associations. For example, when assessing the extent of racial bias in a group of people (e.g., police officers), researchers rely heavily on the people's spontaneous implicit associations. Indeed, some researchers have described measures that elicit spontaneous implicit racial responses as "unobtrusive measure[s] of racial attitudes" (e.g., Fazio, Jackson, Dunton, & Williams, 1995; Frazer & Wiersma, 2001). Moreover, some researchers suggest that among individuals who express no explicit racial bias (i.e., do not behave in a biased manner), only individuals who show no implicit racial bias are "truly unprejudiced" (Fazio, Jackson, Dunton, & Williams, 1995). It is important to note that researchers are not in full agreement that implicit measures reflect people's true attitudes (e.g., Arkes & Tetlock, 2004), but many do argue that attitudes about race (and other topics) can be inferred from implicit spontaneous responses (e.g., Green et al., 2007; Teachman et al., 2003).

ASSOCIATIONS AND COGNITIVE RESPONSES

The content of a wide variety of more general associative and cognitive responses, whether regarding a person, experience, or object, is perceived to be more meaningful when it results from spontaneous rather than deliberative thinking. The recollection of a positive or negative childhood memory is believed to provide more meaningful information about the self if it occurs spontaneously rather than deliberately (Morewedge et al., 2014). For memories of past experiences recovered during therapy, whether or not those recovered memories are accurate, people believe the memories to be more meaningful if they are perceived to have been spontaneously recovered during therapy than if their recovery is perceived to have been deliberately prompted by another client or therapist (even though all such recovered memories are effectively prompted by someone other than the self; Bowers & Farvolden, 1996). Unplanned behaviors such as action slips, and errors of production such as slips of the tongue, are similarly believed to provide more telling information about the producer than comparable actions without error (Norman, 1981).

Spontaneous thought content not only is attributed greater meaning than similar deliberate thought content, but also can more potently influence downstream evaluations. For example, when people identify a person to whom they are attracted other than their present or most recent significant other, they perceive the person whom they identified to reveal more meaningful information about the self if they identified that person through mind-wandering rather than deliberation. Moreover, people report feeling more attracted to the person they identified through mind-wandering than deliberation, an effect mediated by the greater self-insight they attribute to the thought of that person (Morewedge et al., 2014).

Perhaps the most influential form of spontaneous thought may be that which occurs during prayer.

Most Americans (97%) report engaging in prayer (Smith et al., 2011), which typically takes the form of the individual asking a question of God, and then waiting for God to respond (Spilka & Ladd, 2012). Those responses can take the form of a voice, a word, an image, or a feeling. Although diverse in their form, a necessary condition for these mental events to be categorized as divinely inspired, and acted on, is that they are perceived to have occurred spontaneously. Individuals in the Vineyard tradition might seek divine guidance on consequential topics. The few domains they are trained to avoid seeking advice on through prayer include prophesizing a birth, death, or marriage (Luhrmann, 2012).

DREAMS

One of the most curious phenomena is the meaning people attribute to dreams. Rather than viewing dream content as the random byproduct of stimuli encountered, assisting memory consolidation or problem-solving, a majority of participants in college student samples from the United States (56%), India (73.8%), and South Korea (64.9%) endorsed a Freudian view of dream content. They believed that dreams are most likely to reveal hidden emotions, beliefs, and desires to which the thinker normally lacks access than to reflect these other functions (Morewedge & Norton, 2009).

Not only do people believe that dreams provide them privileged access inside their own mind, people seem to believe that dreams provide them with special insight into their external world. A separate group of participants imagined that one of four events occurred the day before they were scheduled to fly: they had a dream of their plane crashing; they had a conscious thought of their plane crashing; the Department of Homeland Security increased the national threat level to "Orange" (indicating a high risk of a terrorist attack); or a real plane crash occurred on the route they planned to fly. Participants in the dreaming condition reported that they would be as likely to avoid flying the next day as did participants in the condition in which there was an actual plane crash. Moreover, participants reported that having a dream of a plane crash would lead them to be more likely to avoid flying than having a conscious thought of a plane crash, or even the issue of a real federal warning suggesting that a terrorist attack was imminent (Morewedge & Norton, 2009).

Why Are Spontaneous Thoughts Attributed Meaning and Importance?

People have a belief in an "authentic" or "true" self (e.g., Aristotle, 350 BCE/1998; Newman, Bloom, & Knobe, 2013; Newman, Lockhard, & Keil, 2010; Schlegel, Hicks, Arndt, & King, 2009) to which they lack full access (Wilson, 2004). The true self is a valued construct, purported to be who one really is, regardless of outward behavior. People who believe they know their true self are more likely to report that their life is meaningful (Schlegel, Hicks, King, & Arndt, 2011). We suggest that the attribution of meaning to a thought is a metacognitive process of determining whether a thought is perceived to reveal meaningful information about the thinker's true self, which follows a general model of source attribution (e.g., Gilbert, 1998; Wilson & Brekke, 1994). Specifically, people anchor on the belief that thoughts provide meaningful insight into the mind of the thinker, but may correct or deviate from this appraisal if the thought appears to be due to external influence. Because spontaneous thoughts are less likely to have an obvious external cause than deliberative thoughts, and are less likely to evoke the recruitment of external justifications, they are less likely to prompt this correction process (Morewedge et al., 2014; Morewedge & Norton, 2009).

Attribution of Meaning as a Correction Process

Any given thought has the potential to reveal information about one's true self to the extent that it is uninfluenced or uncontaminated by external sources. Given that thoughts originate within one's own mind, we argue that the default is to assume that a thought reflects one's true self and is free of external influence (with prayer and disordered thought being notable exceptions). As people believe they see the world objectively (e.g., Ross & Ward, 1996; Scopelliti et al., 2015), they should only correct from this default assumption when they believe that a thought was due to external influence (e.g., Bem, 1967), and only when they have sufficient motivation and capacity to correct from their default assumption.

Consider two examples: love and pizza. At first, the thought of a former lover is likely to be interpreted as providing meaningful information about one's beliefs, attitudes, or desires. If no stimulus that could have evoked the thought is salient, the thinker is likely to assume that the thought occurred for some meaningful reason. If a stimulus that could have evoked the thought is salient, such as the presence of the love interest in a social media feed, the thinker is likely to discount the meaning of the thought if she is motivated to engage in that discounting (e.g., she is currently in love with another person) and has sufficient cognitive resources to perform that discounting (Morewedge et al., 2014). Similarly, the thought of pizza while watching television might be initially interpreted as providing meaningful information about one's self, such as that one likes pizza, is hungry and wants pizza, or is struggling to adhere to one's diet (Kavanagh, Andrade, & May, 2005). If a potential external source of influence is particularly salient, however, such as an advertisement for pizza during the last commercial break, the thinker is likely to discount the meaning of the thought unless the television show is sufficiently distracting or the thinker is not motivated to adhere to his diet (e.g., Gilbert, Pelham, & Krull, 1988).

As evidence of this discounting model, people attribute considerable meaning to their dreams, but attribute more meaning to dreams that are more consistent with their desires and important beliefs. For example, people are more likely to attribute meaning to a pleasant dream that involved a person whom they like than to an unpleasant dream involving a liked person. Motivated reasoning in the attribution of meaning, however, may be overridden by important personal beliefs. For example, agnostics are more likely to attribute meaning to a dream in which God commands them to take a year off from their work to travel the world than to a dream in which God tells them to take a year off from their work to serve the sick and destitute. By contrast, religious believers perceive that both dreams are meaningful (Morewedge & Norton, 2009). It appears that people first appraise spontaneous thoughts, such as dreams, as meaningful—as did agnostics for dreams with pleasant implications (taking off for a year to travel the world), and as did religious believers for dreams with both pleasant and unpleasant implications. When the dream conflicts with an important belief or desire (e.g., betrayal by a loved one or giving up college to serve the poor), however, dreamers discount its meaning.

Religious believers engage in an analogous form of explicit discounting through their process of prayer discernment: how they decide which thoughts to attribute to God. Prayer discernment is an interesting case because individuals test whether another agent caused their thought, rather than test whether they were the agent that caused their thought. When Evangelical Christians have a thought during prayer, they first examine whether the thought was spontaneous or deliberate. Deliberate thoughts are viewed as caused by the person who is praying, and thus are unlikely to have a divine origin. By contrast, spontaneous thoughts are viewed as possibly emanating from God. People then initiate a process of discounting in which they evaluate the thoughts for their adherence with her God concept, which is informed by her understanding of God's values, beliefs, and desires. As a final step, the individual often shares thoughts she believes might be communications from God with other members of her congregation, who often examine those thoughts for motivated reasoning on the part of the individual (Luhrmann, 2012). Although the focus of hypothesis testing is inverted relative to spontaneous thoughts with secular origins, these individuals follow a similar metacognitive appraisal process to discern whether a thought should be attributed to God (an external agent) or a different source.

Our discounting model is rooted in theories elucidating the attribution of causality and person perception. Basic models of animacy and mind perception attribute actions to the actor's mental states to the extent that the actions are internally rather than externally caused (Heider, 1958; Michotte, 1963; for a more recent review, see Morewedge, Gray, & Wegner, 2010). Which hypothesis is tested—whether an action is internally or externally caused—is generally determined by the attentional focus of the person making the attribution (for a review, see Gilbert, 1998). Observers judging the extent to which the behavior of an actor reveals information about her disposition tend to anchor on attributing that behavior to her disposition and fail to correct sufficiently for situational influences on her behavior (Jones & Harris, 1967; Scopelliti et al., 2016). Conversely, observers judging the extent to which an actor's behavior reveals information about the influence of her situation tend to anchor on attributing her behavior to situational influences and fail to sufficiently correct for the role of her disposition (Krull, 1993).

We suggest that when people attribute meaning to a particular thought, the focal hypothesis tested is "Does this reveal meaningful insight about the mind of the thinker?" This focus anchors their judgment on the thinker as a cause, a hypothesis that is likely to be confirmed unless there is compelling reason for adjustment from this anchor or disconfirmatory hypothesis testing (Nickerson, 1998).

Other roots of our model stem from research testing dual-process models of attitudes, such as the heuristic systematic model (Chaiken, Liberman, & Eagly, 1989; Trumbo, 2002; Zhang, Luo, Burd, & Seazzu, 2012) and the elaboration likelihood model (Kupor & Tormala, 2015; Petty & Cacioppo, 1986; Petty & Wegener, 1999; Rucker & Petty, 2006). In these models, the extent to which a persuasive message is incorporated into the recipient's belief system and forms or changes her attitudes is largely a function of whether or not she generates countervailing cognitive responses, such as counterarguments to its message. If the message recipient is unmotivated or is too cognitively overloaded to systematically process the message and correct for its influence (Petty, Cacioppo, & Schumann, 1983; Petty, Wegener, & White, 1998), her attitude is likely to move in the direction of that message.

Spontaneous Thoughts Evoke Less Correction

When people appraise the extent to which a thought reflects their true self, we suggest that spontaneous thoughts are less likely to prompt a correction process than similar deliberate forms of reasoning because the former are less likely to be attributed to external sources. Spontaneous thoughts are less easily linked to an obvious external cause, and they are less likely to prompt thinkers to search for corroborating external reasons to justify those thoughts than similar thoughts generated via deliberation.

The link between spontaneous thoughts and the external stimuli that caused them is often more ambiguous than the link between a deliberate thought and external stimuli. Many of the images, voices, feelings, and thoughts that arise spontaneously explicitly fall into the category of "stimulus-independent thought" (Mason et al., 2007), suggesting that they are less likely to be tied to stimuli in the thinker's immediate environment than more deliberate "stimulus-dependent thought." Indeed, mind-wandering and dreaming are forms of thought that are typically unrelated to the present environment of the thinker. By definition, dreaming occurs while the thinker has no conscious awareness of her present environment. Intuitions are similarly difficult to trace to external causes, as the process by which they were generated is usually inaccessible to the thinker (Johansson, Hall, Sikström, & Olsson, 2005; Nisbett & Wilson, 1977). The more ambiguous link between spontaneous thoughts and their external causes than between similar deliberate thoughts and their external causes should make the thinker less likely to discount the meaning attributed to her spontaneous rather than deliberate thinking.

In addition to less obvious external causes, we argue that thinkers are less likely to explicitly search for external reasons to justify a spontaneous thought than a similar deliberate thought. People are certainly able to generate reasons for their spontaneous thoughts (although they may be spurious reasons; Johansson, Hall, Sikström, & Olsson, 2005; Nisbett & Wilson, 1977), but in many cases people may not naturally generate reasons for their spontaneous thoughts unless they are explicitly directed to do so (e.g., Fernbach, Rodgers, Fox, & Sloman, 2013; Wilson & Schooler, 1991). Consider the judgment, "This is good wine." When made intuitively, no external stimulus other than the wine itself is required to validate the intuition. One could even make the judgment having never tasted the wine, having only seen its name on a menu or label. When made deliberatively, however, reasons are likely to be generated to justify the judgment (e.g., Shafir, Simonson, & Tversky, 1993), which are likely to make external potential causes of the thought more salient. Even if trivial, the mere identification of potential external causes is likely to reduce the attribution of a thought to causes internal to the thinker (Nisbett, Zukier, & Lemley, 1981).

Conclusion

Thinking in the absence of reasoning breeds meaning. Metacognitive appraisals of spontaneous thought imbue those thoughts with meaning. Spontaneous thoughts are believed to provide valuable insight into the self, other people, and the external world. The presence of a spontaneous thought is itself perceived to be a meaningful event, signaling something revealing about the thinker, the truth-value of the thought, or the value of the activity or decision in which the thinker is engaged. Spontaneous thought content is also meaningful thought content. People explicitly believe that some kinds of spontaneous thought provide more insight into the self and the world than similar deliberate thought, and people even value spontaneous thought content more than deliberate thought content when logic suggests that they shouldn't.

We suggest that the greater meaning and insight attributed to spontaneous thoughts is due to a metacognitive appraisal process through which thought is attributed meaning. The greater inaccessibility of their external origins leads the meaning of spontaneous thoughts to be discounted less than similar deliberate thoughts. This is reflected in the metacognitive processes by which people attribute meaning to dreams and engage in discernment during prayer.

Of course, we do not mean to imply that people are wrong to attribute meaning to their spontaneous thoughts. Decisions and thoughts that are truly spontaneous and not prompted by the current context may best reflect chronic preferences and beliefs of the thinker (e.g., Bargh & Chartrand, 2014; Dijksterhuis et al., 2006; Wilson & Schooler, 1991). Moreover, many of the judgments examined in this work are subjective—preferences, attitudes, attraction, and personal faith. Meaning may reside as much in the subjective assessment of the perceiver as in objective properties of the object of perception. We merely attempt in our inquiry to elucidate the fascinating metacognitive processes by which meaning is created and determined.

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CHAPTER

5

The Mind Wanders with Ease: Low Motivational Intensity Is an Essential Quality of Mind-Wandering

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Abstract

Although mind-wandering has received increased attention in the field of cognitive neuroscience, definitions have not always aligned. Most have emphasized the contents of thought, treating it as synonymous with either *task-unrelated thought* or *stimulus-independent thought*. Such definitions miss an important aspect of what it means to let one's mind wander: the easeful way that thoughts move about. A more recent definition looks, instead, at the dynamics of thought—the way that thoughts unfold over time—positioning mind-wandering as a type of *spontaneous thought*. By doing so, it is therefore more readily equipped to incorporate this quality of ease. While the term *mind-wandering* can sometimes refer either to a momentary event or to an ongoing activity, both usages, this chapter argues, will be unsatisfactory if they do not address this gentle mode of movement. Some benefits that *ease* can provide for future research are proposed.

Key Words: mind-wandering, task-unrelated thought, stimulus-independent thought, spontaneous thought, dynamics of thought, ease

When we speak of minds *wandering*, we may find ourselves borrowing, at different times, from different aspects of the word. The predominant definitions at use in our current scientific discourse emphasize the contents of a wandering mind and their relationship to the current sensory environment and/or the current task. As such, their focus is primarily on *where* the mind travels, not on the *way* that it moves around. A recent theoretical development has been aimed at capturing the more dynamic quality of mind-wandering, addressing the need to examine the flow of thoughts over time (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). While this can be seen as an improvement, the discussion thus far has neglected what is arguably one of the most important features of a wandering mind: a phenomenal quality of ease. To move with ease is to move with the "absence of difficulty or effort," or the "absence of rigidity or discomfort" (McKean, 2005). Amidst the constellation of terms related to mind-wandering, a considerable number—including daydreaming, creative thought, aimless attention, and others—seem to share this phenomenal sense of ease as a common thread. In this chapter, we give an argument for why *ease* should be included in definitions of mind-wandering as the field moves forward.

We begin by distinguishing between two main phenomena to which the term *mind-wandering* can refer: a brief attentional shift, and a longer-lasting mental process. After all, it is not uncommon to hear the phrases "my mind just *wandered*" and "I was mind-*wandering*" being used in different contexts. Accounts for either, we argue, are unsatisfactory if they do not include the quality of ease. We suggest that mind-wandering is best described not by *where* the mind ends up, but by the qualities of its movement—and that *ease* is an essential characteristic. Incorporating it would not only better fit our intuitions of what it means to mind-wander, but also provide some benefits for future research.

It would be useful to elaborate on the nature of mental ease itself before considering it in our discussion of mind-wandering. We propose that *ease* should be interpreted in the context of motivation. Indeed, the forces that pull us toward our various shifts in attention seem to be behind both our highly pressured thought states and our periods of tranquil reverie. In the latter case, it is the relative absence of motivational forces that sets the tone of ease. Attention-grabbing, motivationally salient stimuli have been associated with activation of the amygdala, a region known for its involvement in automatic vigilance and physiological preparedness for action (Cunningham & Brosch, 2012; P. J. Lang & Bradley, 2010). This is in line with various theories on emotional/motivational intensity that suggest evidence for their close relationships with bodily arousal and attentional narrowing (Gable & Harmon-Jones, 2010; A. Lang, Bradley, Sparks, & Lee, 2007). This readiness for action, with its concomitant sympathetic nervous system reactivity and its mental constraints, seems to be the antithesis of *ease*. It should be noted that these states need not necessarily be experienced as negatively valenced; positive states high in approach motivation—such as desire or interest—also have been shown to have a range of attention-narrowing effects on visual processing, memory, and other cognitive domains (Gable & Harmon-Jones, 2010).

In addition, it seems that even our deliberately guided thoughts can be influenced by the same motivational sources. Being interconnected with emotion and motivation centers—such as the amygdala—the anterior cingulate cortex has been hypothesized to contribute to the impact of affective information on effortful cognitive control (Pessoa, 2009). It also has been proposed that this region plays a role in initiating executive control when it detects conflicts or errors in information processing that need to be resolved (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). These relationships may be at play when one feels drawn to attend to and cogitate upon highly motivating topics, or to sort out inconsistencies that might pose challenges to oneself; both these conditions, again, seem to oppose the notion of *ease*.

When our attention is held captive by a thought or a compelling event in our surroundings, occasionally something greater comes along to steal the show. If a loud noise interrupts our already firm gaze, or a concerning memory interrupts our focus, we could say that a second motivational impulse out-competed the force that was previously keeping us fixed. This is a good illustration of how we can be *drawn to a thought* or salient object, as opposed to *easing toward it*, and how cascading motivational forces might contribute to states becoming more constrained. As the motivation to attend decreases—for instance, because our curiosity or concern is resolved—other, lower-motivational impulses might then reach a competitive threshold (Desimone & Duncan, 1995; Raymond & O'Brien, 2009). This reduction in motivational intensity seems critical to the easeful and dynamic nature of mind-wandering: We would find ourselves transitioning gently between thoughts, rather than being pressured toward them.

States low in motivational intensity, whether positively or negatively valenced—such as contentment and sometimes sadness—have, interestingly, been shown to broaden the scope of mental activity (Gable & Harmon-Jones, 2010). Low-motivation positive states have been hypothesized to signal that "things are going better than necessary," thus triggering "coasting," in search of new opportunities (Carver, 2003, p. 241). Low-motivation negative states, such as a depression following the loss of a sought-after goal, have been suggested to be adaptive for similar reasons; a "more open, unfocused, unselective, low-effort mode of attention" may force an individual to abandon her unachievable goal, and be receptive to new alternatives (Hecker & Meiser, 2005, p. 456). These descriptions of *coasting* and *unselective/low-effort attention* seem closely related to mind-wandering, and the gentle, shifting states that we can find ourselves in.

"My Mind Just *Wandered*"

When directing our thoughts toward an activity or goal, it is usually not long before we find that we have ended up somewhere entirely different from where we intended. Someplace along the way marked a diversion in our attention from what we were currently doing, toward an unrelated sequence of thoughts. It is this diversion that designates the first type of mind-wandering we will discuss here, and it has been the topic of much study in the field of cognitive neuroscience. Experience sampling research has found that mind-wandering might occur in up to 30%–50% of our day-to-day thoughts (Killingsworth & Gilbert, 2010; Klinger &

Cox, 1987). Even in conversation, it would not be uncommon to hear people refer to this when they remark, with an air of frustration, "my mind wandered."

A recent theoretical review defines mind-wandering as "a shift in the contents of thought away from an ongoing task and/or from events in the external environment" (Smallwood & Schooler, 2015, p. 488). According to this definition, the act is seen primarily as a momentary occurrence; the *moving away from* the task or external world is what is significant, not necessarily what comes after. While this designates certain conditions for the occurrence of mind-wandering, it says little about the nature or the qualities of the shift itself. In this way, this definition could be seen to be lacking in specificity, leaving unclear how mind-wandering can be set apart from other forms of distraction or absorption.

To wander is to "walk or move in a leisurely, casual, or aimless way" (McKean, 2005) or to "move hither and thither without fixed course" (Simpson & Weiner, 1989). If a quality were to be ascribed to a mind-wandering shift, perhaps the best place to start might be to incorporate this sense of casualness, or ease. Indeed, it seems to express a sentiment that we often have when we speak of it in ordinary language. If one's attention to a dry lecture was *pierced suddenly* by the memory of an important and overdue point of business, we may be hesitant to refer to it as the mind having "wandered." On the other hand, if we *drift off* to some casual daydream, the term might come more readily.

These examples are exaggerative, of course, and mind-wandering need not necessarily be restricted to only the gentlest thought-transitions—but hopefully the intuition has been evoked. We are presenting here, once again, the contrast between being *drawn* to a mental experience and *moving casually, with ease* toward it. The two are not only phenomenologically different (i.e., different in how they are subjectively experienced), but would likely also be found to have different originating factors. For example, shifting with high motivational intensity away from a task or from external stimuli might occur in cases of cognitive or emotional dissonance—when information poses a threat to one's beliefs or self-image—or when an alluring distraction or concern arises. Shifting away with low motivational intensity may occur out of boredom or disinterest, mental fatigue, or simply out of amusement with some passing memory. Current definitions lack the ability to discern between this range of experiences, leaving mind-wandering relatively unspecified. Moreover, it is the latter examples, with their reduced motivational intensity, that seem to be most consistent with the origins and nature of a wandering mind. If mind-wandering is seen as a shift, it should be considered to occur with a sense of softness.

While, so far, we have addressed one meaning of the term—*mind-wandered* as a momentary, isolated event—we have left aside another meaning that is also very commonly used: "I was mind-wandering," as an ongoing activity. This usage may also be more prevalent, making its discussion in the context of *ease* all the more consequential.

"I Was Mind-*Wandering*"

The ongoing act of *mind-wandering* is still relatively varied in the range of experiences it can refer to. As a somewhat newly emerging field of study, consensus and differences of opinion are still being balanced. Sometimes we might say that we were mind-*wandering* by virtue of having realized that our mind had *wandered.* The *shifting away*, previously mentioned, can be seen to give rise to ongoing periods of thought, with task-unrelated or stimulus-independent content (Smallwood & Schooler, 2015). A different usage refers to mind-wandering, not as a state of content, but as a mode of movement: When we are mind-wandering, our attention moves freely about, unconstrained by our deliberate control or other strong influences (Christoff et al., 2016). This dynamic view, we believe, is able to avoid a few challenges that the content-based view cannot; these issues will be discussed in the following paragraphs. Incorporating a notion of *ease* in describing the manner in which these experiences unfold will prove to be important for maintaining our common-sense intuitions.

In the content-based view, mind-wandering can be seen as any mental activity that is not related to an ongoing task or to sensory stimuli. This could best capture moments of distraction, where our attention is somewhere other than what we were in the middle of doing. This meaning happens to inherit some of the issues that the *shift* itself carried. Most notably, the states of content are so broad that they may not convincingly speak about only one mental phenomenon; a task-unrelated state could include worrying, pondering, excitement, absent-mindedness; a stimulus-independent state could include the same, and many others. If mind-wandering, as a state of content, can take the form of any or all of these, it might not be narrowly defined enough to be considered a distinct topic of investigation. By looking at it, instead, as a process (Christoff, 2012), or a mode of movement—the way that thoughts change over time—we acquire means by which to narrow its scope. The qualities of its motion can then be incorporated into the mind-wandering definition to add specificity.

In addition, if it is left broad, certain states that seem inconsistent with mind-wandering can be let in the door. One significant example of this is rumination. This automatic preoccupation with past or future-related concerns is a state that we can find ourselves in despite our best efforts. While it can be considered mind-wandering, according to the content-based view—since it is often stimulus-independent, and unrelated to the current task—its fixed nature is inconsistent with the *hither and thither* motions of wandering (Christoff et al., 2016; Irving, 2015). Describing the way thoughts move during mind-wandering is essential, and from the example of rumination we might decide that the quality of *dynamic motion* is an important feature of a wandering mind (Christoff et al., 2016); that is, thoughts do not remain stuck, but are able to *move about* freely.

Another issue with the content-based view is that the contexts, themselves, appear to be too restrictive to account for the range of situations where we would expect mind-wandering to be found. It could be argued that mind-wandering can occur even when an ongoing task is not around for us to wander from. Relaxing on a park bench, for example, we might notice our thoughts drifting about. It also seems that our minds can sometimes wander *in favor* of a task—especially in creative contexts, such as writing. To accommodate these cases, mind-wandering may best be seen as occurring irrespective of any particular context. This is another reason that it should be examined as a mode of movement; in this way, its fluid transitions can be seen to occur across a range of situations.

The dynamic framework of mind-wandering arose as a response to precisely these issues (Christoff, 2012; Christoff et al., 2016). Mind-wandering is seen through this lens as a specific kind of *spontaneous thought*, which is defined according to tendencies of movement: Spontaneous thought is "a mental state, or a sequence of mental states, that arises relatively freely due to an absence of strong constraints on the contents of each state and on the transitions from one mental state to another" (Christoff et al., 2016, p. 719). Mind-wandering is described as fitting within a range of spontaneous thought experiences—being more constrained than dreaming, but less constrained than creative forms of thought (Christoff et al., 2016). This notion of being *constrained* fits closely with our discussion of motivational intensity. We would expect that the constraints on the flow of thought would increase as the motivational intensity to attend or perform some mental action increases.

It is this discussion of constraints that has been used to argue against states of rumination being considered as mind-wandering (Christoff et al., 2016; Irving, 2015). When we are stuck on one topic, we are actually under the pressure of high constraints—and thus, are not mind-wandering. There is another reason, however, aside from the lack of motion or variability, that makes rumination a counterintuitive candidate for wandering: It is typically accompanied with a sense of tension or discomfort—not a sense of leisureliness or casualness.

One can also be in a state affected by high constraints that does not manifest as rigidity, but instead presents itself in a highly dynamic way. An example of one such state could be diffuse anxiety. There are, no doubt, cases where one's anxiety is about a particular item of concern that one's attention is continuously held upon. Anxiety, however, can also arise as a more dispersed state, undirected toward any one concern, as in generalized anxiety disorder or panic disorder (American Psychiatric Association, 2013; World Health Organization, 2004). In a state of panic, one's awareness may be turbulent—tossed to and fro—as each new encounter brings no relief. These examples would also likely not be the ordinary referents when someone expresses "my mind was wandering." They illustrate how *motion*, alone, is not enough to differentiate mind-wandering from other states, and how a lack of strong constraints—even brief ones—is an attribute not to be neglected. Without accounting for this other mode of motion—*ease*—certain states of anxiety could be considered mind-wandering.

While not explicitly discussed in our previous work, the dynamic framework of mind-wandering (Christoff et al., 2016) does indirectly imply a state of ease, as it could be presumed to naturally follow from a lack of constraints. After all, cognitive and attentional constraints likely fluctuate with and are driven by variations in motivational intensity. Exploring the involvement of motivation in the implementation and maintenance of these constraints would be a valuable next step.

Implications

As we have hopefully conveyed, the mind-wandering phenomenon features gentle thought movements, rather than pressured ones. These gentle movements are interpreted as being mental activity low in motivational intensity. Of course, while we feel a motivation behind each and every thought-act, the *easeful* experience can be considered to involve pulls of lower relative force. In a very narrow scope, we might consider mind-wandering to occur when we transition from a constrained state to a more relaxed one. In a broader scope, mind-wandering could involve moving about in an already easeful manner.

A consequence of this is that we may not actually mind-wander as often as we think we do. Our general preoccupation with, and concern for, matters in our lives must see us entertaining highly motivating thoughts on a regular basis (Klinger, 1971). If this is true, then we are more frequently not actually *wandering* about our mental activities, but being forcefully drawn. The experience sampling studies mentioned earlier, which cited mind-wandering in up to 30%–50% of our waking cognition, are thus probably overestimates, if considered in light of the more specific definition of mind-wandering adopted here. In the light of this discussion—if *ease* were to be taken into account—those numbers are likely to be greatly inflated.

In addition, a popular study, claiming that mind-wandering leads causally to feelings of unhappiness, may be interpreted in a new light (Killingsworth & Gilbert, 2010). In this study, mind-wandering was defined as thinking that is not centered on what is happening *here and now*, or "thinking about something other than what you're currently doing" (Killingsworth & Gilbert, 2010, p. 932). Experience sampling reports from daily life found that positive mind-wandering topics had very little effect on peoples' overall happiness, whereas neutral and negative topics had a significant detrimental effect (Killingsworth & Gilbert, 2010). While negatively valenced states are not necessarily inconsistent with mind-wandering, highly motivational ones are, and this study did not include questions that could determine the motivational intensity of a thought experience. Again, given the prevalence of various pressures in our day-to-day life, it is not unlikely that much of what was reported as mind-wandering in this study was not, in fact, *wandering*, but was, instead, made up of other less easeful forms of preoccupation.

One might raise the concern that the *thinking about something other than what you were doing* mind-wandering is just a different kind than the ongoing periods of gentle, dynamic movement, and, thus, would have no need to account for the quality of ease spoken about here. If mind-wandering can be considered entirely separate from a sense of *ease*, however, then a different term might be more appropriately used—one without such qualitative connotations. Wandering, after-all, implies the "leisurely, casual, or aimless way" that one is moving (McKean, 2005). In this event, a shift in terminology could also help to minimize the confusion caused by having a number of different meanings sharing the same word. Given the frequent linking of off-task or stimulus-independent thought with prospective thinking, planning, and meaning-making (Baird, Smallwood, & Schooler, 2011; Mooneyham & Schooler, 2013; Smallwood & Andrews-Hanna, 2013; Smallwood & Schooler, 2015)—processes by which we sort through and organize our mental lives—perhaps *mind-ordering* might be a more fitting term.

Another concern could be brought up about the relative nature of *ease* in the view presented here. If mind-wandering is seen as a dynamic mode of mental movement that happens with ease, we might be making it harder to identify specific wandering events. It may seem that, since each mental movement may be *more* or *less* easeful, relative to some other, all movements are to be considered wandering. While the presence of a continuum of ease is undeniable, this does not present a strong theoretical challenge. We can easily speak meaningfully of someone being *more* or *less* excited, nervous, focused, or content—mind-wandering should be no exception from these other non-discrete states. The trouble arises only when one tries to pinpoint an exact event of mind-wandering. Settling for rougher boundaries is not far off from the way researchers commonly go about it, anyway.

Benefits for Future Research

The benefits of incorporating the quality of *ease* into future definitions are numerous. First, as we hopefully have conveyed through this chapter, it captures a defining characteristic of what it means to wander—both physically, and in its metaphorical application to the mind. Second, we are afforded the opportunity to draw connections between a variety of other mental phenomena that share similar qualities of motion. Mind-wandering, we may find, is situated among an array of other experiences: from daydreaming—being perhaps its most easeful waking-state relative—to creative thought, which includes rapid fluctuations between periods of high and low constraints (Ellamil, Dobson, Beeman, & Christoff, 2012) (see also Dobson, Chapter 23 in this volume). The quality of *ease* provides us with another point from which to explore these various mental states.

Third, in a research context, we acquire two new sets of tools with which we can investigate mind-wandering. One set of tools could be a series of additional questions that can be posed to participants in a thought-sampling context, to gauge the degree of motivational intensity in their experience: "Were your thoughts moving with a sense of casualness or ease?" "Did you feel a strong draw to your thoughts, or did you feel like you were going gently along with them?" "Do you feel calm right now, or tense?" Given that levels of motivational intensity have been related to degrees in cognitive narrowness and broadness (Gable & Harmon-Jones, 2010), we might also ask questions like "To what extent were your thoughts focused on specific topics?" or "Did your mind feel expansive and broad, or more focused and narrow?" If personal significance is any indicator of one's motivational intensity, as has been suggested, then we could ask "How important were your thoughts to you?" "Did you feel like your thoughts were working toward resolving a certain concern or attaining a desired outcome?" "How anxious or uncomfortable would you become if you were forced to stop thinking about these thoughts?" (Irving, 2015). While refinement is needed, this general line of questioning could provide a valuable method for determining the extent to which a period of thought-flow is accompanied by the quality of ease.

The other set of tools could be gained from the incorporation of various physiological monitoring techniques into mind-wandering studies. The measurement of stress responses—through heart rate and skin conductance, for example—could be an indicator of the person's overall state of ease. These could be captured alongside functional magnetic resonance imaging (fMRI) or electroencephalograhy (EEG) data, and analyzed at points of interest, helping to give extra context to how relaxed someone was when certain brain activity was occurring. They could also be measured immediately before experience-sampling probes in everyday-life contexts. Physiological thresholds could even be used, in whatever form of study, as cues to question individuals about their thought-state, especially when states of ease or arousal are detected. While motivational intensity overlaps significantly with arousal, states of physiological arousal appear to exist independently, and without any influence on attentional narrowing (Gable & Harmon-Jones, 2013). Since arousal may not always correlate with patterns of thought movement, caution should be used when incorporating these measures. Nevertheless, even further investigation into the extent that they do would be a worthwhile pursuit.

Summary

The term *mind-wandering* encompasses a range of different uses across scientific and everyday contexts—perhaps partly, in the former, due to the infancy of this field of study. One of the most important features of what it means to *wander*—the sense of casualness by which we move—has not received proper attention in the scientific literature. Two broad meanings of *mind-wandering* were explored here: brief attentional shifts, and ongoing mental events. Both, we have argued, neglect this sense of ease, and could be improved by including it. For mind-wandering as an ongoing mental event, seeing it as a *mode of movement* rather than a particular *kind of content* holds most theoretical promise. When it is seen as a *dynamic* mode of movement, a quality of ease helps distinguish mind-wandering episodes from other highly variable, but still more constrained states. Adopting this quality not only fits with predominant intuitions, but provides experimental tools that can help us better discern between subjective experiences, as well as neurophysiological data.

As mind-wandering exists within a sea of other mental phenomena, framing it in isolation might lead to an incomplete or narrow view. By recognizing it as part of a wider continuum, we gain access to means by which to explore its nature more fully. The quality of *ease* provides one such avenue for this investigation.

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CHAPTER

6

How Does the Brain's Spontaneous Activity Generate Our Thoughts?: The Spatiotemporal Theory of Task-Unrelated Thought (STTT)

Georg Northoff

Abstract

Recent investigations have demonstrated the psychological features (e.g. cognitive, affective, and social) of task-unrelated thoughts, as well as their underlying neural correlates in spontaneous activity, which cover various networks and regions, including the default-mode and central executive networks. Despite impressive progress in recent research, the mechanisms by means of which the brain's spontaneous activity generates and constitutes thoughts remain unclear. This chapter suggests that the spatiotemporal structure of the brain's spontaneous activity can integrate both content- and process-based approaches to task-unrelated or spontaneous thought—this amounts to what is described as the "spatiotemporal theory of task-unrelated thought" (STTT). Based on various lines of empirical evidence, the STTT postulates two main spatiotemporal mechanisms, spatiotemporal integration and extension. The STTT provides a novel brain-based spatiotemporal theory of task-unrelated thought that focuses on the brain's spontaneous activity, including its spatiotemporal structure, which allows integrating content- and process-based approaches.

Key Words: task, thought, spatiotemporal theory of task-unrelated thought, brain, spatiotemporal, cognition

Introduction

Content Versus Process Models of Task-Unrelated Thought

Our daily mental life is characterized by strong thoughts that are unrelated to various external tasks and distractions in 25%–50% of our waking hours (Christoff et al., 2016; Smallwood & Schooler, 2015). These thoughts have been described by various terms, including *spontaneous thoughts* (see Andrews-Hanna, Irving, Fox, Spreng, & Christoff, Chapter 13 in this volume), *mind-wandering* (Mason et al., 2007), *task-unrelated thoughts* (Doucet et al., 2012), *random thoughts* (Andreasen et al., 1995), *self-generated thoughts* (Smallwood & Schooler, 2015), or *stimulus-independent thoughts* (Christoff et al., 2016; Dixon, Fox, & Christoff, 2014; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015). Regardless of how we name them, these thoughts imply that we no longer focus on some externally given task or stimuli and their respective external mental contents, but are instead drifting away to some internal mental contents that remain more or less unrelated to specific stimuli or tasks. These internal mental contents shall here be described as task-unrelated thoughts that, at the same time, are also stimulus-independent (Fox et al., 2015; Smallwood & Schooler, 2015). These task-unrelated thoughts (as implying stimulus independence) are the focus in the present chapter.

Different kinds of task-unrelated thoughts have been suggested. Smallwood and Schooler (2015), for instance, distinguish between self-generated and perceptually guided thoughts, with the former being generated internally by the self, while the latter originate rather externally in perceptions. Importantly, both forms of thought can occur either in the absence or presence of a task (i.e., task-related or -unrelated). The distinction between self-generated and perceptually guided thoughts seems to be more or less analogous to the one between internally and externally directed thoughts (Dixon et al., 2014). Both forms of thought may then be either spontaneous without any goal or with a goal, and thus unintentional or goal-directed (Dixon et al., 2014).

The various distinctions (i.e., self- vs. perceptually generated thoughts, as well as internally vs. externally directed thoughts) are mainly based on contents that either are self-related and thus internally or perceptually based, or are not related to self and thus externally based. Such content-based approaches have recently been complemented by focusing on induction mode and dynamic or process-related features (Andrews-Hanna et al., Chapter 13 in this volume; Christoff et al., 2016). The induction mode, for instance, is considered when distinguishing spontaneous versus deliberate thoughts, as well as unintentional versus intentional task-unrelated thoughts (Andrews-Hanna et al., Chapter 13 in this volume; Christoff et al., 2016)—these distinctions reflect different degrees of voluntary control when inducing task-unrelated thought, while the dynamic or process-related features pertain to, for instance, the duration and flow ("stream of consciousness" as based on W. James) of task-unrelated thoughts.

The different forms of task-unrelated thoughts suggest a basic distinction between content models and process models of task-unrelated thoughts (Andrews-Hanna et al., Chapter 13 in this volume; Christoff et al., 2016; Ellamil et al., 2016). The long dominating content models focus on different contents and our cognition, which supposedly determine task-unrelated thoughts—content models can therefore be considered cognitive models. Process models, on the other hand, emphasize the dynamic and process-based nature of task-unrelated thoughts (Andrews-Hanna et al., Chapter 13 in this volume; Christoff et al., 2016). How are both content and process models related to each other? I hypothesize that both contents and dynamic or process-based features of task-unrelated thoughts can be integrated and linked by spatiotemporal features. For that reason, I here suggest what I describe as the *spatiotemporal theory of task-unrelated thought* (STTT) (see Figure 6.1).

From the Brain's Spontaneous Activity to Task-Unrelated Thoughts

Psychologically, these different forms of task-unrelated thoughts have been associated with cognitive, affective, and social functions. For instance, self-generated thoughts have been associated with affective functions like anxiety and depression while, at the same time, being decoupled from perception (Andrews-Hanna et al., 2013; Baird, Smallwood, Lutz, & Schooler, 2014; Ruby, Smallwood, Engen, & Singer, 2013; Ruby, Smallwood, Sackur, & Singer, 2013; Smallwood & Schooler, 2015). In contrast, perceptually derived thoughts are closely linked to the perception of external events or objects in the environment (Smallwood & Schooler, 2015).

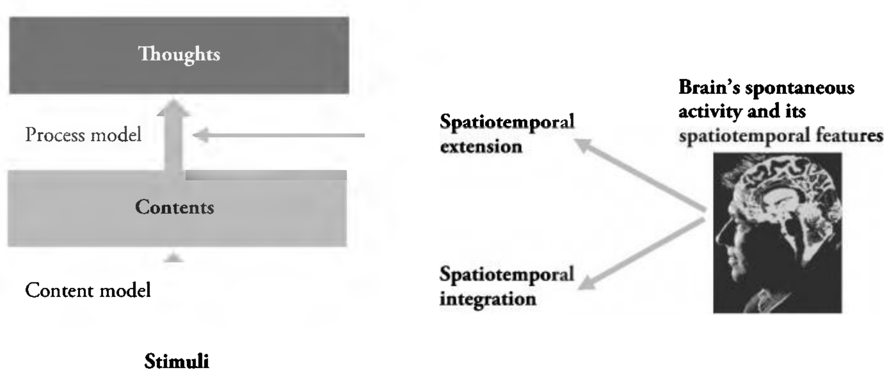

Figure 6.1. Spatiotemporal theory of task-unrelated thought (STTT). (See Color Insert)

Neuronally, spontaneous or resting state activity (see later discussion for details) in the default-mode network (DMN; Raichle, 2015a, 2015b) and especially the cortical midline structures (Northoff & Bermpohl, 2004) has been highlighted in thoughts or mind-wandering (Andrews-Hanna, Smallwood, & Spreng, 2014; Doucet et al., 2012; Mason et al., 2007). However, other regions and networks like temporal cortical regions and the central executive network (CEN) have also been shown to be recruited during spontaneous or task-unrelated thought (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fox et al., 2015). These data suggest widespread recruitment of regions and networks across the entire brain in the resting state during task-unrelated and stimulus-independent thought.

Spontaneous thoughts are clearly related to and based on the brain's resting state or spontaneous activity (see later discussion for conceptual differentiation). The brain's resting state can be characterized spatially by different neural networks (including DMN and CEN) and temporally by different frequency fluctuations in the range between 0.001 and 200 Hz (Cabral, Kringelbach, & Deco, 2013; Northoff, 2014a for details). This suggests that the brain's spontaneous activity shows an elaborate spatiotemporal structure, whose details will be discussed later.

How does the brain's spontaneous activity constitute or generate our thoughts? Or in other words, how does something neuronal like the brain's spontaneous activity generate or constitute something that is psychological (i.e., thoughts)? The question for transforming neuronal activity into something psychological (i.e., thoughts) must be distinguished from the question of how those same thoughts and their contents stand in relation to sensorimotor, cognitive, affective, or social functions.

My focus here is on the first question, the one for transformation, which encounters a serious problem. When measuring the brain's spontaneous activity, we do not detect any thoughts at all; all we see are firing rates of neurons, different networks, and different frequency fluctuations. Beyond that, we will not detect anything else in the brain's spontaneous activity. How is it possible for the brain's spontaneous activity and its neuronal features to generate or constitute task-unrelated thoughts? This is the central question guiding the present chapter.

To address this question, one may want to suppose a common denominator that makes it possible to transform the brain's spontaneous activity into task-unrelated thought. I here suggest spatiotemporal features to be one such common denominator underlying both neuronal and psychological activity. This leads me to suggest the spatiotemporal theory of task-unrelated thought (STTT), which postulates two spatiotemporal mechanisms. First, the STTT supposes that the brain's spontaneous activity integrates (and thereby transforms) different stimuli into content—this amounts to "spatiotemporal integration" and the contents of task-unrelated thoughts. Second, the STTT postulates that the brain's spontaneous activity and its spatial and temporal features allow the extension of the contents beyond their original points in time and space—this amounts to "spatiotemporal extension," by means of which contents are transformed into thoughts. Taken together, as in its name, the STTT can be conceived a spatiotemporal (rather than cognitive) theory that links content and process models, as well as neuronal and psychological levels of task-unrelated thoughts.

"Spatiotemporal Integration": Transformation of Stimuli into the Contents of Thoughts

The Brain's Spontaneous Activity: Different Stimuli and Their Baselines

How can we better describe the brain's spontaneous activity? I here understand the concept of the brain's spontaneous activity in a purely neuronal sense, as distinguished from a cognitive sense (as is often presupposed in the context of task-unrelated thought). Often the brain's spontaneous activity is considered to be devoid of the processing of specific stimuli or tasks, for instance the absence of a particular visual picture during task-evoked activity. In that case, the concept of spontaneous activity is more or less equated with the "resting state" that is defined by the absence of specific external stimuli (Logothetis et al., 2009; Northoff, 2014a). However, it is important to note that the absence of specific stimuli or tasks does not imply the complete or total absence of any kind of stimuli (or tasks). Even in the resting state, there are still plenty of stimuli that are processed.

When closing the eyes, as during the resting state, there is the continuous interoceptive input or stimuli from the body that need to be processed. There is, for instance, continuous input from the heart (heartbeat) and lungs (respiration). One would therefore expect that neural activity in the resting state is related to the interoceptive activity in the body. This possibility is supported by a study that demonstrated that resting state functional connectivity in the resting state is directly related to (i.e., correlates with) heart variability (Chang et al., 2013), and by a recent meta-analysis of functional neuroimaging studies of spontaneous thought showing that the insula—the key interoceptive cortex—is consistently recruited (Fox et al., 2015). The close link between interoceptive stimuli from the body and the brain's spontaneous activity is further supported by recent studies from the group around Tallon-Baudry that show how the heartbeat and the gastral dynamics (as related to slower frequencies) are directly related and coupled to neural activity in the brain's spontaneous activity (Babo-Rebelo et al., 2016; Park and Tallon-Baudry, 2014; Richter et al., 2016).

Due to the strong input of the body's interoceptive stimuli, Marx and colleagues (2004) therefore characterize the resting state as obtained during eyes closed as an "interoceptive state" where neural activity is strongly determined by and reflects the predominant processing of interoceptive stimuli from the body by the brain. Correspondingly, Barry, Clarke, Johnstone, Magee, and Rushby (2007) speak of an "arousal baseline," referring to an unspecific level or state of arousal as triggered mainly by the body's interoceptive input.

What happens if subjects open their eyes? In that case, additional exteroceptive input (e.g., visual input) is added to the ongoing exteroceptive input stemming from gustatory, olfactory, auditory, and tactile input (that is already ongoing in the interoceptive state). The balance between the continuous interoceptive and exteroceptive input may thus shift toward the latter when opening the eyes. The primarily interoceptive state and its "arousal baseline" is then transformed into a primarily "exteroceptive state" and a corresponding "activation baseline" (Barry et al., 2007).

In addition to the continuous interoceptive and exteroceptive input from body and environment, there is also input from the brain itself and its intrinsic activity. The thalamus, for instance, generates its own activity pattern with oscillations that may be imputed into other regions. Analogously to interoceptive and exteroceptive input, one may want to speak here of "neural input" with a "neural state" and a corresponding "neural baseline" (Northoff, 2014a). These different baselines (i.e., activation, arousal, and neural baseline) may be prevalent throughout the whole brain and thus in all regions and networks.

Different brain regions and networks may show different balances between the three different states, though. For instance, subcortical regions in the brain stem receive strong interoceptive inputs from the body such that the interoceptive state and its arousal baseline may predominate here in the resting state. On the other hand, sensory regions and their respective sensory networks receive rather strong exteroceptive input so that the exteroceptive state and the activation baseline may predominate here. Finally, the "neural state" and its neural baseline may predominate in regions like the cortical midline structures that neither receive direct stimulus input (either interoceptive or exteroceptive) nor send out stimulus output (like the motor cortex and the executive control network) (Northoff, 2014a).

Taken together, these short deliberations show that the brain's spontaneous activity is far from a true "resting" state in the literal sense of the term. There are many different stimuli being processed, interoceptive and exteroceptive and neural, which leads to different balances between interoceptive and exteroceptive and neural states (and their respective baselines) across different regions and networks in the brain. This raises the question of how the integration of these different stimuli ultimately results in the brain's spontaneous activity (or resting state, if taken in an operational way). How are the different continuous inputs, interoceptive and exteroceptive and neural, linked or bound together such that they constitute what we observe as spontaneous (or resting state) activity? I suggest in the following section that "spatiotemporal integration" and, more specifically, "spatiotemporal binding" may be central for that.

"Spatiotemporal Binding": Transforming Stimuli into Contents

What is spatiotemporal binding? The concept of binding has been used often in the context of consciousness, where it describes the linkage (e.g., binding) between different stimuli into one content by means of which the latter is supposed to become conscious (Crick & Koch, 2003). This has been called the "binding hypothesis" of consciousness (Crick & Koch, 2003; Rhodes, 2006). For instance, stimuli are supposed to be bound together by 40 Hz (i.e., gamma band) oscillations in the visual cortex that allow the stimuli to be synchronized, amounting to "binding by synchronization" (Mudrik et al., 2014). However, the association of such binding of different stimuli into contents with conscious awareness has been contested. Studies have demonstrated that the linkage or binding between different stimuli, for instance during multisensory integration, can occur in the absence of consciousness (Mudrik et al., 2014; Revonsuo, 2006; Zmigrod & Hommel, 2011).

Independent of the association with consciousness, one can conceive binding nevertheless as a central mechanism to link different stimuli. I suggest that such binding occurs in the brain's spontaneous activity: the different continuous interoceptive and exteroceptive and neural inputs are temporally and spatially linked and thus bound together in that they result in contents that later resurface as the contents of thought. Such binding between the different contents occurs, I propose, on the grounds of the spatiotemporal features of the brain. Let us detail the mechanisms of such "spatiotemporal binding," as I call it (I will distinguish it from other forms of binding in the next section).

Each region in the brain shows specific spatial and temporal features in its spontaneous activity. Spatially, brain regions may show a certain functional connectivity pattern with other regions. For instance, cortical midline structures, the core part of the DMN, have shown a rather high (if not the highest) degree of functional connectivity within the brain's spontaneous activity (when compared to other regions and networks) (de Pasquale et al., 2012; Hagmann et al., 2008; Honey et al., 2009). In contrast, sensory regions show a much lower degree of functional connectivity. Temporally, each region (and network) seems to have its own range of time windows within which it can bind or integrate different stimuli into one pattern of neural activity. These intrinsic time windows may surface in what has been described as "temporal receptive windows" (Hasson, Chen, & Honey, 2015; Honey et al., 2009; Murray et al., 2014) that have been shown to be rather short in sensory cortex (60–80 ms), whereas they seem to be rather long in other areas, especially the cortical midline structures (up to 250–300 ms).

What do these spatial and temporal features imply for the binding of interoceptive and exteroceptive and neural inputs in the brain's spontaneous activity? They suggest that different regions may bind different inputs in different ways, depending on their respective spatial and temporal profile. For instance, the sensory cortices, with their low degrees of functional connectivity and short intrinsic time windows, may not be able to bind as many and or as wide a range of stimuli, including their different points in time and space, together as the cortical midline structures, with their high degree of functional connectivity and long intrinsic time windows. There consequently may be different spatiotemporally based "neural binding patterns" for integrating different stimuli across the brain's different regions and networks.

How are these different neural binding patterns related to thoughts and their contents? I propose that the contents of thought result from and are constituted or generated on the basis of the binding between different stimuli, including their different points in time and space. By binding different stimuli and their different points in time and space together, a certain unity (an "objectual unity," as philosophers would call it; cf. Bayne & Chalmers, 2003) is constituted, which may correspond to what we describe as the content (or object) of thought.

Contents may then be distinguished on the basis of their neural binding pattern and its spatiotemporal features. Different contents (or objects) of thought may consequently be assumed to correspond to different neural binding patterns and different spatiotemporal features. Depending on the predominant content, one may want to distinguish between somatically guided, perceptually guided, and self-generated thoughts.

If, for instance, interoceptive input prevails over exteroceptive input in the brain's spontaneous activity, the contents of our spontaneous thought may more likely concern one's body rather than referring to the environment. Such somatically guided thoughts may, for instance, predominate in psychiatric patients with anxiety, panic, or depression, who can be abnormally preoccupied with their body (or parts of it, such as the heart), resulting in various somatic symptoms. In that case, one would expect that the balance of spontaneous activity shifts toward the subcortical or interoceptively involved regions like the insula and the somatosensory cortex, which is indeed the case (Andrew-Hanna et al., 2016; de Greck et al., 2012).

If, in contrast, exteroceptive input predominates, the spontaneous activity balance may shift more toward the sensory cortices, resulting in the predominance of external thoughts contents, for example "externally guided cognition" (Dixon et al., 2014) or alternatively, "perceptually guided thought" (Smallwood & Schooler, 2015). Finally, the neural input from the brain's spontaneous activity itself and especially that from the cortical midline structures may predominate in the brain's spontaneous activity. In that case, one would expect internally guided cognition (Dixon et al., 2014), with thought contents strongly related to the self,

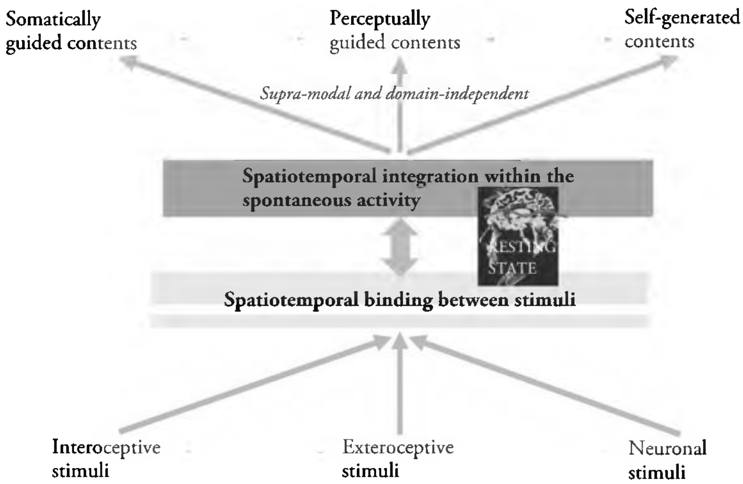

Figure 6.2. Spatiotemporal integration and binding. (See Color Insert)

amounting more or less to self-generated thoughts (Smallwood & Schooler, 2015) (see Figure 6.2).

How are the three different kinds of content related to each other? Since interoceptive, exteroceptive, and neural stimuli are all integrated and bound together within the brain's spontaneous activity, there are no exclusively somatically or perceptually guided thoughts, nor solely self-generated thoughts. Instead, the contents of our thoughts are supramodal and domain-independent and can therefore be traced to the balance between interoceptive, exteroceptive, and neural stimuli. Rather than considering each type of stimulus independent of the others, it is rather a matter of their balance and the degree to which one predominates over the others. The hypothesis of such a balance is consistent with recent findings of decoupling from sensory processing, including sensory cortex, during self-generated thought (Andrews-Hanna et al., 2014; Baird et al., 2014; Gorgolewski et al., 2014).

"Spatiotemporal Integration": Basic and Fundamental Form of Integration

I have suggested that "spatiotemporal integration" and, more specifically, "spatiotemporal binding" are central in constituting the contents of our thoughts. What exactly do I mean by integration? One can describe different forms of integration, such as multisensory integration, perceptual integration, semantic integration, cognitive integration, and formal mathematical integration (see Mudrik, Faivre, & Koch, 2014, for an excellent overview). These forms of integration implicate sensory and perceptual functions like multisensory integration and perceptual integration, as well as cognitive functions such as semantic and cognitive integration, or even higher-order cognitive functions as required in mathematical integration.

Those more complex forms of integration must be distinguished from the kind of integration proposed here. The integration between different stimuli in spontaneous brain activity does not yet implicate any specific active recruitment of sensorimotor, perceptual, cognitive, or higher-order cognitive functions. Instead, the integration by the spontaneous activity occurs in an automatic way, by default, due to the nature of the spontaneous activity's spatiotemporal structure. The interoceptive and exteroceptive and neural stimuli constituting the different baselines are by default (i.e., automatically) integrated within the brain's spontaneous activity. No recruitment of sensory, perceptual, motor, cognitive, or higher-order cognitive functions is required.

Instead, the different stimuli and their spatial and temporal features are integrated by and within the spatiotemporal features of the brain's spontaneous activity so that one may want to speak of "spatiotemporal integration." Such spatiotemporal integration features a most basic and fundamental level of integration that is inherent in the spontaneous activity and its spatiotemporal structure prior to and independent of any subsequent sensorimotor, affective, cognitive, and social function, including their respective forms of integration (i.e., multisensory, cognitive, etc.). Accordingly, taken together, spatiotemporal integration can be characterized by (1) its automatic nature occurring by default because of the spontaneous activity's spatiotemporal structure; and (2) prior to and independent of the recruitment of specific sensorimotor, affective, cognitive, and social function.

One may want to argue that such spatiotemporal integration is trivially true. Any integration between different stimuli occurs at one particular or discrete point in time and space within the brain, for instance at a particular region or cell population, as well as in a specific frequency range. This is not contested here. Taken in this sense, the characterization of integration as spatiotemporal is indeed trivially true. However, that is not the sense that I mean by the concepts of space and time as the core of spatiotemporal integration. Rather than referring to discrete points, here the concepts of space and time refer to a distribution of different points across space and time entailing a stochastic or statistically based and ultimately neural, rather than mental, meaning of time and space.

Let us illustrate such stochastic meaning of space and time by the example of multisensory integration (Ferri et al., 2015; Stein et al., 2009). Multisensory integration is assumed to rely on different principles, including spatial and temporal coincidence between the cross-modal stimuli: if the two cross-modal stimuli coincide at the same point in space, as for instance in a particular cell population or region, their likelihood of being integrated is much higher than when they do not spatially coincide (see Stein et al., 2009, as well as Chapter 10 in Northoff, 2014a, for details). The same holds analogously for temporal coincidence: if the two stimuli temporally coincide and do thus occur stochastically at the same point in time, they can be much better integrated with each other than when occurring at different points in time. This makes it clear that multisensory stimuli are integrated with each other on stochastically based spatial and temporal grounds.

I now assume the same in an analogous way to hold for the integration of the ongoing interoceptive and exteroceptive and neural stimuli with each other into the brain's spontaneous activity. The more the temporal and spatial features of interoceptive stimuli coincide with the spatial and temporal features of the brain's spontaneous activity, the better the former will be integrated within the latter. The same holds, obviously, for the integration of exteroceptive and neural stimuli into the spontaneous activity, which also occurs on purely spatial and temporal grounds.

Instead of the single stimulus itself and its specific points in time and space, the spontaneous activity encodes the relation (e.g., difference) of the former's points in time and space to its own points in time and space (i.e., its own spatial and temporal features). The resulting neural activity is thus based on the stochastically based spatiotemporal difference between stimulus and spontaneous activity—this presupposes difference-based coding (as distinguished from stimulus-based coding) (Northoff, 2014a). I now postulate that such stochastically based spatiotemporal encoding strategy (i.e., difference-based coding) allows for the kind of spatiotemporal integration and binding that transforms simple stimuli into contents.

Such encoding strategy (i.e., difference-based coding) is based on the spatiotemporal features of stimuli; this distinguishes it from other strategies that are rather based on the nature of the stimuli themselves, like their origin, as in body, environment, or brain, or, alternatively, on associated sensorimotor, cognitive, affective, or social function, as in more complex forms of integration (see earlier discussion). Therefore, the concept of "spatiotemporal" as presupposed in spatiotemporal integration cannot be considered trivially true but rather substantial in that it describes a most basic and fundamental form of integration. I postulate that spatiotemporal integration in this most basic and fundamental sense (i.e., prior to and independent of other more complex forms of integration) is central for integrating and binding and thus transforming stimuli into contents as essential ingredients of task-unrelated thought.

"Spatiotemporal Extension": Transformation of Contents into Thoughts

The Brain's Spontaneous Activity: Spatial and Temporal Features

The brain's intrinsic activity (or spontaneous activity) can spatially be characterized by various neural networks that consist of regions showing close functional connectivity with each other. There is, for instance, the DMN that includes mainly the cortical midline structures (Andrews-Hanna et al., Chapter 13 in this volume; Northoff et al., 2006), which show strong low-frequency fluctuations (Northoff, 2014a; Raichle, 2009; Raichle et al., 2001). Other neural networks include the sensorimotor network, the salience network, the ventral and dorsal attention network, the cingulum-operculum network, and the CEN (see Menon, 2011, for a review). These neural networks are related to each other in continuously dynamically changing constellations (de Pasquale et al., 2010, 2012), resulting in what may be described as a spatial structure that, through its functional nature, supercedes the anatomical structure.

In addition to such spatial structure on the functional level, the spontaneous activity can also be characterized by fluctuations in its neural activity in different frequency bands, ranging from infraslow (0.0001–0.1 Hz) through delta (1–4 Hz), theta (5–8 Hz), alpha (8–12 Hz), and beta (12–30 Hz) to gamma (30–180 Hz). Most important, these different frequency bands are coupled with each other, with for instance the phase of lower frequency bands being coupled to the phase or power of higher ones (Buzsaki, 2006; Buzsaki, Logothetis, & Singer, 2013; Northoff, 2014a). This amounts to a complex temporal structure in the brain's intrinsic activity that, as shown most recently, is related in some yet unclear ways to the spatial structure and its various neural networks (e.g., Ganzetti & Mantini, 2013; Northoff, 2014a).

To be more specific, the spontaneous fluctuations as observed in the functional magnetic resonance imaging (fMRI) signal, i.e., BOLD, are found in lower frequency ranges, including the delta band (1–4 Hz), up- and down-states (0.8 Hz), and infraslow fluctuations (ISFs) (0.001–0.1 Hz) (Logothetis, 2008, Zhigalov et al., 2015). The slow-frequency fluctuations observed in fMRI have been assumed to correspond to what is measured as slow cortical potentials (SCPs) in electroencephalography (EEG) (He & Raichle, 2009; Khader, Schicke, Röder, & Rösler, 2008). These SCPs are not easy to obtain in EEG because they are subject to artifacts caused by sweating, movements, and electrode drift; their measurement therefore requires a more direct approach by so-called direct current (DC) recording. There is some evidence that what is measured as SCP in EEG corresponds, or is even identical, to the low-frequency fluctuations obtained in fMRI (He & Raichle, 2009; Khader et al., 2008).

In addition to such low-frequency fluctuations, there are also higher frequency fluctuations in the brain's resting-state activity. These cover 1 Hz and higher frequency ranges, thus including delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–30 Hz), and gamma (>30 Hz) (Mantini, Perrucci, Del Gratta, Romani, & Corbetta, 2007; Sadaghiani, Hesselmann, Friston, & Kleinschmidt, 2010). This raises the question of how low and high frequencies are related to each other in the brain's resting state (Canolty & Knight, 2010; Fell & Axmacher, 2011; Fries, 2009; Sauseng & Klimesch, 2008). For instance, Vanhatalo et al. (2004) conducted an EEG study in healthy and epileptic subjects during sleep using DC-EEG to record low-frequency oscillations. All subjects showed infraslow oscillations (0.02–0.2 Hz) across all electrodes—and thus the whole brain—without any specific, visually obvious spatial distribution evident.

Most interestingly, Vanhatalo et al. (2004) observed phase-locking or phase-synchronization between the phase of slow (0.02–0.2 Hz) oscillations and the amplitudes of the faster (1–10 Hz) oscillations: the amplitudes of the higher frequency oscillations (1–10 Hz) were highest during the negative phases or deflection (e.g., during periods in the fluctuating cycle of the low-frequency oscillation that show higher degrees of excitability for subsequent stimuli when compared to positive periods in the cycle) of the slow oscillations (0.02–0.2 Hz) (see Figure 6.3).

Such phase-locking of high-frequency oscillations' power to the phases of lower ones is described as *phase-power coupling*, with phase-phase and power-power coupling also being possible (Canolty & Knight, 2010; Sauseng & Klimesch, 2008). Generally, the coupling seems to occur in the direction from low- to high-frequency fluctuations as well as from phase to amplitude/power (Buzsaki, 2006; Buzsaki et al., 2013)—the phase of the lower

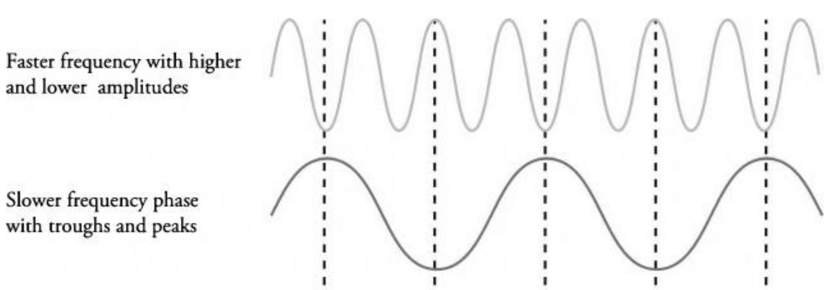

Figure 6.3. Schematic illustration of cross-frequency coupling. (See Color Insert)

frequency entrains the amplitude of the higher frequency. Such low–high frequency entrainment may be central in integrating and embedding the stimuli (and their respective contents) into the ongoing temporal structure of the brain's intrinsic activity.

"Spatial Extension" of Contents: Functional Connectivity

What does the spontaneous neural activity's spatiotemporal structure imply for the constitution or generation of thoughts? Thoughts are based on contents. However, thoughts are more than contents, since we can have contents that do not transform into thoughts. Therefore, we need to consider additional mechanisms that transform contents into thoughts. For that, the STTT supposes yet another spatiotemporal mechanism, that is, *spatiotemporal expansion*.

We discussed earlier the different inputs into the brain's spontaneous activity, including their binding into contents. Contents can consequently be determined as the linkage or binding of different stimuli into one unity, the unity of content (the "objectual" unity to which philosophers refer). This, however, leaves open the question of how contents can become thoughts. For that I assume that contents need to be *spatiotemporally extended*. This shall be explicated in the following. For that, we first need to consider the regions that have been shown to be recruited during task-unrelated thought. Most prominent among them are the cortical midline structures.

The cortical midline structures show the highest degree of functional connectivity within this region, as well as to all other regions in the brain (de Pasquale et al., 2012; Hagmann et al., 2008; Honey et al., 2009). This suggests that any content generated in, for instance, sensory regions gets somewhat linked and bound to midline regions. Conversely, it means that the contents generated in the midline impact contents elsewhere (see later in this chapter for details of what will be described as *self-expansion*). The original content is thus spatially extended beyond itself and its local origin at one particular point in space, entailing what I describe as spatial extension of content. The higher the degree of functional connectivity, the more the content can be spatially extended beyond its single discrete point in space, and the stronger the respective thought contents will be experienced or perceived as spatially extended across self, body, and environment. (See Figure 6.4).

The assumption of such spatial extension is in accordance with an early study by Mason and colleagues (Mason et al., 2007). They demonstrated a direct correlation between cortical midline neural activity in the DMN and the degree of mind-wandering: the stronger the midline activity in the DMN, the stronger the degree of mind-wandering (as sampled by a questionnaire). Unfortunately, they

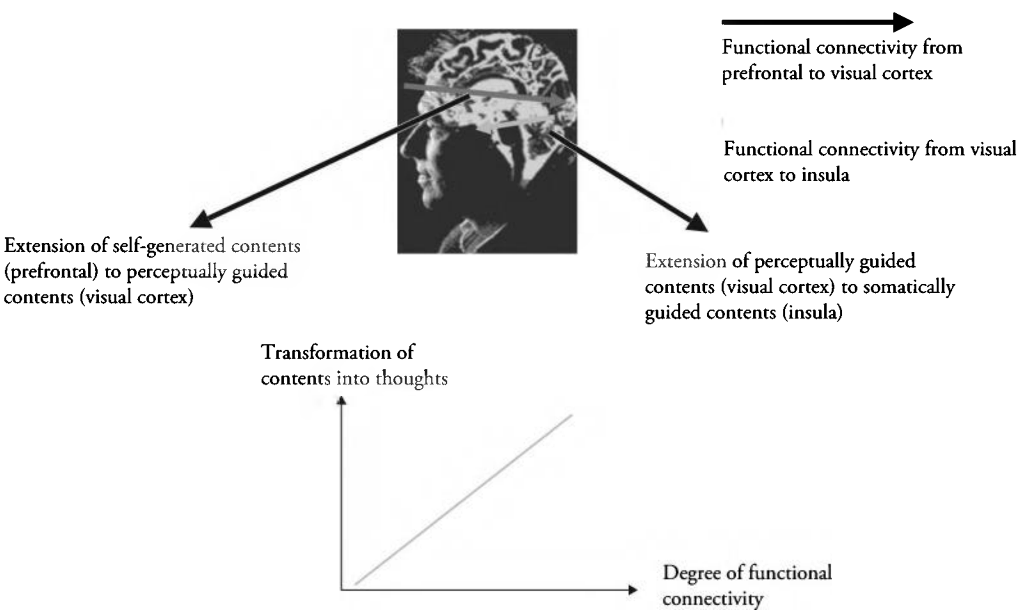

Figure 6.4. Spatial extension of contents into thoughts. (See Color Insert)

did not include functional connectivity measures of the midline regions, which, as I suggest, may be directly proportional to the degree of recruitment of midline structures during task-unrelated thought.

We have to be careful, though. In addition to cortical midline structures, various other regions and networks have been implicated in task-unrelated thought. A subsequent study by Christoff and colleagues (Christoff et al., 2009) observed that other regions, for instance the lateral prefrontal cortex and the CEN, are also recruited during mind-wandering (see Fox et al., 2015, for a recent meta-analysis, as well as Dixon et al., 2014, for a discussion of competition vs. co-occurrence between internally and externally directed cognition). Relevant neuronal measures like inter- and intra-regional synchronization (as measured by functional connectivity and regional homogeneity), neuronal variability, and positive and negative BOLD responses, have been shown to be modulated by episodes of mind-wandering in both the DMN and CEN (and other networks like the dorsal attention network and the salience network) (Allen et al., 2013; Andrews-Hanna et al., 2014, Chapter 13 in this volume; Christoff et al., 2016; Doucet et al., 2012; Fazelpour & Thompson, 2015; Gorgolewski et al., 2014; Zabelina & Andrews-Hanna, 2016).

Additionally, other regions like the dorsomedial prefrontal regions, the insula, the dorsal anterior cingulate cortex (as part of the salience network), and the medial temporal regions/network (that includes the hippocampus and its central role in episodic memory retrieval) have also be shown to be activated during mind-wandering (see Andrews-Hanna et al., 2014, as well as Fox et al., 2015, for a recent meta-analysis). The involvement of non-DMN regions is further supported by a recent meta-analysis of neuroimaging studies on mind-wandering (Fox et al., 2015).

The authors reported involvement of typical DMN regions (like ventromedial prefrontal cortex, medial prefrontal cortex, precuneus/posterior cingulate cortex, bilateral inferior parietal lobule, and left medial temporal lobe/parahippocampal cortex). In addition, they observed many regions from the executive control network, including dorsal anterior cingulate cortex, right rostro- and left ventrolateral prefrontal cortex, right anterior inferior parietal lobule, and precuneus. Finally, regions outside both the DMN and CEN were also implicated, including right secondary somatosensory cortex, left mid-insula, and left lingual gyrus. This further suggests that mind-wandering is not limited to the DMN but involves brain regions and different networks and, ultimately, can involve more or less the entire brain, which may reflect the heterogeneity and complexity of task-unrelated thought (Fox et al., 2015).

Why is the involvement of different regions and networks relevant for task-related thought? The different regions and networks show different functional connectivity patterns. For instance, as pointed out, the cortical midline structures show the highest degree of functional connectivity when compared to other regions like sensory regions (see earlier discussion). I now postulate that each region will contribute to the spatial extension of contents into thoughts based on its respective functional connectivity pattern. By showing a high degree of functional connectivity to other and more distant regions, the point in space featuring the respective content can be extended further, that is, connected with others, and thereby put into a larger spatial context.

Based on their functional connectivity patterns, different regions like sensory and midline regions may contribute to the spatial extension of contents in different ways. The spatial point of a content originating strongly in sensory cortex (i.e., perceptually derived content) may not be as spatially extended as a content related to the self (i.e., self-guided content). The different regions' functional connectivity patterns, including their balance, may then strongly impact the degree to which a particular content and its particular point in space are extended to others and thus put in a larger spatial context. And, importantly, the larger the degree of spatial extension of the content, the more likely the content will be transformed into a thought. Accordingly, I hypothesize direct proportional relationship between the degree of functional connectivity (of particular regions or networks) and their recruitment during task-unrelated thought.

"Temporal Extension" of Content: Cross-Frequency Coupling

The same kind of extension of the contents of thought may analogously occur on the temporal side. The different frequencies are not isolated from each other, but can become coupled. Accordingly, the infraslow-frequency fluctuations with their long cycle durations may couple to the shorter, higher-frequency fluctuations entailing cross-frequency coupling (Huang et al., 2017; Zhiaglov et al., 2015). Especially the long cycle durations of the infraslow-frequency fluctuations may provide the perfect means to extend the single thought beyond its own temporal features at one particular point in time into a longer duration: the longer the cycle duration and hence the lower the frequency range, the more and thus longer the respective content can be temporally extended beyond its own original discrete point in time, and the more the thought will be perceived or experienced as temporally continuous.

As discussed earlier, the long cycle durations of the infraslow-frequency fluctuations may be especially central here. If the timing of a content falls into the beginning of the phase of an infraslow-frequency fluctuation with a cycle duration of, for instance, 100 s (as in 0.01 Hz), the content's initial and discrete point in time (at 5 s into the onset of cycle duration) may be extended into the high excitability phase of the ongoing fluctuations (e.g., the trough, as distinguished from the peak). Since the trough covers half the cycle duration (e.g., 50 s of the 100 s total cycle duration), the content will be extended for an additional 45 s beyond its occurrence of 5 s into the cycle duration. In contrast, the shorter cycle durations of higher frequencies (like delta at 1 Hz) may not be able to temporally extend the thought to such a degree.

One could consequently hypothesize that regions and networks with a high degree of infraslow-frequency fluctuations may be able to temporally extend contents to a much higher degree than regions and networks with low degrees of the same frequency fluctuations. Investigations have indeed shown that the cortical midline structures that are part of the DMN show the highest and strongest degree of infraslow-frequency fluctuations, and sensory regions and networks exhibit a much lower degree of these frequency ranges while showing relatively stronger power in higher frequency ranges (Huang et al., 2016; Lee, Northoff, & Wu, 2014). One may now hypothesize that these temporal features may contribute to the often observed recruitment of cortical midlines structures in spontaneous thoughts and the overlap with the DM (Fox et al., 2015) (see Figure 6.5).

How can we link such temporal extension to thoughts? Future investigations may want to directly relate the infraslow-frequency fluctuations to the duration of spontaneous thought contents. One would expect that thought contents that last longer show stronger recruitment of infraslow-frequency fluctuations and cortical midlines regions than short-duration thought contents that may implicate higher frequencies and eventually the sensory regions to a higher degree. Methodologically, one may want to ultimately establish spatial and temporal features of the thoughts themselves, including their contents, for instance on the basis of subjective reporting and timing. These spatial and temporal features of the thought contents can then be related to corresponding spatial and temporal features in the brain's spontaneous activity. For instance, self-guided thought, as mainly based on midline regions and their strong infraslow frequencies, may last longer when compared to perceptually derived thought as it involves mainly sensory cortex that shows less power in infraslow frequencies.

"Spatiotemporal Extension" and the "Virtual" Nature of Thoughts

Spatiotemporal extension allows for the content to be extended beyond the discrete point in time and space of its original generation. This constitutes *spatiotemporal continuity* of contents. As based on the preceding evidence, I assume that the degree of

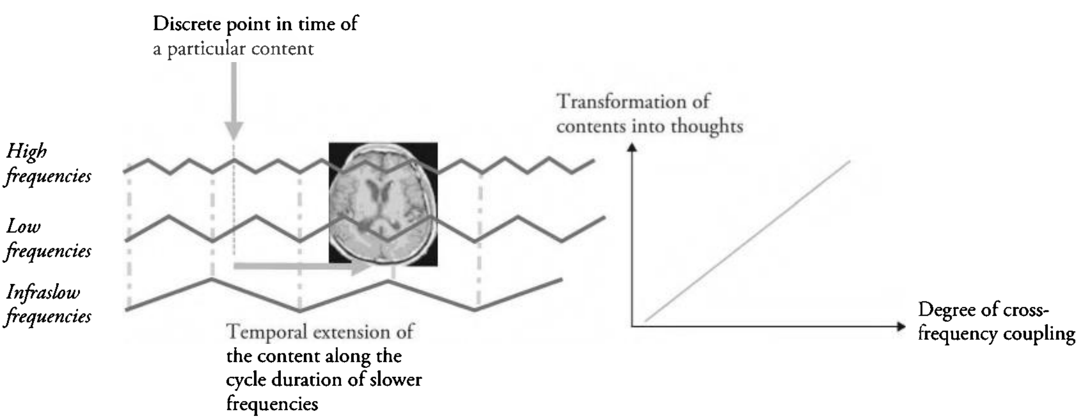

Figure 6.5. Temporal extension of contents into thoughts. (See Color Insert)

spatiotemporal extension and thus the spatiotemporal continuity of thought contents are directly proportional to the degree of functional connectivity and cross-frequency coupling in the brain's spontaneous activity: the higher the degrees of functional connectivity and cross-frequency coupling, the higher the degree to which contents and their single discrete points in time and space can be spatiotemporally extended and thus constituted in a spatiotemporally continuous way, and the more we will perceive the respective thought content to be spatially and temporally continuous (rather than discrete).

This description, however, applies merely to the extension of contents into space and time of the brain's spontaneous activity. How and why are these contents transformed into thoughts? By virtue of its spatial and temporal features, spontaneous activity may extend content beyond its single discrete point in time and space. That means that the single content becomes detached from its original origin, including its discrete point in time and space, at the same time that it becomes linked to other contents.

Conceived in spatiotemporal terms, this means that the contents become by default "virtual" within the spatiotemporal structure of the spontaneous activity. "Virtual" means that the content can no longer be located at one particular discrete point in time and space within the spontaneous activity. Instead, due to its spatiotemporal extension, the content occupies several discrete points in time and space, thus being stochastically distributed across different regions/networks and frequencies in the brain's spontaneous activity. In that sense, the concept of "virtual" can be more or less equated with being distributed: task-unrelated thoughts and their contents are spatiotemporal distributed.

However, there is more to task-unrelated thoughts. They constitute relations between different points in time and space (i.e., relational time and space) that as such can no longer be observed by us (in a direct way). Such a relational component allows the simulation of objects, events, or scenes (in a more or less realistic way); the constitution of such relational time and space (as distinguished from mere observational time and space) with subsequent simulation allows the transformation of mere content into task-unrelated thought. Based on its spatiotemporally relational and simulative nature, I describe task-unrelated thought as "virtual." How can we explain the virtual nature of task-unrelated thought in more detail? The contents become stochastically and virtually extended in a three-dimensional way across different points in time and space within the spontaneous activity's spatiotemporal structure. Due to spatiotemporal extension into the three-dimensional space of the spatiotemporal structure, the original content becomes distributed and "virtualized." That, I postulate, is the moment when the mere content transforms into a thought: the higher the content's degree of stochastic spatiotemporal extension within the three-dimensional spatiotemporal structure of the brain's spontaneous activity, the more virtual the content will become in spatial and temporal terms, and the more likely the content will be transformed into a thought.

Based on this assumption, one may want to suggest the following neuronal hypotheses. The stronger the degree of functional connectivity of regions such as cortical midline structures with the strongest infraslow-frequency fluctuations, the higher the degree to which contents are transformed into thoughts and the longer those thoughts should last. This is supported by an example from psychiatry where patients with depression show an abnormally high degree of functional connectivity of cortical midline structures, while they suffer from excessive thoughts with abnormally long duration—described as rumination (Berman et al., 2011; Kaiser et al., 2015; Northoff, 2015a, 2015b, 2015c, 2015d; Northoff & Sibille, 2014; see Hamilton et al., 2015, for an excellent overview).

Moreover, the degree to which contents are transformed into thoughts should also be related to the degree of cross-frequency coupling. The higher the degree of cross-frequency coupling, especially between infraslow and higher frequency fluctuations, the more likely it is that contents will be transformed into thoughts. One would consequently expect increased cross-frequency coupling in disorders like depression where patients suffer from increased amounts of thoughts, as in depressive rumination (Northoff, 2015a). In contrast, a decrease in cross-frequency coupling, observed for instance in schizophrenia, should then go along with a blockade of and decrease in thoughts, which are frequently observed in these patients (Northoff, 2015c, 2015d; Northoff & Duncan, 2016).

Spatiotemporal extension not only allows for extending particular contents in stochastic or virtual time and space, but also may link different contents. This should result in a continuous flow of thoughts, a "stream of thoughts" (as analogous to James's "stream of consciousness") with both internally and externally directed contents (Smallwood & Schooler, 2015). One would assume that such a "stream of thoughts" recruits the entire spontaneous activity's spatiotemporal structure and its full extension. Again, especially the infraslow-frequency fluctuations with their long cycle durations may be central in linking different contents and consequently thoughts. By being linked to other contents, the single content becomes even more stochastically virtual and extended beyond itself, which makes its transformation into a thought even more likely. Ideally, one would then want to investigate the spatiotemporal dynamics of the spontaneous activity as whole (see Fox et al., 2015, for a discussion of this issue). In that case, one would want to apply, for instance, measures of global temporal structure like power law spectrum and exponent to characterize both the spontaneous activity's spatiotemporal structure (Huang et al., 2016) and the time series of the spontaneous thoughts. Higher degrees of temporal structure in the spontaneous activity should then lead to a higher probability of contents being transformed into thoughts.

Are the transformation of content into thought and the supposed involvement of the entire brain accompanied by consciousness? This is a separate question, which I leave open here. The Global Neuronal Workspace Theory (GNWT) by Daheane (Dehaene & Changeux, 2011; Dehaene et al., 2014) postulates that the degree of neuronal globalization in spatial (i.e., prefrontal and parietal cortex) and temporal (i.e., late potentials like P300) terms is central for eliciting consciousness. How does such *neuronal globalization* compare to *spatiotemporal extension* as postulated here? The GNWT argues that neuronal globalization is necessary to recruit cognitive functions that, in turn, are necessary for consciousness. This is different in the case of spatiotemporal extension. Spatiotemporal extension does not refer to cognitive functions, as in neuronal globalization in the GNWT. Instead, it refers to the degree of spatial and temporal extension of a particular content and its point in time and space prior to and independent of recruiting cognitive functions. The concept of spatiotemporal extension must therefore be distinguished from neuronal globalization and, as one may want to say, *cognitive extension*. In a nutshell, neuronal globalization as in the GNWT is cognitive, while spatiotemporal extension as in the STTT is strictly spatiotemporal rather than cognitive. How much such spatiotemporal extension is related to consciousness remains then to be discussed on separate grounds (Northoff, 2014b).

Conclusion

I here introduced a novel theory of thought, the spatiotemporal theory of thought (STTT). The STTT is primarily a spatiotemporal rather than a cognitive, sensorimotor, or semantic theory of thought. The STTT shifts the focus from the cognitive features of task-unrelated thought to its spatiotemporal features. The spatiotemporal features of task-unrelated thought are supposed to provide a common denominator that underlies both content and process. Therefore, STTT may be ideally suited to link and integrate content models and process models of task-unrelated thought.

Moreover, the STTT is strongly based on the brain and the spatiotemporal structure of its spontaneous activity. Unlike in cognitive theories, the STTT focuses not so much on the contents of thought, but rather on the temporal and spatial features of those contents and how they are integrated into each other on the basis of their spatial and temporal features. I directly link the spatial and temporal features of task-unrelated thought to the spatiotemporal structure of the brain's spontaneous activity, including its concrete physiological mechanisms, such as functional connectivity and cross-frequency coupling.

Future psychological investigation may want to characterize our thoughts not only in terms of their contents, but also with respect to their stochastically based spatial and temporal features, such as their spatial and temporal continuity (i.e., extension in our experience). Tackled in this way, thoughts and their contents are understood as stochastically based distributed and virtual three-dimensional spatiotemporal structures that are continuously sculpted and shaped by the spontaneous activity's spatiotemporal structure: the more the contents are spatiotemporally extended by the stochastically based spatial and temporal features of the spontaneous activity's spatiotemporal structure, the more distributed and virtual they become, and the more likely it is that they will be transformed into thoughts.

Such a spatiotemporal approach to thoughts can be tested experimentally on both neuronal and perceptual-experiential levels. Neuronally, one may want to focus not so much on the neuronal correlates of specific contents like sensorimotor, affective, and cognitive contents, but rather on those neuronal mechanisms related to the respectively underlying spatial and temporal features of thought contents. Correspondingly, one may also sample the spatial and temporal features underlying the contents, in addition to the contents themselves, on the perceptual-experiential level. This allows us to examine the relationship between the spatiotemporal features of the thoughts and their contents, on the one hand, to different aspects of the brain and its spontaneous activity, on the other hand. The STTT postulates spatiotemporal correspondence (and, even stronger, spatiotemporal isomorphism; Fell, 2004) of the spatial and temporal features at the neuronal level with those at the perceptual-experiential level of thoughts.

Finally, it should be mentioned that I have left out a number of dimensions of thought. For instance, our thoughts show a higher or lower degree of personal relevance or self-relatedness. Our thoughts are frequently highly personal and thus individual in nature. This raises the question of the relationship between thoughts and the self, with the latter expanding to the former. This expansion has been referred to as "self-expansion" (Sui & Humphreys, 2015), and has been shown to be closely linked to the cortical midline structures (Northoff, 2015, 2016, 2017; Northoff et al., 2006). Moreover, we can become consciously aware of our thoughts. This raises the question of the relationship between thoughts and consciousness. Both spatiotemporal integration and extension occur automatically and therefore remain unconscious. One would consequently need to search for an additional mechanism by means of which awareness or consciousness is assigned to the thoughts. These questions remain important subjects for future research (Northoff, 2014a, 2014b).

Acknowledgments

I thank Wendy Carter for sorting the references. Financial contributions to GN are acknowledged from the Canada Research Chair program (CRC), the Canadian Institute of Health Research (CIHR), the Michael Smith Foundation, and the National Science Foundation of China.

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CHAPTER

7

Investigating the Elements of Thought: Toward a Component Process Account of Spontaneous Cognition

Jonathan Smallwood, Daniel Margulies, Boris C. Bernhardt, *and* Elizabeth Jefferies

Abstract

Spontaneous thoughts come in a large variety of different forms, varying in their experiential content as well as the functional outcomes with which they are associated. This chapter describes a component process architecture for spontaneous thought in which different types of experience arise through the combinations of different underlying neurocognitive processes. These underlying elements of cognition are not specific to spontaneous thought, since many, if not all, of these neurocognitive processes can be engaged when participants perform an externally directed task. We consider neurocognitive evidence that shows how this component process architecture provides explanatory value for accounts of spontaneous thought since it provides a mechanism that captures both the complex variety of spontaneous experiences that characterize the human condition, as well as the different functional outcomes that these different experiences are associated with.

Key Words: spontaneous thought, cognition, component process, functional outcome

Introduction

Our mind does not merely buzz into life in response to external events; it often generates ordered patterns of activity without the guidance of immediate sensory input. A manifestation of this capacity for spontaneous thought is the experience of mind-wandering (Smallwood & Schooler, 2006), a state observed across cultures (Deng, Li, & Tang, 2012; Killingsworth & Gilbert, 2010; Levinson, Smallwood, & Davidson, 2012; Smallwood, Nind, & O'Connor, 2009; Song & Wang, 2012; Tusche, Smallwood, Bernhardt, & Singer, 2014) and which occupies almost half of our waking thought (Killingsworth & Gilbert, 2010). Although familiar to every member of our species, we know surprisingly little about the process through which spontaneous thought arises, as can be seen by the controversial status of the mind-wandering state in cognitive science and neuroscience (Franklin, Mrazek, Broadway, & Schooler, 2013; Gilbert, Dumontheil, Simons, Frith, & Burgess, 2007; McVay & Kane, 2010; Smallwood, 2010, 2013a, 2013b). These controversies arise because (1) the legacy of behaviorism has led to a focus on cognitive states that relate *directly* to behavior, despite the ubiquity of the mind-wandering state (Callard, Smallwood, & Margulies, 2012); and (2) there are methodological challenges that arise when considering how to empirically capture spontaneous experiences (Smallwood, 2013a).

Spontaneous thought relates to a large class of experiences that arise with few obvious causes in the external environment, and at the psychological level includes a wide range of experiences, such as daydreaming about a holiday while commuting to work, catching one's mind wandering about an unrelated matter while reading. These experiences can be at odds with a task, but need not be. They are characterized by an onset that has no particular association to stimuli in the environment, and this property has meant that they have been described as reflecting processes that are decoupled from perceptual input (see Smallwood, 2013). Over the last decades, methodological advances have allowed spontaneous changes to be measured more effectively, leading to insight into their relationship to functional outcomes and to ongoing neurocognitive functioning. Although this has advanced our understanding of the importance of spontaneous processing at both the neural and psychological level, these developments have also demonstrated how much more we need to understand before we will have a mature scientific account of how spontaneous thought operates. This chapter considers the psychological and neural evidence that spontaneous thought is a complex and varied phenomenon, and examines how this heterogeneity can be captured by a component process architecture in which different forms of experience are produced through the flexible combination of different modular subsystems.

Spontaneous Thought Is Heterogeneous in Both Content and Functional Outcome

Spontaneous thought allows us to mentally escape from the moment and to imagine realities that are different from the way things currently are (Buckner, 2010; Maguire & Hassabis, 2011; Smallwood, 2013a). When we imagine an event, place, or person in a way that they *might be*, we are deriving experiential content from representations of how we remember and understand the world (Buckner, 2010; Buckner & Carroll, 2007; Smallwood, 2013a). Accordingly, spontaneous thoughts can take many forms, and measuring the variety of these experiences is an important goal for research.

Initial investigations highlighted different aspects of spontaneous thoughts, such as awareness, temporal focus, intentionality, and emotional features (for a recent review, see Smallwood & Schooler, 2015). More recently, however, studies have begun to directly examine the heterogeneity of the content of spontaneous thought in a more systematic manner through the identification of patterns of statistical variance that emerge from experience sampling reports that simultaneously probe different elements of experience. This approach is known as *multi-dimensional experience sampling* (MDES), and Figure 7.1 illustrates how it can be implemented in an experimental situation. Typically, participants complete a laboratory

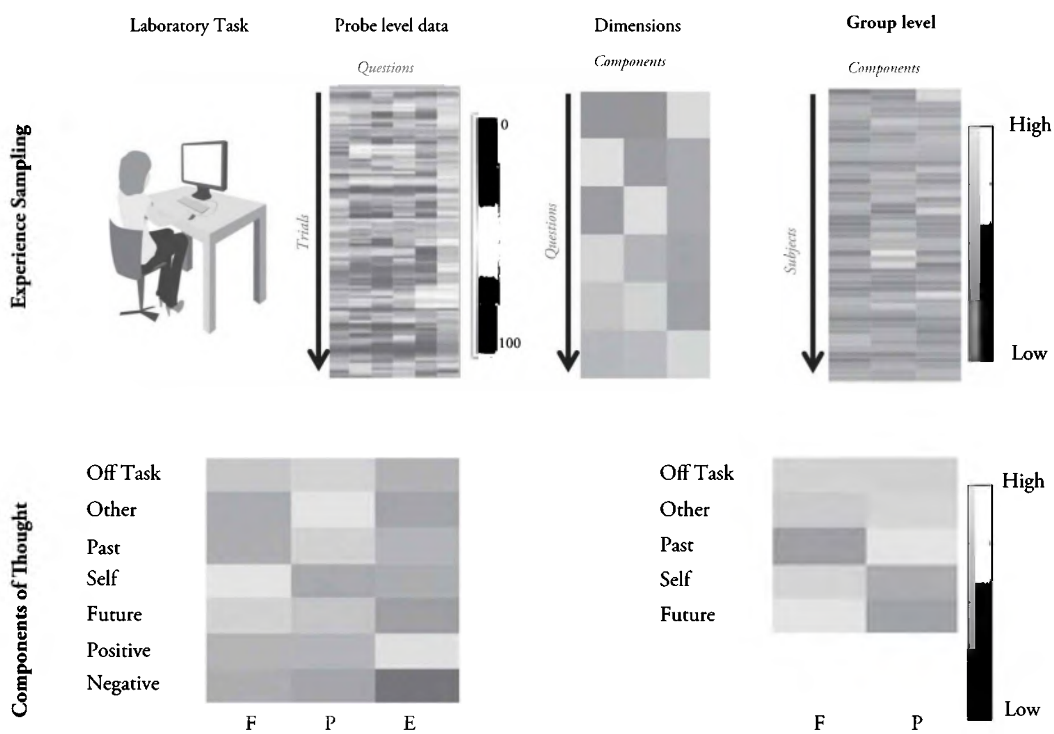

Figure 7.1. Multi dimensional experience sampling (MDES). Participants are asked to provide information on multiple different aspects of their ongoing experience. (See Color Insert)

task in which different aspects of experience (such as the relation to an ongoing task, temporal focus, etc.) are assessed on many occasions. These data are then decomposed using techniques such as ***principal components analysis*** (PCA) at the trial level, a procedure that reveals the dimensional structure that underlies the momentary experiential reports. This research has shown that there are reasonably stable patterns that emerge across multiple different samples (see Figure 7.1) and suggests that these patterns may have unique cognitive and affective correlates (Engert, Smallwood, & Singer, 2014; Ruby, Smallwood, Engen, & Singer, 2013; Ruby, Smallwood, Sackur, & Singer, 2013).

Not only is the content of spontaneous thought variable, the functional outcomes that are associated with it are also heterogeneous. Studies have shown that spontaneous thought is common when the environment lacks compelling demands and we can mentally "switch off," and this seems ubiquitous across cultures (Deng et al., 2012; Killingsworth & Gilbert, 2010; Levinson et al., 2012; Smallwood et al., 2009; Song & Wang, 2012; Tusche et al., 2014). Under these conditions, spontaneous thought allows us to plan the future in our idle moments (Baird, Smallwood, & Schooler, 2011; Smallwood, Brown, et al., 2011; Smallwood et al., 2009; Smallwood, Schooler, et al., 2011) and affords creative solutions when we have reached an impasse on a problem (Baird et al., 2012; Ruby, Smallwood, Sackur, et al., 2013); however, it is also implicated in the ruminations that are linked with unhappiness (Ruby et al., 2013; Smallwood & O'Connor, 2011). Moreover, studies have shown that sometimes spontaneous thoughts occur when we are engaged in a task, and when this happens, it can disrupt performance in complex tasks such as reading or tasks that require sustained vigilance to the external world. Under these circumstances, spontaneous thought can be the cause of absent-minded errors (McVay & Kane, 2009, 2011, 2012a; Smallwood, Beach, Schooler, & Handy, 2008; Smallwood, McSpadden, & Schooler, 2008). Figure 7.2 illustrates some of the beneficial and detrimental outcomes that have been associated with spontaneous thought.

Altogether, psychological investigations have shown that there are multiple aspects of the experience of spontaneous thought and that these are linked to a complex balance of beneficial and detrimental functional outcomes. A comprehensive scientific account of spontaneous thought, therefore, must be able to account for this heterogeneity both in terms of content and functional outcomes.

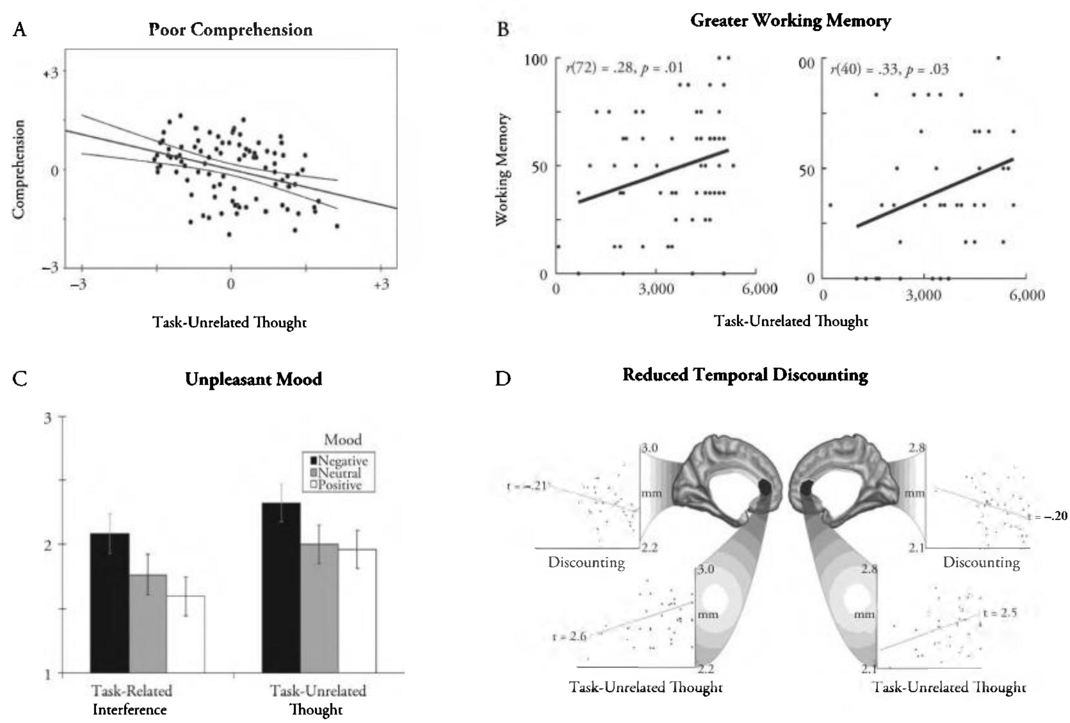

Figure 7.2. Heterogeneous functional outcomes linked to spontaneous thought.

Spontaneous Neurocognitive Activity Is Both Ubiquitous and Heterogeneous

A pivotal moment in our understanding of spontaneous thought occurred at the turn of the twenty-first century through the identification of a neural system, anchored on anterior and posterior regions of the medial surface of the cortex, which is often more active during baseline conditions relative to tasks depending on a concentrated focus on external input (Raichle et al., 2001). This system is now known as the *default mode network* (DMN), and its spatial distribution, as defined by its intrinsic behavior during a period of wakeful rest state, is presented in Figure 7.3. Regions that make up this network and include the medial prefrontal cortex, posterior cingulate cortex, the angular gyrus, and regions of the anterior temporal lobe and medial temporal lobe (including the hippocampus and parahippocampal gyrus). Subsequent to the identification of the DMN through meta-analysis, it was shown to be active during periods of spontaneous thought, as assessed using experience sampling (Allen et al., 2013; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Kucyi & Davis, 2014; Mason et al., 2007; Stawarczyk & D'Argembeau, 2015; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011; Tusche et al., 2014). It was also shown to be activated by tasks that mimic states that make a likely contribution to the experiential content of naturally occurring spontaneous thought, such as a focus on the self (Kelley et al., 2002; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004), imagining what may take place in the future (Schacter & Addis, 2007; Daniel L Schacter, Addis, & Buckner, 2007), or attempts to understand the thoughts and feelings of other people (Amodio & Frith, 2006).

Since the seminal work on the DMN, however, it is now known that it is wrong to equate this network with the spontaneous neurocognitive activity occurring at rest. Rather than being limited to regions of the DMN, spontaneous activity during wakeful rest is ubiquitous across multiple neural networks, and this activity is spatially indistinguishable from that which arises when performing a task. Figure 7.4 illustrates two recent examples of the whole brain nature of spontaneous neurocognitive activity. The left-hand panel shows the result of a statistical decomposition of resting state networks conducted by Yeo and colleagues, which identified seven canonical networks that include motor cortex, lateral prefrontal regions, and parietal and occipital cortex—regions known to be important in acting on the external environment (Yeo et al., 2011). The right-hand panel shows a decomposition of resting state data using independent component analysis (ICA) performed by Smith and colleagues, who demonstrated that these components were spatially similar to networks generated through the application of the same technique to a meta-analysis of task data (Smith et al., 2009). Crucially, as can be seen in this figure, the DMN is almost identical, regardless of whether it is identified through the application of ICA to task data or resting-state data.

Neuroimaging studies over the last decades, therefore, have implicated the DMN in conscious reports of spontaneous thought, while at the same time illustrating that spontaneous neural activity is a general property of how neural function is organized. The contrast between the seeming specificity of the DMN to spontaneous cognition,

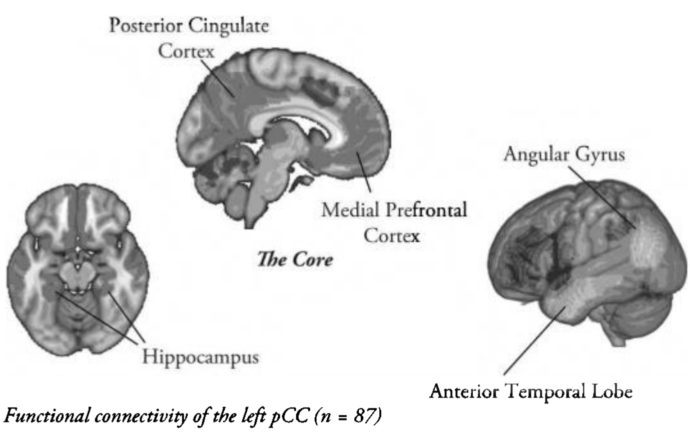

Figure 7.3. Spatial distribution of the core hubs of the default mode network. (See Color Insert)

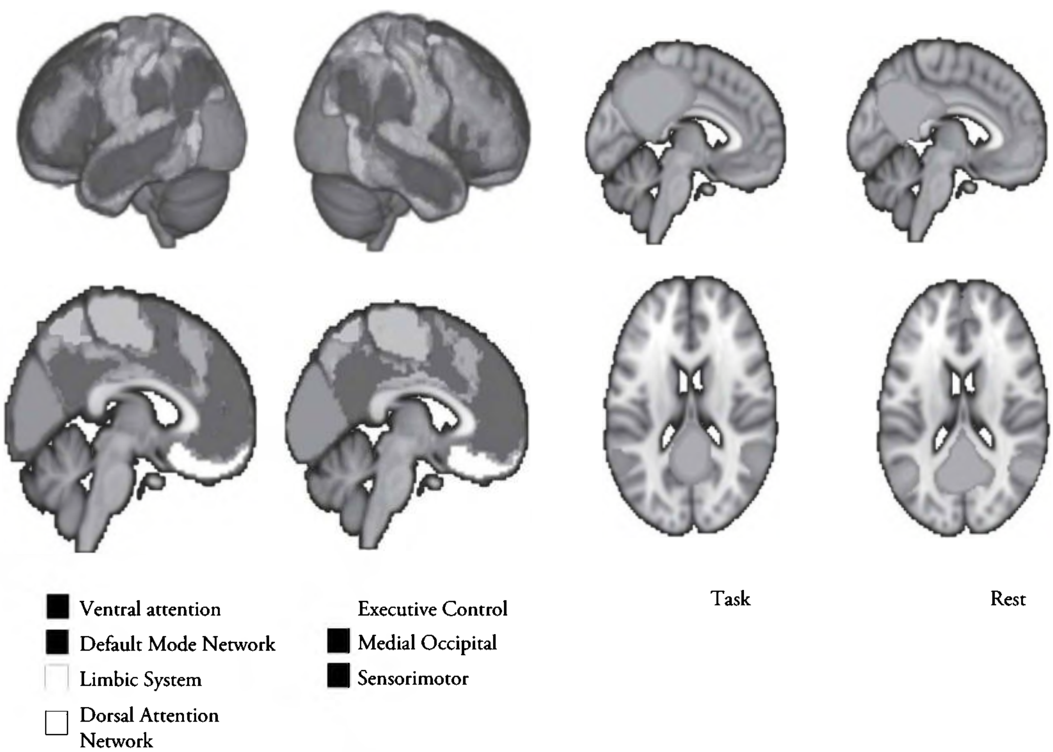

Figure 7.4. Default mode network as observed in tasks and at rest. (See Color Insert)

on the one hand, and the ubiquity of spontaneous activity in the cortex highlights, on the other, highlights that spontaneous conscious experience cannot be reduced to spontaneous neurocognitive activity since this would implicate regions of the cortex unlikely to be involved directly in conscious experience.

Interim Summary

Psychological investigations of spontaneous thought have demonstrated the complex and heterogeneous nature of this form of experience, and studies of the unconstrained brain have revealed that spontaneous neurocognitive activity is not a property of a single brain system, but rather a general property of neural functioning. Together, these two observations constrain formal scientific accounts of spontaneous thought in important ways. For example, conceptualizing spontaneous thought as a consequence of a simple *module* is clearly at odds with the evidence for the rich heterogeneous nature of spontaneous experience identified through psychological studies. Similarly, the argument that spontaneous conscious experience is a primary consequence of the *process* of spontaneous neurocognitive activity is inconsistent with the observation that these changes are not limited to the neural system that studies suggest is most important in spontaneous cognitive experience (i.e., the DMN).

Toward a Neurocognitive Component Process Account of Spontaneous Thought

The inability for simple modular or process accounts to provide a reasonable neurocognitive account of spontaneous thought highlights the need for a more complex treatment of the experience, and a starting point is a careful consideration of the information processing steps that take place when we generate a train of spontaneous thoughts (Smallwood, 2013a). Studies in Figure 7.1 illustrate that during spontaneous thought we often represent people, places, and events that are not present in the immediate environment, a phenomenon often described as mental time travel (Suddendorf & Corballis, 2007). This depends on retrieving internally stored representations that capture our memories of past episodes and our conceptual knowledge of the world, and attending to these rather than events in the here and now. Furthermore, our spontaneous experiences often form a coherent train of thought, suggesting that we may recombine and remodel representational information to allow new thoughts and experiences to emerge. In experiential terms, there seem to be at least three distinct elements of our conscious experience of spontaneous thought: (1) a focus away from the events in the here and now (*decoupling*); (2) the generation of mental content whose referent is absent from the environment (*representation*); and (3) the integration and evaluation of this information over time as the experiences evolves in a dynamic fashion (*coordination*).

Acknowledging that spontaneous thought depends on multiple distinct neurocognitive processes is the basis of what is known as the *component process account* of mental states (Smallwood, 2013a, 2013b; Smallwood & Schooler, 2015), which assumes that spontaneous conscious thought is produced through the flexible interaction of a number of underlying subsystems. Unlike a simple modular view, the component process account can explain the large variety of spontaneous thoughts that we can experience, since this type of architecture can support a greater number of states than there are components. Furthermore, since different experiential states would arise through differences in the way that information processing takes place, they would naturally give rise to different functional outcomes, and so the component process account can naturally explain why spontaneous thought has a complex suite of functional outcomes. Finally, since not all neural systems are equally important for conscious experience (e.g., Rees, Kreiman, & Koch, 2002), only spontaneous neurocognitive activity in a subset of neural systems should be linked to core aspects of spontaneous thought, explaining why many more cortical regions than those in the DMN exhibit organized spontaneous changes at rest.

In principle, therefore, a component process account of spontaneous thought can successfully explain key features of the empirical data because it provides an architecture in which heterogeneous experiential states naturally emerge through the variable combination of the components. The remainder of this chapter considers recent evidence that helps support scientific accounts of spontaneous thought by focusing on three specific questions regarding the neurocognitive basis of spontaneous thought:

1. What neurocognitive systems support the mental representations that form the content of spontaneous thought?
2. How do we flexibly organize information processing to allow a focus on internal rather than external sources of mental content?
3. How do we monitor, evaluate, or coordinate cognition during spontaneous thought?

The Default Mode Network Is Important for the Representational Content That Is Produced During Spontaneous Thought

A more nuanced exploration of the role of the DMN illustrates that it is active under task conditions, and understanding the task conditions in which it is activated provides an important constraint on its role in spontaneous thought. One view is that this network is important for the integration of representations (based on prior knowledge) that provide self-generated mental content (Andrews-Hanna, Smallwood, & Spreng, 2014). Advances in neuroimaging, including distortion-corrected imaging techniques (Binney, Embleton, Jefferies, Parker, & Lambon-Ralph, 2010; Visser, Jefferies, Embleton, & Lambon-Ralph, 2012) and tools for large-scale meta-analysis (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011), have led to the recognition that a number of tasks that depend on the processing of information from memory tend to activate regions in the DMN. For the purposes of illustration, Figure 7.5 shows the results of meta-analysis using the search tool Neurosynth (Yarkoni et al., 2011) for two task domains that depend on manipulating knowledge of the world—episodic and semantic memory. For comparison, functional connectivity analysis of the posterior cingulate activity is presented to represent the canonical DMN. There is substantial neural overlap in each map, as well as important differences. For example, all three spatial maps show regions of the anterior temporal lobe, angular gyrus, as well as the medial core of the DMN. The evidence of similarity between the DMN and these meta-analytic maps illustrates that the core network can be activated under conditions that require the processing of external information as part of a task. Since the DMN is activated by cognition that relies on our knowledge of the world as part of a task, it is parsimonious to assume that it plays the same role in spontaneous thought.

Reductions in Perceptual Processing During Spontaneous Thought

Figure 7.5 illustrates the spatial similarity between the neural activation that occurs during tasks and the organization of the DMN as observed at rest. If the

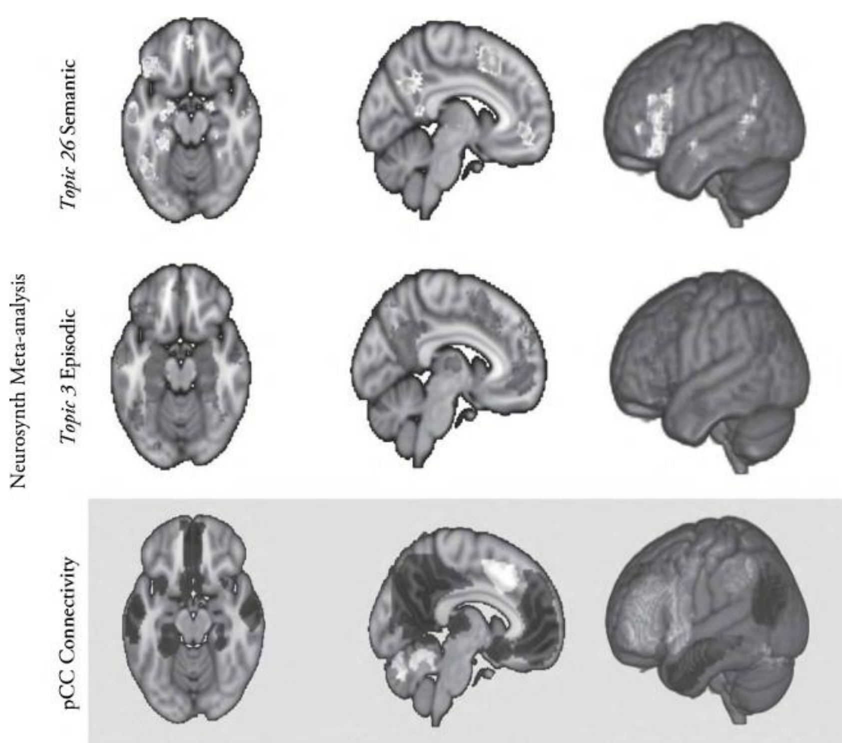

Figure 7.5. Relationship between the default mode network and the semantic and episodic systems. (See Color Insert)

DMN can be recruited under externally demanding conditions as well as during spontaneous thought, then there must be a mechanism that allows this system to generate cognition based on both external cues and intrinsic changes (Smallwood, 2013). It has been hypothesized that this ability to flexibly organize cognition to have an internal as opposed to an external focus is reflected in the process of *perceptual decoupling* known to occur during the mind-wandering state. Studies have shown that during periods of spontaneous thought, evoked responses to external stimuli are reduced, particularly in the visual domain (Baird, Smallwood, Lutz, & Schooler, 2014; Kam et al., 2011; Macdonald, Mathan, & Yeung, 2011; Smallwood, Beach, et al., 2008). This process is argued to lead to the neglect of external input, which can account for the enhanced errors that occur during periods of spontaneous thought (McVay & Kane, 2009, 2012b; McVay, Kane, & Kwapil, 2009; Smallwood, McSpadden, et al., 2008; Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Unsworth, & McMillan, 2013; Unsworth, McMillan, Brewer, & Spillers, 2012). It is also thought to reduce the likelihood that attention is focused on external input, facilitating attention to representations that are generated internally and so helping to preserve the integrity of spontaneous thought. Conceptually the phenomenon of perceptual decoupling can explain how the DMN can represent either information pertinent to an external task, or to a train of spontaneous thought, since under conditions when external input is reduced, it would be easier to devote attention to the internal environment.

Figure 7.6 presents neurocognitive evidence for perceptual decoupling during periods of spontaneous thought. A primary source of evidence that external events are neglected during the mind-wandering state is derived from electroencephalographic recordings during task performance. The upper left-hand panel shows studies demonstrating that electrical responses evoked by task are reduced during periods of spontaneous thought (Barron, Riby, Greer, & Smallwood, 2011; Kam et al., 2011). The lower left-hand panel illustrates that this reduction in evoked responses is attributable to changes in phase locking in the neural populations in regions of parietal and occipital cortex that are known to play an important role in the representation of visual information from the environment (Baird et al., 2014). The right-hand panel shows evidence from a functional magnetic resonance imaging (fMRI)

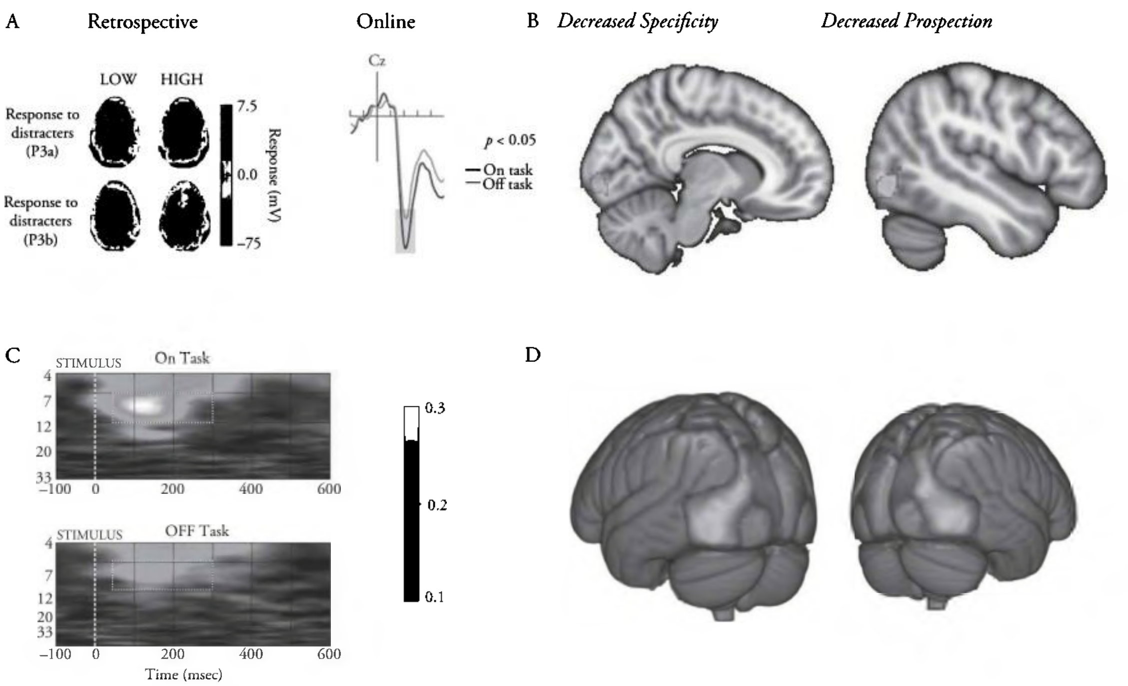

Figure 7.6. Evidence of perceptual decoupling during spontaneous thought. (See Color Insert)

study that found that individual differences in the intrinsic changes in regions of medial and lateral occipital cortex were associated with retrospective reports of different aspects of spontaneous thought (Gorgolewski et al., 2014). Together these studies show that elevated aspects of spontaneous thoughts are linked with reductions in evoked responses and intrinsic processing in visual or parietal cortex—observations that are compatible with the hypothesis that neglect of environmental input is important in allowing attention to be focused internally.

Focusing on Spontaneous Representations

Our spontaneous thought can often be focused on a specific topic, such as where to go for dinner with a friend, what type of holiday we might like to go on, or how we might be able to solve a work-related problem. Unlike a specific focus on external properties of the environment, a train of spontaneous thought cannot capitalize on the inherent organization of the stimuli in the environment to constrain cognition. Instead, intrinsic processes must be able to control the retrieval of information that is taking place to ensure that representations that are relevant to ongoing thought are generated. Task paradigms have highlighted that attending to memory depends in part on processes taking place in lateral parietal cortex (Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Ciaramelli, Grady, & Moscovitch, 2008).

Figure 7.7 illustrates evidence from both task-based studies and studies of spontaneous thought that implicate the temporoparietal cortical regions in governing the specificity of thought. For example, the application of transcranial magnetic stimulation to the left angular gyrus disrupted the speed with which participants made judgments of semantic association when the items were related at a specific level (Davey et al., 2015). A similar region in the right hemisphere was coupled to the medial prefrontal cortex for participants who exhibited high levels of meta-cognitive accuracy for semantic information from memory (Baird, Cieslak, Smallwood, Grafton, & Schooler, 2015; Baird, Smallwood, Gorgolewski, & Margulies, 2013). Similarity judgments when two items are strongly associated and subjective confidence in the voracity of episodic memory may both depend upon the capacity to access specific features of knowledge. The consequence of this region of cortex for task-related processing provides an important parallel for studies of spontaneous thought, which have observed more activity in a similar right hemisphere region for participants whose spontaneous thought content was more specified (Gorgolewski et al., 2014). Also, the left hemisphere homologue of this region was more

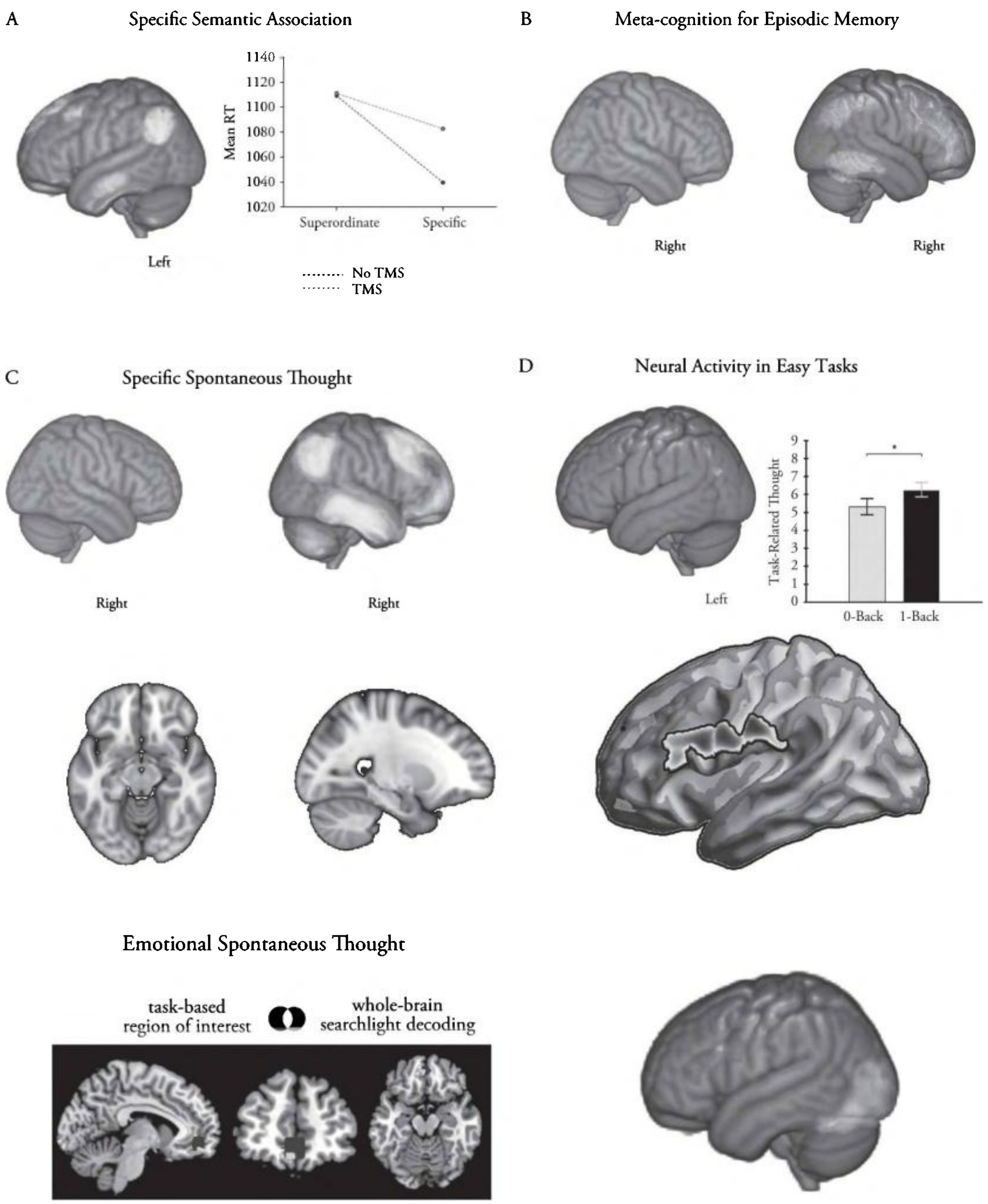

Figure 7.7. The role of parietal cortex in specific memory retrieval. (See Color Insert)

active in a non-demanding task in which spontaneous thought occurs more commonly (Konishi, McLaren, Engen, & Smallwood, 2015). Experience-sampling studies have shown that people who tend to engage in spontaneous thought under non-demanding conditions have greater executive control (Levinson, Smallwood, & Davidson, 2012) and a less impulsive style of decision-making (Bernhardt et al., 2014). Furthermore, studies have shown that the intensity with which participants imagine the outcomes of a decision-making process in which long-term and short-term opportunities must be contrasted leads to an increase in the likelihood that a more distant option was chosen (Benoit, Gilbert, & Burgess, 2011; Hakimi & Hare, 2015). Together these studies suggest that a mechanism in lateral parietal cortex might allow for more specific imaginary experiences, and which in turn could be important in determining functional outcomes that emerge from spontaneous cognition. Consistent with this view, it is well established that the parietal cortex is important in allocating attention to particular types of stimuli (Corbetta & Shulman, 2002).

Conclusions and Future Directions

This chapter has summarized evidence indicating that spontaneous thought can be conceived as emerging from the interaction of component processes that represent the building blocks of cognition. This perspective can easily accommodate the heterogeneity of spontaneous thought in terms of both content and functional outcomes, since both are a natural consequence of the fact of relative differences in the contribution of different component processes for different experiential states. It can also explain why spontaneous neurocognitive activity at rest is not a specific property of the DMN per se, since only those neurocognitive processes that are important for conscious experience would be readily linked to spontaneous conscious experience. The chapter has outlined a rudimentary set of component processes that together could explain the representation of information during spontaneous thought, how this is decoupled from the external environment, and how we are able to focus on this information in order to evaluate it in a specific manner. Although this provides basic support for the viability of a component process account of spontaneous thought, research in this area is still at a very early stage, not least because only a handful of studies have explored the brain correlates of spontaneous thought directly. It is therefore important to bear in mind that firm conclusions on either the specific nature of the neurocognitive components, or the manner with which they interact, are premature. Moving forward, there are a number of important questions that more specified component process accounts of spontaneous thoughts must address.

It is apparent from Figure 7.5, for example, that there are regions that are traditionally uncorrelated with the core of the DMN as defined by functional connectivity, which are nonetheless present in the meta-analytic maps of both semantic and episodic tasks. These regions include inferior regions of the lateral prefrontal cortex and the pre-supplementary motor area. One conclusion that can be drawn from this observation is that, at least under certain conditions, the DMN does not act in isolation, but instead cooperates with other large-scale networks to perform certain cognitive operations. There is now a growing body of task paradigms that have shown that this is indeed the case, including situations in which participants must plan their future (Gerlach, Spreng, Gilmore, & Schacter, 2011; Spreng, Gerlach, Turner, & Schacter, 2015; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010), and even demonstrations that these network interactions occur when a task demands memorial information to guide behavior in the context of a working memory task (Konishi et al., 2015; Spreng et al., 2014). One open question, therefore, concerns the functional significance of interactions between the DMN and other large-scale networks for spontaneous thought, particularly lateral prefrontal regions, as these regions are often uncorrelated with the DMN at rest (see also Fox et al., 2015).

A second important question is the extent to which it is possible to differentiate the DMN into a set of subsystems. The DMN has been successfully fractionated into a set of underlying components using both graph theoretical and meta-analytic tools (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010; Andrews-Hanna et al., 2014). It is possible that different aspects of the larger DMN serve different functions during spontaneous thought, suggesting that variation in the content or form of experiences during spontaneous thought may depend on the differential involvement of particular aspects of the larger DMN. One way that this question could be addressed would be through combining MDES with simultaneous measures of neurocognitive function. This would help determine whether the differences between different types of spontaneous thoughts result from differences in neural activation in different aspects of the DMN.

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PART III

Philosophical, Evolutionary, and Historical Perspectives

CHAPTER

8 The Philosophy of Mind-Wandering

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Abstract

This chapter provides an introduction to the philosophy of mind-wandering. It begins with a philosophical critique of the standard psychological definitions of mind-wandering as task-unrelated thought or stimulus-independent thought. Although these definitions have helped bring mind-wandering research onto center stage in psychology and cognitive neuroscience, they have substantial limitations. They do not account for the dynamics of mind-wandering, task-unrelated thought that does not qualify as mind-wandering, or the ways in which mind-wandering can be task-related. The chapter reviews philosophical accounts that improve upon the current psychological definitions, in particular an account of mind-wandering as "unguided thinking." It critically assesses the view that mind-wandering can be defined as thought lacking meta-awareness and cognitive agency, as well as the view that mind-wandering is disunified thinking. The definition of mind-wandering as unguided thinking not only is conceptually and phenomenologically precise, but also can be operationalized in a principled way for empirical research.

Key Words: mind-wandering, psychology, neuroscience, cognition, task-unrelated thought, stimulus-independent thought, mental action

Before the twenty-first century, research on the wandering mind was "relegated to the backwaters of mainstream empirical psychology" (Smallwood & Schooler, 2006, p. 956). Not anymore. Indeed, some researchers have dubbed our time "the era of the wandering mind" (Callard, Smallwood, Golchert, & Margulies, 2013). Nevertheless, because the cognitive science of mind-wandering is so young, foundational questions remain unanswered. In particular, there is no consensus about how to define mind-wandering (Christoff, 2012; Irving, 2016), although recent philosophical work on mind-wandering has addressed this foundational issue (Carruthers, 2015; Dorsch, 2015; Irving, 2016; Metzinger, 2013, 2015; Sutton, 2010; Thompson, 2015). In this chapter, we provide an introduction to the philosophy of mind-wandering, and we argue that mind-wandering is best defined as "unguided thinking" (Irving, 2016).

We begin by criticizing the standard definitions of mind-wandering in psychology, according to which mind-wandering is "task-unrelated thought" or "stimulus-independent thought" (see Irving, 2016). Scientists have used these definitions to produce important findings and bring mind-wandering into center stage in psychology and cognitive neuroscience (Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011; Smallwood & Schooler, 2006, 2015). Nevertheless, these definitions have substantial limitations that must be overcome in order for research to move forward. Specifically, the standard definitions do not account for (1) the dynamics of mind wandering, (2) task-unrelated thought that does not qualify as mind-wandering, and (3) the ways that mind-wandering can be task-related.

We then survey three philosophical accounts that improve upon the current psychological definitions in various ways. We first present our account of mind-wandering as "unguided thinking" (Irving, 2016). Next, we review Thomas Metzinger's (2013) view that mind-wandering can be defined as thought lacking meta-awareness and cognitive agency, as well as Peter Carruthers's (2015) and Fabian Dorsch's (2015) definitions of mind-wandering as disunified thinking. We argue that these views are inadequate, and we show that our definition of mind-wandering as unguided thinking not only is conceptually and phenomenologically precise, but also can be operationalized in a principled way for empirical research.

Mind-Wandering as Task-Unrelated Thought or Stimulus-Independent Thought

Experientially, we all know mind-wandering when we see it. On the commute home, a programmer's thoughts drift away from the sights and sounds of the subway car. At first she imagines the chicken she is brining for dinner. She can almost taste the thyme and rosemary when, suddenly, a line of code pops into her head. She plays with the code for a while, and then, smiling, remembers a joke she heard today . . . and so on. Clearly, the programmer's mind is wandering. But what exactly makes her train of thought a case of mind-wandering? What precisely is mind-wandering?

Scientists in the empirical literature typically define mind-wandering as thought that is "task-unrelated" or "stimulus-independent," or both. For example, Smallwood and Schooler define mind-wandering as "a shift in the contents of thought away from an ongoing task and/or from events in the external environment to self-generated thoughts and feelings" (Smallwood & Schooler, 2015, p. 488). This definition correctly identifies paradigm cases of mind-wandering. For example, the programmer's wandering thoughts are unrelated to her ongoing task—commuting home—and to her external environment—the subway car.

Nevertheless, this definition abstracts away from a central feature of mind-wandering, namely, its *dynamics* (Christoff, 2012; Irving, 2016). Wandering trains of thought unfold in a distinctive way over time. Experientially, the thoughts seem to drift freely from one topic (a line of code) to another one (a joke). Irving (2016) notes that the term "mind-wandering" reflects these dynamics: according to the *Oxford English Dictionary* (online), "to wander" means "to move hither and thither without fixed course or certain aim." The preceding definition of mind-wandering, however, focuses only on individual mental states and seeks to determine whether their content is related to one's task or environment. This focus tells us nothing about how trains of thought unfold over time. As we now argue, this definition of mind-wandering in static terms is unsatisfactory in two ways: it cannot differentiate between mind-wandering and other kinds of task-unrelated and stimulus-independent thought; and it cannot account for the fact that mind-wandering can be task-related.

Varieties of Task-Unrelated Thought

Current definitions of mind-wandering cannot distinguish it from depressive rumination, which is typically task-unrelated and stimulus-independent, but which has dynamics that fundamentally differ from that of mind-wandering (Irving, 2016).

Rumination is "a mode of responding to distress that involves repetitively and passively focusing on symptoms of distress and on the possible causes and consequences of these symptoms. . . . People who are ruminating remain fixated on the problems and on their feelings about them" (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Rumination is strongly associated with major depressive disorder, but also is found in the normal population (Zetsche & Joormann, 2011). For example, a non-depressed teacher might ruminate about how to discipline a problem student.

Rumination is frequently task-unrelated and stimulus independent. For example, when a teacher ruminates about a problem student during her commute home, her thoughts are unrelated to her current task (commuting home) and perceptual environment (the subway train). Current researchers, therefore, classify rumination as a form of mind-wandering (e.g., Smallwood & Schooler, 2006, 2015).

Rumination, however, seems antithetical to mind-wandering. Consider the ruminating teacher in contrast to the programmer whose mind is wandering. Both individuals have task-unrelated and stimulus-independent thoughts on their commute home. But the dynamics of their thoughts could hardly contrast more: whereas the teacher's thoughts fixate on her problem student, the programmer's thoughts drift from dinner to her computer code to a joke. In general, whereas rumination remains fixed on a single topic, mind-wandering drifts from one topic to the next. One has not wandered—"moved hither and thither"—if one has stayed on a single spot.

Mind-Wandering and Goal-Directed Thought: A Dilemma

Current definitions of mind-wandering face a dilemma concerning the relationship between mind-wandering and cognitive tasks. On the one hand, if we say that all stimulus-independent thinking is mind-wandering, then some mind-wandering will be task-related, because some stimulus-independent thinking is goal-directed. On the other hand, if we say that mind-wandering must be task-unrelated thinking, then we run afoul of empirical evidence that suggests that mind-wandering can be task-related. Let us explain each alternative and its problems in turn.

Suppose we define mind-wandering as any and all stimulus-independent thought. Smallwood and Schooler adopt this view, because they define mind-wandering as "a shift in the contents of thought away from an ongoing task and/*or from events in the external environment*" (2015, p. 488, emphasis added). According to the most restrictive conception in the literature, stimulus-independent mental states not only are non-perceptual states, but also are unrelated to any immediately present perceptual stimuli (Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011). For example, imagining or thinking about kicking the pigeon in front of you would not count as a stimulus-independent thought, but rather as a stimulus-related thought. Similarly, in a visual detection experiment, thinking "these pictures are flashing by too quickly," would count as a stimulus-related thought, not a stimulus-independent one. Nevertheless, even this restricted specification of what is required for a thought to be stimulus-independent—that it be a non-perceptual state unrelated to any immediately present perceptual stimuli—classifies much of our goal-directed thought as stimulus-independent and hence (counterintuitively) as mind-wandering.

Consider a mathematician solving a proof in her head or a politician rehearsing a speech under her breath. Both women have thoughts unrelated to their external environments, so they count as mind-wandering, despite their thinking being goal-directed. The problem is that one's thoughts cannot *wander*—"move hither and thither without fixed course or certain aim"—if they are directed by a goal. Indeed, theorists at least since Thomas Hobbes (1651) have defined mind-wandering by contrasting it to goal-directed cognition. In one of the first European philosophical discussions of mind-wandering, Hobbes states that thoughts that "wander . . . seem impertinent to each other, as in a Dream" (1651, p. 20). In contrast, he wrote that goal-directed thinking is "more constant; as being regulated by some desire, and designe. For the impression made by such things as wee desire, or feare, is strong and permanent, or, (if it cease for a time,) of quick return" (1651, pp. 20–21).

To distinguish mind-wandering from goal-directed thought, we could maintain that all mind-wandering is task-unrelated thought. According to this conception, neither the mathematician thinking about her proof nor the politician thinking about her speech is mind-wandering, because both are thinking about a task.

But now we face the second horn of the dilemma: *Some mind-wandering is task-related* (Irving, 2016). Consider our vignette of a programmer whose mind is wandering on her commute home. Her thoughts drift to two personal goals—making dinner and writing code. Empirical evidence indicates that our minds often wander in this way to personal goals (Klinger, 1999). Indeed, one study reported that at least 25% of a person's wandering thoughts are about a "specific goal (defined as an objective or desired result that an individual endeavors to achieve)" (Baird, Smallwood, & Schooler, 2011, p. 1606). Another study found similar results with an experimentally induced goal. Participants were told that they would be quizzed on the names of US states after a "concentration task" (Morsella, Ben-Zeev, Lanska, & Bargh, 2010). When participants had this goal, approximately 70% of their wandering thoughts were about geography (especially US state names). In contrast, the minds of participants in control conditions wandered to geography less than 10% of the time. This finding suggests that goals *cause* our minds to wander to goal-relevant information.

To see how such findings bear on the current definitions of mind-wandering, we must consider how "task-unrelated" is defined in the scientific literature. Laboratory studies define mind-wandering as thought that is unrelated to the experimental task (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). So far, so good: thoughts about personal goals such as making dinner are unrelated to the experimental task, and so correctly count as mind-wandering.

In studies of "real-world" mind-wandering outside the lab, however, "tasks" are operationally defined as *whatever the person is currently doing*. For example, participants are asked whether "my mind had wandered to something *other than what I was doing*" (Kane et al., 2007, p. 616, emphasis added), or "are you thinking about something other than *what you're currently doing*?" (Killingsworth & Gilbert, 2010, p. 932, emphasis added).

Here is the problem. *What you are doing* often includes working toward the personal goals to which your mind wanders. For example, if we ask you, "what are you doing?" it would be natural for you to answer, "planning dinner" or "preparing for a test." Therefore, rather than supposing that mind-wandering is task-unrelated thought, we could argue that individuals switch tasks when their minds begin to wander. According to this view, when the programmer's mind wanders to computer code on the commute home, her task switches to coding from watching for her subway stop. Relative to the new task of coding, her thoughts about code count as task-related.

We can now bring the dilemma into full view. On the one hand, if we say that any and all stimulus-independent thought is mind-wandering, then we muddy the distinction between mind-wandering and goal-directed thinking. On the other hand, if we try to hold onto this distinction by supposing that mind-wandering must be task-unrelated thinking, then we contradict the empirical evidence that shows that task-related mind-wandering is not only possible but frequently actual.

Our diagnosis of the dilemma highlights the dynamics of mind-wandering. The distinction between mind-wandering versus goal-directed thinking does not concern whether *mental states* are task-unrelated or stimulus-independent. Rather, the distinction concerns how *trains of thought unfold over time*. When a mathematician solves a problem in her head, she maintains her attention on this problem for a prolonged period of time. In contrast, wandering thoughts "move hither and thither," drifting between topics unchecked. Because current definitions of mind-wandering abstract away from its dynamics, they cannot distinguish mind-wandering from either rumination or goal-directed thinking. We now propose a theory that overcomes these limitations: mind-wandering is unguided thinking (Irving, 2016).

Mind-Wandering Is Unguided Thinking

We define mind-wandering as unguided thinking. This definition depends on a particular concept of *guidance* taken from the philosophy of action. Thought or behavior is said to be guided when it is monitored and regulated as it unfolds over time (Pacherie, 2008; Railton, 2006). Harry Frankfurt provides a classic philosophical explanation of guidance:

> Behavior is purposive when its course is subject to adjustments which compensate for the effects of forces which would otherwise interfere with the course of the behavior. . . . This is merely another way of saying that their course is guided. (Frankfurt, 1978, pp. 159–160)

According to this account, "guidance" includes as part of its meaning a counterfactual aspect. To say that behavior is guided implies the following: Were one's behavior to go off course or deviate from some standard—as a result, for example, of interfering forces—one would alter that behavior in order to bring it back on course. In other words, as Frankfurt states, guidance implies adjusting behavior to compensate for deviations. Thus the concept of guidance also includes a normative aspect: It implies the monitoring and correcting of behavior in relation to some norm or standard. For example, consider conversational interaction. In a conversation, you are guided to maintain a certain distance from your partner, for were your partner to stand too close to you, you would feel discomfited and drawn to step back (Brownstein & Madva, 2012). In other words, your behavior is guided in the sense that it compensates for deviations from the (culturally specific) standards or norms of conversation. It follows that for behavior to be guided, there must be regulatory processes for bringing "deviant" behavior back on track.

We use this technical concept of guidance in order to specify what it means for thought to be guided. We propose that one's thinking is guided only if one would feel pulled back to its topic, were one distracted from that topic. We also suppose that thinking can be guided in a variety of ways. Our thoughts can be guided back to goal-relevant information, as happens when we are goal-directed, or guided back to affectively salient information, as happens when we ruminate. Although different neurocognitive processes may underlie these two kinds of thinking, we argue that both kinds implement guidance in our technical sense.

Consider goal-directed thinking. In goal-directed thinking, one would feel pulled back to pursuing the goal were one to focus on information that seems irrelevant to it. Imagine a mathematician intently constructing a proof in a busy library. Her attentiveness manifests partly in how her attention is guided back from distractors. Were she to become momentarily distracted by students shuffling their papers, she would likely feel frustrated and pulled

Table 8.1 Varieties of Guided Thinking

	Goal-Directed Thinking	Rumination
Guided toward	Goal-relevant information	Distress, etc.
Implemented thought	Cognitive control	Affective biases
Voluntary	Yes	Often not
Guided	***Yes***	***Yes***
Dynamically stable	***Yes***	***Yes***

back to her work. Thus her mental activity is guided in its being regulated in relation to her goal.

We hypothesize that rumination also is guided. We predict that individuals who break away from their ruminative thoughts will feel pulled or drawn back to them. For thinking to be pulled or drawn back to a particular focus in this way is precisely for it to be counterfactually regulated and thus guided.

Our hypothesis that rumination is guided does not entail that it has the same psychological and neural profile as goal-directed attention (Table 8.1). On the contrary, as mentioned earlier, the genus "guided thought" allows for different species of guided thinking that are subserved by different brain processes. For example, top-down cognitive control processes appear to be largely responsible for the guidance of goal-directed thought (e.g., Corbetta & Shulman, 2002; Kane & Engle, 2002), whereas affective biases of attention and memory (Todd, Cunningham, Anderson, & Thompson, 2012) likely play a strong role in one's being guided toward ruminative thoughts. Furthermore, goal-directed attention is paradigmatically voluntary, whereas rumination typically is involuntary. The ruminator might complain, "I don't want to think about distressing thoughts; they just keep pulling me back in." Nevertheless, we propose that rumination and goal-directed attention are both guided in our technical sense: in either case, if individuals were mentally distracted from their current focus, they would feel their thoughts pulled back to it.

That goal-directed thought and rumination are both guided explains why both kinds of thinking are dynamically stable. Our thoughts remain fixed on a restricted set of information because they are guided to remain there.

In contrast, we define mind-wandering as unguided thinking (Irving, 2016). Whereas a guided thinker would feel pulled back if she were distracted from her current focus, an unguided thinker wanders from one topic (dinner) to another (computer code); her mind drifts unchecked, with nothing to pull her back to a particular focus.

This lack of guidance explains why mind-wandering has an itinerant or unstable dynamics rather than a stable dynamics. Thoughts drift from topic to topic because nothing holds them in place. Thus our definition captures the dynamics of mind-wandering. Moreover, we provide a principled way to distinguish between different varieties of task-unrelated and stimulus-independent thought: in rumination, thoughts are guided to remain on the same topic and hence exhibit greater dynamical stability, whereas in mind-wandering, thoughts are unguided and hence exhibit greater dynamical instability.

Our account avoids the earlier-mentioned dilemma arising from the possibility of task-related mind-wandering. Recall that both wandering thoughts and goal-directed thoughts can be related to everyday tasks, such as planning dinner or writing computer code. Because of this possibility, current definitions of mind-wandering cannot properly distinguish it from goal-directed thinking. According to our account, the difference between them concerns how trains of thought are guided as they unfold over time. Goal-directed thinking is guided to remain on the same topic (e.g., writing code). Mind-wandering is unguided, so it is free to drift from one topic to the next. Its dynamics are unguided even when one's mind wanders to a personal goal (such as writing computer code). The crucial point is that if one's thoughts were to drift onward (e.g., to a joke one heard today), one would not be drawn back to a particular focus.[1]

Our definition of mind-wandering as unguided thinking overcomes the limitations of previous definitions in the empirical literature. Our definition is based on an account wherein stretches of mind-wandering consist of trains of thought whose dynamics are unguided. This account, however, is not the only account of mind-wandering in the philosophical literature. We will now review two other accounts and critically assess them in relation to our own.

Mind-Wandering as Thought Lacking "Veto Control"

Thomas Metzinger (2013; see also Metzinger, Chapter 9 in this volume) proposes a theory of mind-wandering that helps to explain the relationship between mind-wandering and cases of goal-directed thinking, such as a mathematician constructing a proof.[2] Metzinger allows that mind-wandering can be goal-directed, and so his theory can accommodate the evidence that our minds frequently wander to our personal goals. Nevertheless, he maintains that mind-wandering differs from fully "autonomous" forms of goal-directed thinking, such as a mathematician consciously constructing a proof. In Metzinger's view, goal-directed thinking is "mentally autonomous" only if one has the kind of cognitive control over one's thoughts that he calls "veto control."

The concept of "veto control" comes from cognitive science. It refers to the person's ability to "withhold a . . . [behavior][3] whose preparation and path towards execution has already begun" (Filevich, Kühn, & Haggard, 2012, p. 1108). Consider the following example in which you exercise veto control:

> You are posting a letter, and are just about to release your grip on it and let it fall into the post box, when you suddenly get the feeling that you should check whether you put a stamp on the envelope. You tighten your grip and inspect the letter. (Filevich et al., 2012, p. 1108)

Note that you would have possessed veto control even if you had released the letter, because veto control requires only that you are able—and know that you are able—to suspend the relevant behavior (Metzinger, 2013, p. 4).

Metzinger argues that when our minds wander, we lack veto control over our thoughts. Thus he distinguishes mind-wandering from autonomous goal-directed thinking that we can suspend at will—for example, consciously constructing a math proof. In support of this view, Metzinger appeals to evidence that mind-wandering unfolds without meta-awareness (Schooler et al., 2011).[4] "Meta-awareness" is defined as one's explicit knowledge of the current contents of thought or one's current conscious state (Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011). Thus meta-aware mental states are higher-order mental states that are about one's ongoing or just past mental states. One example is a lucid dreamer's meta-awareness that she is dreaming (see Windt and Voss, Chapter 29 in this volume). Another example is the sudden realization that your mind was wandering.

Metzinger's argument has two premises. First, meta-awareness is necessary for veto control over a mental state or process (Metzinger, 2013, p. 3): A person cannot knowingly terminate something of which she is unaware. (Suppose I discover that you were not paying attention and I ask, "Why didn't you stop your mind from wandering earlier?" You might reasonably respond, "I didn't know my mind was wandering until just now.") Second, Metzinger contends that whenever a person's mind is wandering, she lacks meta-awareness of her wandering thoughts. From these two premises, it follows that people lack veto control over their wandering thoughts. Thus, Metzinger's account suggests that mind-wandering can be defined as thinking that lacks meta-awareness and veto control.

The problem with this account is that the second premise—that mind-wandering always occurs without meta-awareness—is questionable. The evidence suggests that although mind-wandering sometimes occurs without meta-awareness, this is not always the case (Christoff et al., 2009; Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011; Smallwood & Schooler, 2006). Many studies of mind-wandering use self-reports to assess meta-awareness. Individuals who catch themselves mind-wandering or who report that their minds were wandering upon being probed are asked whether they were previously aware that their mind was wandering. For example, Smallwood and colleagues gave participants the following instructions in order to distinguish between aware ("tuning out") versus unaware ("zoning out") mind-wandering:

> *Tuning Out*: Sometimes when your mind wanders, you are aware that your mind has drifted, but for whatever reason you still continue to read. This is what we refer to as "tuning out"—i.e., when your mind wanders and you know it all along.
>
> *Zoning Out*: Other times when your mind wanders, you don't realize that your thoughts have drifted away from the text until you catch yourself. This is what we refer to as "zoning out"—i.e., when your mind wanders, but you don't realize this until you catch it. (Smallwood, McSpadden, & Schooler, 2007, p. 533)

Across all conditions, Smallwood and colleagues found that tuning out occurred as frequently or more frequently than zoning out. Therefore, it may be that mind-wandering occurs at least as often with meta-awareness as without it (cf. Smallwood et al., 2004; Smallwood, Beach, Schooler, & Handy, 2008).

Metzinger argues that cases of apparently autonomous mind-wandering involve the mere "illusion of control" (Metzinger, 2013; cf. Schooler et al., 2011), so he might question the reliability of reports of "tuning out" (mind-wandering with awareness). Nevertheless, tuning out and zoning out have different behavioral and neural profiles (Schooler et al., 2011). For example, compared to tuning out, zoning out is associated with better reading comprehension (Smallwood et al. 2008) and more activation of default network and executive regions (Christoff et al. 2009) that are generally associated with mind-wandering (Fox et al. 2015). It is not clear how to explain these differences, if reports of tuning out are entirely illusory.

Another limitation of Metzinger's theory is that it neglects the dynamics of mind-wandering. Veto control and the presence versus absence of meta-awareness have no essential connection to how one's thoughts unfold over time, according to his account. Therefore, his account cannot distinguish mind-wandering from rumination. Ruminators often seem to lack meta-awareness and hence veto control over their thoughts. For example, a commuter might fixate on her problems and distress without realizing that she has stopped watching for her subway stop. Because she is unaware that she has begun to ruminate, she cannot disengage from (veto) her distressing thoughts and bring herself back on task. Indeed, trait ruminators show impaired disengagement across a range of tasks (Whitmer & Gotlib, 2013). This finding suggests that rumination frequently unfolds without veto control. Metzinger's theory does not have the resources to explain how mind-wandering differs from this antithetical phenomenon of rumination.

Our account of mind-wandering as unguided thinking therefore has two advantages over Metzinger's account (Irving, 2016, pp. 567–568). First, we allow that mind-wandering can unfold with or without meta-awareness. During cases of tuning out—"when your mind wanders and you know it all along" (Smallwood et al., 2007, p. 533)—we propose that you have meta-awareness of and thus veto control over your stream of unguided thoughts. Second, our account captures the dynamics of mind-wandering. Accordingly, we can explain how rumination and mind-wandering differ: Whereas the former is guided, the latter is not.

Mind-Wandering as Disunified Thinking

Peter Carruthers (2015) and Fabian Dorsch (2015) independently have proposed accounts of mind-wandering that rival the explanatory power of our own account. We focus on Carruthers's theory, but our critical discussion applies to both philosophers. Carruthers discusses mind-wandering because it provides an apparent counterexample to his view that all thinking is active and goal-directed. He concedes that mind-wandering does "not seem, introspectively, to be active in nature. Sometimes one's thoughts change direction for no apparent reason (especially when one's mind is wandering)" (Carruthers, 2015, p. 166). Therefore, he must explain away the apparent difference between mind-wandering and goal-directed thought.

Carruthers explains away this apparent difference by drawing an analogy between mind-wandering and wandering around a garden: "Mind wandering is active, I suggest, in much the same sense that someone physically wandering around in a garden is active" (Carruthers, 2015, pp. 167–168). Dorsch (2015) draws a similar analogy between mind-wandering and physically wandering around a city. Both philosophers maintain that short stretches of physical and mental wandering are active. As you wander around a garden you might actively smell a rose or wish upon a dandelion. Similarly, you might actively plan dinner or write code while your mind wanders. Nevertheless, longer stretches of physical and mental wandering seem passive because no overarching goal unifies your thoughts. Given this point, Carruthers and Dorsch can explain away the apparent difference between mind-wandering and paradigm cases of goal-directed thought, such as a mathematician solving a proof in her head. Whereas the mathematician's thoughts are all unified under a single goal (solving the proof), the mind-wanderer's thoughts concern many goals (planning dinner, writing code, and so on). Thus mind-wandering seems more passive than goal-directed thought, though both are active when we look at them closely enough.

Carruthers's and Dorsch's discussions suggest that mind-wandering be defined as disunified thinking. A sequence of thoughts constitutes mind-wandering if and only if those thoughts are not unified under a common goal. This definition has major advantages. First, it captures the dynamics of mind-wandering: by definition, our wandering thoughts are dynamically unstable in the sense that they are not unified under a common goal. Second, this definition can account for the puzzling relationship between mind-wandering and goal-directed thought. On the one hand, short stretches of mind-wandering are related to tasks (such as preparing for a quiz), as the empirical evidence suggests. On the other hand, mind-wandering contrasts with goal-directed thinking because it is disunified.

Despite the advantages of this conception of mind-wandering, it has a problematic consequence, which we can bring out in the following example. Imagine someone who works for 10 minutes composing part of a lecture, then opens his web browser and responds to some emails for 6 minutes, and then looks outside the window, studying the pigeons across the street for 90 seconds. Furthermore, suppose that the person attentively pursues each goal. Nevertheless, no overarching goal unifies this whole sequence of thoughts, so they count as mind-wandering. Shifting from goal to goal in this way seems commonplace. Therefore, if we define mind-wandering as disunified thinking, most trains of goal-directed thinking will count as mind-wandering. But then it seems that Carruthers and Dorsch have not captured the difference between mind-wandering and goal-directed thinking at all.

A deeper problem lurks in the vicinity. Whether thinking counts as disunified, and thus as mind-wandering, depends on the scale of observation or how far we zoom out (Figure 8.1). Suppose we examine the person's thoughts in the previous example. In the first five minutes, his attention is wholly guided by the goal of composing his lecture. During that interval, his attention is unified and his mind is not wandering. But if we zoom out to a seventeen-minute interval, we find thoughts about three separate goals—composing a lecture, writing emails, and watching pigeons. From this broader perspective, his attention is disunified and his mind is wandering. The problem is that we lack principled reasons for deciding how far to zoom out, and therefore we lack principled reasons for saying whether his mind is wandering at any given point in time.

This consequence undermines the scientific methods we use to study mind-wandering. These methods require that we be able to specify when the mind is wandering versus when it is not, so that

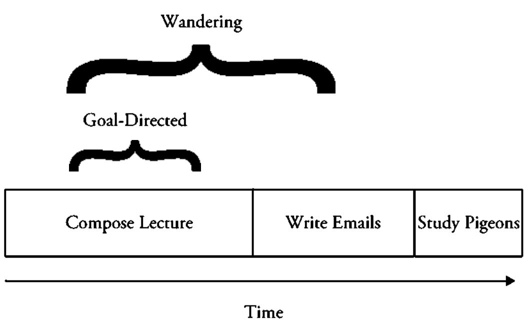

Figure 8.1. Disunity and zoom.

we can study the distinctive features of MIND-WANDERING (such as ITS contents and neural correlates) versus other kinds of THINKING. For example, Christoff et al. (2009) compared neural activation when individuals were concentrating on a task versus mentally wandering away from it. If we define mind-wandering as disunified thinking, then we cannot use these methods, because if we zoom out, then the on-task thoughts are probably going to count as wandering thoughts. No methodological innovation could solve this problem. In other words, given the definition of mind-wandering as disunified thinking, there will be no principled way to distinguish mind-wandering from goal-directed thought. Therefore, this definition is a non-starter for the cognitive science of mind-wandering.

In contrast, our definition of mind-wandering as unguided thought does not face these problems. We provide a principled way to distinguish goal-directed and wandering thought: The former is guided; the latter is not. Therefore, our definition is preferable on conceptual grounds as well as being more amenable to empirical investigation.

Conclusion

Psychologists, cognitive neuroscientists, and philosophers should be partners in the scientific investigation of mind-wandering. The challenges facing this young field are not only empirical, but also conceptual and theoretical. Our chapter begins with a philosophical critique of the most widely accepted definitions of mind-wandering in cognitive psychology. This critique stems from the idea that mind-wandering is fundamentally dynamic. Our definition uses the technical philosophical notion of "guidance" to capture its dynamics. Compared to the other extant philosophical definitions, our definition of mind-wandering as unguided thought is not only more theoretically defensible, but also more scientifically tractable. Putting this definition to work in cognitive science will require close collaborations with psychologists and cognitive neuroscientists. For example, difficult questions remain about how to measure the dynamics of mind-wandering (Christoff, 2012) and how to relate the philosophical notion of guidance to dynamical neural networks and psychological processes (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). The path forward requires that psychologists, cognitive neuroscientists, and philosophers work together to advance our understanding of mind-wandering.

Notes

1. One might worry that our view characterizes mind-wandering as *too disordered.* Although mind-wandering is certainly *less* stable than goal-directed or ruminative thought, our wandering thoughts are not entirely random: for example, our minds often wander to personal goals and concerns (as noted earlier) and between associated thoughts. For similar reasons, we elsewhere propose a neuroscientific model on which the dynamics of mind-wandering are somewhat constrained, albeit less so than goal-directed or ruminative thoughts (Christoff, Irving, et al., 2016). Fortunately, our philosophical model of mind-wandering is compatible with the presence of dynamic constraints on mind-wandering. This is because guidance is not the only way that thought can be constrained. Mind-wandering can be *probabilistically* constrained, in that we *often* think of particular things (e.g., close associations, personal goals and concerns). Yet we contend that when the mind wanders, no guidance mechanism holds our thoughts in place; when the mind wanders to unusual ideas, or from one topic to another, nothing pulls us back. See Irving (2016) for an in-depth discussion of the different types of constraints on thought, including those that are present and absent during mind-wandering.
2. Much of the material for this section is adapted from Irving (2016).
3. Filevich and colleagues originally defined "veto control" as the ability to "withhold an action." We have changed the definition, replacing "action" with "behavior," because veto control arguably is necessary for action (as opposed to mere movement). In that case, defining "veto control" as the ability to withhold an action would trivially imply that one never lacks veto control.
4. Thus Metzinger expands upon Smallwood and Schooler's (2006) thesis that mind-wandering differs from goal-directed thought because the former always begins without meta-awareness.

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CHAPTER

9 Why Is Mind-Wandering Interesting for Philosophers?

Thomas Metzinger

Abstract

This chapter explores points of contact between philosophy of mind and scientific approaches to spontaneous thought. While offering a series of conceptual instruments that might prove helpful for researchers on the empirical research frontier, it begins by asking what the explanandum for theories of mind-wandering is, how one can conceptually individuate single occurrences of this specific target phenomenon, and how one might arrive at a more fine-grained taxonomy. The second half of this contribution sketches some positive proposals as to how one might understand mind-wandering on a conceptual level, namely, as a loss of mental autonomy resulting in involuntary mental behavior, as a highly specific epistemic deficit relating to self-knowledge, and as a discontinuous phenomenological process in which one's conscious "unit of identification" is switched.

Key Words: mental autonomy, mind-wandering, philosophy of mind, self-knowledge, consciousness, mental behavior, unit of identification

The main goal of this chapter is to isolate and draw attention to a number of conceptual issues in the now burgeoning empirical literature on mind-wandering. This is only a first outline of such issues and is not intended to be an exhaustive list. However, I am convinced that such philosophical questions are not only relevant, but that—on a different level of analysis—they may reveal potentially rewarding targets for future research. One way to view philosophy of mind is as a *meta-theoretical* enterprise: While first-order experimental work tries to get as close as possible to the target phenomenon itself, the second-order theoretical work of philosophers focuses on methodological issues and the conceptual structure of first-order, data-driven theories. A philosophical approach will therefore mostly be not about mind-wandering itself, but rather about the *concepts* that we use and develop to understand it. In practice, of course, both levels of investigation are deeply intertwined; empirical researchers have a strong interest in methodological issues and a tendency to make implicit conceptual background assumptions, while philosophers may not only offer novel conceptual instruments to experimentalists, but also formulate empirical hypotheses themselves.

Philosophers of mind often try to contribute to a more comprehensive and unified general framework that can guide and inspire empirical research, and of course they always have their own, more abstract, questions in the back of their minds. From a philosophical perspective, it has proven to be interesting and fruitful to select specific, increasingly well-researched target phenomena and to see what can be learned about them from the empirical literature. By always keeping an eye on the value of findings as "bottom-up constraints" for a more general, comprehensive model of the human mind, while at the same time, in a critical vein, trying to uncover conceptual inconsistencies or unwarranted background assumptions that may block further progress, the philosopher can make important contributions to the field. Interdisciplinary cooperation works best when focused on a specific target phenomenon like conscious experience in virtual reality (Metzinger, forthcoming), dreaming (Metzinger, 2013b), out-of-body experiences (Metzinger, 2009), or identity disorders (Metzinger, 2004), and this short chapter can be seen as another installment in a series of attempts to lay some conceptual foundations for an empirically grounded theory of self-consciousness.

In the first three sections of this chapter I will ask many questions. In doing this, my aim is to flag some epistemic targets of potential interest for an interdisciplinary readership. I will ask what the *explanandum* for theories of mind-wandering is, how we can conceptually *individuate* single occurrences of our target phenomenon, and how we might arrive at a more fine-grained *taxonomy*. In the three subsequent sections (constituting the second half of the chapter), I will suggest some answers, sketching a series of positive proposals as to how we might understand mind-wandering on a conceptual level: as a loss of *mental autonomy* resulting in involuntary mental behavior; as a highly specific *epistemic deficit* relating to self-knowledge; and as a *phenomenological* process in which our conscious "unit of identification" is switched ("UI-switching" is a new technical term I will introduce in the final section).[1]

The Explanandum

What, exactly, is it that we want to explain in scientific research on mind-wandering? Is the target phenomenon really a unitary phenomenon, for instance a distinct type or class of mental processes? And what would therefore *count* as an explanation of the phenomenon in its entirety?

Let us take the widespread notion of "spontaneous, stimulus-independent or task-unrelated thought" (Antrobus, 1968; Giambra, 1989) as a starting point. It is important to note how, in its origin, "spontaneity" is an exclusively phenomenological concept, because it is based on the introspective experience of an apparently uncaused, subjectively unexpected, and sudden onset of conscious thought. "Spontaneity" is therefore not an objective property, but rather an entirely subjective characteristic of certain thoughts. It therefore cannot function as an empirical demarcation criterion to define the boundaries of our target domain. Empirically, it is plausible to assume that there will always be unconscious neural precursors of mind-wandering. These could, for example, be specific introspectively inaccessible goal representations that drive the high-level phenomenology of mind-wandering (Klinger, 2013), such as postponed goal-states that have been environmentally cued by goal-related stimuli under high cognitive load (Cohen, 2013; McVay & Kane, 2009). To understand the overall process, we may have to adopt the "dolphin model of cognition": Just as dolphins cross the boundary between water and air, thought processes often cross the border between conscious and unconscious processing, and in both directions. For example, "spontaneously occurring" chains of cognitive states may have their origin in unconscious goal-commitments triggered by external stimuli, then transiently become integrated into the conscious self-model for introspective availability and selective control, only to disappear into another unconscious "swimming bout" below the surface. Conversely, information available in the conscious self-model may become repressed into an unconscious, modularized form of self-representation where it does not endanger self-esteem or overall integrity (Pliushch & Metzinger, 2015).

Conceptually, to take the "spontaneity" characterizing the onset of a mind-wandering episode seriously as an objective property of the human mind would mean to accept it as causally indeterminate—and therefore inaccessible to standard experimental methods.[2] On a physical or functional level of description, to call something "spontaneous" means to describe it as "uncaused" and "lawless"—and doing so could even be seen as a form of hand-waving. For this reason, the first semantic element in "spontaneous, task-unrelated thought" will not help us in isolating the explanandum.

A more moderate and nuanced account could attempt to describe *degrees* of spontaneity and analyze them as degrees of constraint satisfaction on different levels of analysis. For example, one traditional philosophical distinction is between the "content" and the "vehicle" of a mental process. We could then separately investigate constraints governing the content of thought, as well as the constraints determining the dynamic neural carriers (i.e., the "vehicles") of this content, and we could accordingly distinguish different degrees of constraint-satisfaction. As Christoff et al. (2016, p. 719) have proposed, "spontaneous thought" could then be characterized by the absence of strong content-constraints imposed either by deliberate cognitive control and/or "automatic" constraints. Automatic constraints would presumably influence the neural carriers in a functionally more direct way, for example by mechanisms implicitly processing affective or sensory salience.

Importantly, however, fundamental methodological issues remain, because one has to distinguish between the representational content of a given neurodynamical state as ascribed from a third-person perspective and as introspectively reported from a first-person perspective. First, the content of a mind-wandering episode might be described as "unconstrained" relative to some theory of mental representation or under a specific mathematical model of neural computation; it would then be a property ascribed by an external observer. On the other hand, if the "content" is what can be introspectively accessed and reported by experimental subjects—for example, by asking, "Was your mind moving about freely?"—then subjectivity is back in. Researchers get a statistical measure of self-reports and can fruitfully and legitimately employ what Daniel Dennett calls the "heterophenomenological method" (Dennett, 1991, pp. 72–81), but are ultimately still dealing with a phenomenological construct.

One path toward a solution may consist in analyzing "spontaneity" not as a phenomenological or a metaphysical property of certain thought processes, but as an *epistemic* feature: Perhaps it is a systematic lack of knowledge, a specific form of introspective blindness characterizing a very large portion of conscious thought. As Smallwood and Schooler (2015, p. 491) put it, "the spontaneous occurrence of mind wandering means that the causal path that links the experience to ongoing processes and outcomes is opaque." If this is correct, then one way to transform "spontaneity" into a proper, experimentally tractable explanandum for research would be to isolate exactly those causal conditions in the brain that make the causal precursors of a given cognitive event functionally available for introspective attention and verbal report. "Opaque" then means that there is no internal model of the causal path that can be introspectively accessed, and this would also give us a first functional-level notion of "spontaneity." We could then ask what exactly the neural mechanisms creating an internal model of what philosophers call "horizontal mental causation" (i.e., the linear causation of one mental event by another) are. What is the domain or the subset of cognitive processes on which these mechanisms operate? How do they break down? Can they be experimentally modulated?

Perhaps it is *never* the case that what one ascribes or introspectively reports as the "content" of an episode actually causes the "content" of the next episode. Alternatively, perhaps it is only sometimes the case; possibly our internal, introspectively accessible model of horizontal mental causation simply is a misrepresentation most of the time—a high-level confabulation that has proved to be adaptive? It is important to understand that all we can ever introspectively attend to is a *model* of our own cognitive processing. We never have a mysterious "direct" form of access to the cognitive processes in our heads, because all knowledge—including self-knowledge—always is knowledge *under a representation*. Therefore, the core target for research may actually be the way in which our brains *model* the causal relations between their own inner states, the way the system creates an internal model of itself by trying to predict and "explain away" its own mental behavior. A brain that was functionally unable to generate dynamic models of horizontal mental causation could only support a phenomenology of one "spontaneously occurring" mental content after another. An organism with such a brain could experience mental causation together with a high degree of "freedom," subjective unpredictability, or a lack of cognitive control in terms of rational connection between content elements, but in the complete absence of an internal self-model explicitly portraying horizontal causal chains connecting mental events, the cognitive first-person perspective would simply dissolve. For such an organism, there would never be a coherent *train* of thoughts, only events, and never a unified process in terms of a temporally extended cognitive *Gestalt*. The self-conscious mind would be largely unintelligible to itself, a constant source of surprise and uncertainty—it would be hard for the organism harboring it to experience it as its own mind. It could therefore never develop an inner image of the system carrying it as an embodied "thinker of thoughts," as an entity that is not only a bodily, but also a cognitive agent. Perhaps some animals have a cognitive phenomenology of exactly this kind, unfolding on a more robust and stable platform of bodily and emotional self-consciousness. Our brains are different.

Now take the second semantic element, "task-unrelatedness." Philosophers will immediately see that there is a very strong implicit background assumption hiding behind this idea: that human beings pursue one and only one task at a time. But we know that this is false. A biological organism has multiple tasks and many problems to be solved at the same time—it is continuously faced with a multitude of challenges that have to be met. Any higher biological organism is a paradigmatic example of parallel processing, and there are many levels of functional granularity on which it must continuously operate—sustaining its existence; preserving homeostatic stability; continuous prediction error minimization relative to the dynamic, internal self-model created by the brain; successfully achieving procreation; rising in a social dominance hierarchy by effectively deceiving self and others (Pliushch & Metzinger, 2015; von Hippel & Trivers, 2011). At any given point in time, in the organism's central nervous system, there will be multiple goal-representations competing for the control of overt behavior, for the focus of attention, and for high-level cognitive. In addition, for embodied agents like ourselves who constantly refine and update the interoceptive layers of their self-model, there never really is anything like an absence of internal constraints (*pace* Andrews-Hanna, Irving, Fox, Spreng, & Christoff, Chapter 13 in this volume).

An analogous point holds for the notion of "stimulus-unrelated thought." As the human self-model is functionally anchored in elementary processes of bioregulation (Metzinger, 2003a, 2014), no form of cognitive processing is ever fully disembodied or independent of the continuous bombardment by stimuli originating in the *interior* of the body. Interoceptive input, proprioception, the continuous flow of vestibular information, or the "background buzz" generated by autonomous activity in the input-independent layers of the body-schema are examples of permanent sources of stimulation. These internal sources of stimulation and constant perturbation influence not only bodily self-awareness, but also our emotional self-model, thereby setting an internal context. We may not be subjectively aware of this context at all times, and we may be even less aware of the detailed causal pathways by which it shapes and relates to the contents of our thoughts, but it certainly exists. Upon closer inspection, the notion of "stimulus-unrelatedness" really relates to a phenomenal property: the conscious experience of our ongoing thoughts as not being caused by something subjectively represented as belonging to the extracorporeal environment—to an *external* stimulus. In order to bridge the gap between an implicitly phenomenological concept and a productive functional analysis, we could proceed from looking at the content to focusing on the physical dynamics on which this content "rides"—for example, by looking at the way in which the brain *predicts* incoming stimuli by "canceling out" sensory input.

Similarly, "task-unrelatedness" may also ultimately only be a phenomenological property, one that is derived from the high-level introspective experience of only being able to solve one problem at a time. A strong metaphysical interpretation of the second element of "task-unrelatedness" would have to say that a large portion of human cognition is actually aimless—an arbitrary process that in a fundamental way cannot count as goal-directed, perhaps not even as a form of intelligence. This would make task-unrelatedness difficult to understand from an evolutionary perspective, because it would involve paying a high metabolic price for a ubiquitous dynamic feature that ultimately doesn't serve any of the organism's needs (but see Simonton, Chapter 10 in this volume).

Again, an epistemological perspective may prove to be fruitful in defining the explanandum more clearly: Mind-wandering is an inner process experienced by an organism for which the organism possesses no conscious knowledge of the goals the process serves, simply because there is no introspectively available model of the goal-state. In the generation of intelligent behavior, when exactly is it necessary to have an internal model of the goal-state? When is it a superfluous waste of resources? Is there a specific functional advantage of explicit goal-representation (e.g., veto control or the creation of an illusion of trans-temporal identity)? Elsewhere (Metzinger, 2013a, 2015) I have argued that mind-wandering is an unintentional form of mental behavior.[3] Unintentional mental behaviors may surprise the organism in which they emerge and may be basically inexplicable to it from its limited inward perspective, while still being a very efficient and adaptive form of intelligence. For example, one speculative but perhaps novel hypothesis is that a considerable portion of mind-wandering actually is "mental avoidance behavior": an attempt to cope with adverse *internal* stimuli or to protect oneself from a deeper processing of information that threatens self-esteem. There is nothing wrong with the idea of a cognitive system whose behavior is driven by a multiplicity of goal-representations, the content (and the continuous hierarchical restructuration) of which it does not consciously know or understand. Before claiming the existence of an objective property like "task-unrelatedness," it may therefore be more interesting to look at the dynamic mechanisms of task-*representation* first. This leads to genuinely philosophical questions: How are "goal-states" or "tasks" individuated in the first place? What is different for exclusively *mental* forms of goal-relatedness, and are there specific sets of satisfaction conditions characterizing cognitive actions, and only cognitive actions? Such questions provide further reasons why mind-wandering can be interesting for philosophers, especially as one of the many reasons why mind-wandering is interesting for philosophers is that it directs our attention to the problem of mental action (the "contrast class," if you will); mind-wandering poses the interesting challenge of describing the deeper principles of goal-state selection and action initiation while subtracting the non-neural body and abstracting from issues of motor implementation (Metzinger, 2017).

"Thought" is the third semantic element in our notion of "spontaneous, task-unrelated thought." On the one hand, it is difficult to define what "thought" is in the first place; on the other hand, one of the greatest contributions of the field of mind-wandering research to cognitive science may exactly lie in finally introducing a massive and empirically grounded taxonomical differentiation for the term "cognition." Philosophers have, of course, thought about this third semantic element characterizing mind-wandering for centuries. I will not even begin to sketch the theoretical landscape. Instead, I will confine myself to pointing out that terms like "cognition" or "cognitive" have long become empty buzzwords in neuroscience and empirical psychology, and that this problem has to be solved in a principled manner—at least if a conceptual construct like "spontaneous, task-unrelated thought" is to be used by serious people wishing to treat it as referring to a potential explanandum for rigorous empirical research.

But here are some questions one might ask to get started: Is "conscious thought" simply a folk-psychological term that should be eliminated in favor of a fine-grained neuroscientific theory? Are there necessary conditions, such as agentive direction, for verbally reportable types of mental activity to count as "thought"? Is the target phenomenon tied to the wakeful state, or does conscious cognition in the dream state similarly present us with an example of "thought"? Philosophers individuate thoughts by their contents, by what they are *about*. Can mind-wandering be about anything, or are there specific forms of content characterizing the target phenomenon? The problem to be solved is that in developing a systematic catalogue of explananda, we might end up with a very long disjunction ("Mind-wandering is *a* or *b* or *c* or . . .") and risk the danger of widespread fallacies of equivocation. In informal logic, the "fallacy of equivocation" refers to the misleading use of a term with more than one meaning or sense. Therefore, one needs to be able to say clearly what one *single* and what *one and the same* occurrence of the target phenomenon are. As I will explain in the next section, in order to do proper science, mind-wandering episodes have to be turned into countable entities, and we need criteria to determine their identity. I take it that empirical researchers currently are unable to do this.

Individuation

What are the temporal boundaries of a given, single episode of mind-wandering or a specific period of "spontaneous, task-unrelated thought"? When exactly does such an episode begin, and when does it end? Putting the question slightly differently, if we conceive of an individual episode as a chain of mental events, what counts as the *first* event in this chain and what is the *last*? Such questions raise further important issues. For example, could there be episodes constituted by one single mental event only? Or is there a minimal number of events—say, the attentional lapse, the appearance of the first retrospectively reportable (e.g., "task-unrelated") content, plus the terminal moment of meta-awareness?

To "individuate" episodes means to turn them into single, countable entities. To turn mind-wandering into a proper target for empirical research, we do not want to ask, "How *much* mind-wandering was there, during a given period of time?" but rather "How *many* individual occurrences of our target phenomenon could we experimentally detect?" In principle, it must be possible to say, "During the last 300 seconds, subject *s* had 14 distinct episodes of mind-wandering, namely, episode *a*, which lasted 2,834 milliseconds and began just after 5,398 milliseconds, episode *b*, [. . .], and finally episode *n*, which lasted 4,793 milliseconds and ended precisely 2.5 seconds before the end of the experimental period." In order to achieve this, one needs not just testable, objectively viable criteria marking the onset and the end of each episode, but also a criterion for counting psychological items of this newly introduced kind, as well as a criterion helping us to decide on identity or non-identity among items of that kind. For example, would our future theory of mind-wandering allow that a patient has *one and the same* recurring negative thought pattern again, at multiple points or intervals in time? Are there context-invariant "cognitive atoms," distinct units of mental content that can be activated in the subject's conscious mind, again and again? There are deep and complex conceptual questions lurking in the background. Here is another one: We do not want individual mental episodes to possess proper parts that themselves are of that psychological kind we call "mind-wandering" or "spontaneous, task-unrelated thought"—else we may have problems counting them. What, then, is the smallest explanatory unit? Perhaps most of all, some of us may also want to know what the "essence" of our target phenomenon actually is, *what* that kind of phenomenon is.

In earlier work, I have made some positive proposals. One proposal is that the essence or inner nature of mind-wandering is "UI-switching," a sudden, subjectively unpredicted, and often unnoticed change in the phenomenological unit of identification (see the last section of this chapter). Recall that a unit of identification simply is whatever is currently experienced as the conscious self, whatever conscious content would give rise to reports of the type "I *am* this!" I have grave doubts that "essences" in a strong metaphysical sense really exist, but framing an answer in this more modest manner could perhaps help us to specify what, in our world and under the laws of nature that hold in it, is common to all occurrences of mind-wandering—what constitutes their inner nature. If I am correct, mind-wandering occurrences can be characterized by a single UI on the level of their content, and in time they are "bracketed" by shifts in the UI (again, see the last section). Second, I have also formulated an empirical hypothesis saying that the onset of every single episode must be characterized by a discontinuity in phenomenal self-awareness—an experimentally detectable "self-representational blink" (SRB; Metzinger, 2013a, p. 9). Third, I have proposed that the end of every single episode that leads to a regaining of cognitive self-control is marked by another shift in the self-model involving the reappearance of an explicit representation of the ability for mental veto control, typically accompanied by a voluntary termination of the ongoing mental chain of events. This creates a new unit of identification, namely, the "meta-aware self"—an internal model of an active entity that has the ability to end an ongoing chain of task-unrelated thought and to return the focus of attention to what is now consciously remembered as "the" original task.

Taxonomy

Imagine you are sitting in a boring lecture and have drifted off into a pleasant erotic fantasy. After you become aware of the fact that you have just completely zoned out, you carefully tune back into the fantasy while paying some attention to the lecture. Whenever you notice that you have had another full attentional lapse and completely zoned out (the lecture still hasn't got any better), you deliberately tune back into the fantasy again, afterward "letting it go," observing it as it unfolds by itself. Is this interplay between mental action and the ensuing loss of cognitive control, the recurring cycle between "zoning out," "coming to," and "tuning out" again a form of mind-wandering? Only one-half to two-thirds of it can really be characterized as "task-unrelated thought." Perhaps the real "task" here is not actually listening to the lecture. Maybe the highest-priority task consists in keeping up the outer appearance of being an interested listener and in being a well-rested and relaxed conversant at the conference dinner afterward, remembering just a minimally sufficient number of keywords to (in a social emergency) be able to fake an intelligent question or two? How much of the contents of your erotic fantasy was "spontaneous" in the sense that there really was a strong introspective experience of sudden onset, novelty, and unexpectedness? Was it caused by unconscious interoceptive stimuli? Was its introspectively available content really "conceptual" in the sense of high-level symbolic cognition, something that can be called "thought" in a stricter and narrower sense, or was the experiential content rather one constituted by visual and motor imagery, an embodied and increasingly complex simulation of the tactile, kinesthetic, or interoceptive stimuli to be expected and of the emotional arousal they would cause?

From a traditional philosophical perspective, a systematic taxonomy would have to individuate mind-wandering episodes by their verbally reportable content and by the functional context in which they occur. This may already lead to helpful taxonomical differentiations. It also draws attention to another methodological constraint that empirical research has to satisfy: namely, always clearly distinguishing between "content" as experienced and ascribed from a first-person perspective (1PP) and "content" as ascribed from the scientist's third-person perspective (3PP). For example, there are highly developed and centuries-old 1PP approaches to what, today, we like to call "online experience sampling" (namely, classical mindfulness meditation of the "open monitoring" type), and there are much more recent 3PP approaches involving external cueing and a statistical analysis of the results related to whole groups of individuals (see Andrews-Hanna et al., Chapter 13 in this volume). These approaches lead to diverging results, as 3PP content is a much more abstract theoretical construct than

1PP content. However, intuitions anchored in 1PP content may contaminate theory formation on the level of science, and scientifically informed subjects will at some point re-import 3PP content into their individual phenomenological reports.

Take the example of depressive rumination. Is it really "task-independent"? What about the diminished attentional control caused by worry and self-referential negative thoughts in anxiety disorders (Forster et al., 2015)? Maybe it actually reflects, from a neurocomputational perspective, a close-to-optimal form of processing, just as many visual illusions can count as "optimal percepts" if analyzed mathematically. We must never forget that first-person description and third-person functional analysis may greatly diverge. For example, for certain taxonomical categories, there may be hidden epistemic benefits that are "invisible" from a subjective, first-person perspective.

Here is another example of a philosophical concept that I think might possess great heuristic fecundity for future research on "stimulus-independent, task-unrelated thought": "epistemic innocence." Philosopher Lisa Bortolotti (Bortolotti, 2015a, 2015b) has recently introduced this concept to articulate the idea that certain mental processes such as delusion and confabulation (which may count as suboptimal from an epistemological perspective) may actually have not just psychological, but also epistemic benefits. Their psychological benefits may not simply be purchased with epistemic costs—what superficially appears as an imperfect cognitive process may actually be epistemically innocent, causally enabling not only coherence, but also mental knowledge acquisition. I believe this philosophical idea can be fruitfully applied in the domain of mind-wandering. For example, does depressive rumination perhaps serve the interests of the individual or its group, fulfilling a task that is introspectively inaccessible to the patient and which, scientifically, we simply haven't understood yet? Are the comparably perseverative forms of thinking happening during NREM sleep (including slow-wave sleep) a form of conscious thought, too? In what sense are they "task-unrelated"? Are there perhaps hidden epistemic benefits to dreamless sleep experience? Mentation during sleep as well as cognition during ordinary and lucid dreams are examples of candidates for our taxonomy of states of mind-wandering, which are characterized by a special functional context (shallow levels of embodiment and situatedness) and, with the exception of lucid dreams, are generally absent cognitive self-control (Metzinger & Windt, 2007). Interestingly, there is a strong overlap between theoretical issues in empirical research on dreaming and mind-wandering (Fox et al., 2013; Metzinger, 2013b; Windt, 2015; see also Windt & Voss, Chapter 29 in this volume). Again, here are some examples: What exactly is the relationship between mental self-control, the occurrence of dream lucidity, and what researchers in mind-wandering call "meta-awareness"? Can both lucid lapses and mind-wandering lapses plausibly be interpreted as the disintegration of an internal epistemic agent model (see later discussion in this chapter)? Are there common *positive* functionalities connecting dreaming and mind-wandering during wake states, such as the encoding of long-term memory, complex, preparatory motor planning, or creative incubation? Philosophically, it is also interesting to look at "false lucidity" and the phenomenology of insight (Kühle, 2015; Voss & Hobson, 2015): in becoming lucid at night and during daytime mind-wandering, is the experience of *oneself* having actively regained meta-awareness (and thereby mental autonomy) an illusion of control over a mental event that was really triggered by an unconscious process? Currently, this is only a conceptual possibility; What kind of experimental design could settle the issue?

An even more radical approach could take the step from a content-taxonomy to a vehicle-taxonomy. We could stop speaking of the "content" of mind-wandering episodes altogether, for example by exclusively focusing on dynamical properties of its minimally sufficient neural correlates. Is depressive rumination "spontaneous, task-unrelated thought"? Kalina Christoff and colleagues arrive at a negative answer (cf. Christoff et al., 2016, p. 725), by proposing a wider dynamicist framework for understanding mind-wandering under which depressive rumination would be understood as a member of a family of spontaneous-thought phenomena. Drawing on Ludwig Wittgenstein (e.g., *Philosophical Investigations* I: 66), a philosophical analysis of this point could say that "mind-wandering" actually is a cluster concept (i.e., a term that is defined by a weighted list of criteria, such that no one of these criteria is either necessary or sufficient for membership). Recall how a more nuanced account of mind-wandering could attempt to describe *degrees* of spontaneity and analyze them as degrees of constraint satisfaction at different levels of analysis. For depression, we clearly find rigidity and an involuntary fixation on symptoms of distress at the content level. In addition, one level of description below, there is a diminished degree of constraint satisfaction for the functional property of M-autonomy (Metzinger, 2015; see later discussion in this chapter), because in depressive rumination patients have great difficulties in disengaging from their own involuntary behavior, as their capacity for veto control on the mental level is weakened. Here, the overall functional context would be a clinical one, with a local microfunctional correlate on the molecular level (e.g., a dysbalance of certain neurotransmitter systems characterizing the "vehicle" or carrier), while the content might be redundant, repetitive, and characterized by negative affective valence. This opens the radical possibility of increasingly proceeding without the ascription of "content" at all, semantically enriching our initial cluster concept of "mind-wandering" by *exclusively* defining it by criteria on the vehicle level. In their synthesis of the new interdisciplinary field of spontaneous thought, Jessica Andrews-Hanna and colleagues (Chapter 13 in this volume) propose exactly this—breaking out of the "flashlight" of 1PP content into the rich darkness of lower levels of description. But what exactly is it that we are trying to find in the dark, and is it something that should still be called "thought"?

I hope that my readers will agree that more than enough new questions have been asked in the three preceding sections—it is now time to offer some answers. The general point I have been trying to make should be clear by now: to sustain its great initial success, experimental research on spontaneous thought needs a much more systematic and fine-grained taxonomy of its research targets. Such a taxonomy cannot be constructed in a purely data-driven, bottom-up manner, because it rests on implicit conceptual assumptions and on our epistemic interests. What exactly is it that we want to *know*? I will not discuss any further examples in the remainder of this chapter. Instead I will present a series of positive proposals for developing a conceptual framework, plus some first conceptual tools that empirical researchers could operationalize and apply in the design of experiments. I will begin with the subjective sense of agency and the possibility of illusions of control on the mental level.

Losing and Regaining Mental Autonomy: Mental Action Versus Unintentional Mental Behavior

Philosophers have thought long and hard about what distinguishes "actions" from other kinds of events in the physical world (Davidson, 1988/2001; Dretske, 1988; Wilson & Shpall, 2016). Indeed, "action theory" can be considered a small subfield within the discipline of academic philosophy. There are, however, also *mental* actions—and this is another point of contact where mind-wandering becomes interesting to philosophers (Metzinger, 2017; O'Brien & Soteriou, 2009; Pezzulo, 2017). Perhaps some elements of the philosophical toolkit can prove to be interesting for experimentalists as well.

Deliberately focusing one's attention on a perceptual object and consciously drawing a logical conclusion are examples of mental actions. Just like physical actions, mental actions possess satisfaction conditions (i.e., they are directed at a goal state). Although they mostly lack overt behavioral correlates, they can be intentionally inhibited, suspended, or terminated, just like bodily actions can. Additionally, they are interestingly characterized by their temporally extended phenomenology of ownership, goal-directedness, a subjective sense of effort, and the concomitant conscious experience of agency and *mental* self-control.

Let me distinguish the two most important types of mental action:

- *Attentional agency* (AA): the ability to control one's focus of attention;
- *Cognitive agency* (CA): the ability to control goal/task-related, deliberate thought.

AA and CA are functional properties that are gradually acquired in childhood, can be lost in old age or due to brain lesions, and whose incidence, variance, robustness, and so on, can be scientifically investigated. However, they also have a subjective side. Attentional agency (Metzinger, 2003a, 6.4.3; 2006, Section 4; 2013a; 2013b; 2015) also possesses a phenomenal signature, as is the case for other forms of subjective experience, like pain or the subjective quality of "blueness" in a visual color experience. For this reason, AA also has a phenomenological reading: as the conscious experience of actually initiating a shift of attention, and of controlling and fixing its focus on a certain aspect of reality. AA involves a sense of effort, and it is the phenomenal signature of our functional ability to actively influence what we will come to know, and what, for now, we will ignore.

Consciously experienced AA is theoretically important because it is probably the earliest and simplest form of experiencing oneself as a knowing self, as an epistemic agent. Human beings learn to control the focus of their attention long before they can control symbolic, high-level cognition.

Research into animal intelligence and human phenomenology shows that AA can and does exist without cognitive control, but modern dream research and various psychiatric syndromes demonstrate that cognitive agency causally depends on and might actually be a functional derivative of attentional agency (e.g., Windt, 2015). To consciously enjoy AA means that you (the cognitive system as a whole) currently identify with the content of a particular and highly specific type of mental self-representation, an "epistemic agent model" (EAM; Metzinger, 2013a, 2013b, 2015, 2017). Whenever such an EAM is active in your brain, you experience yourself as a knowing self, an agent searching to improve its knowledge about the world. AA is fully transparent:[4] The content of your conscious experience is not one of self-*representation* or of an ongoing process of self-modeling, of depicting yourself as a causal agent in certain shifts of "zoom factor," "resolving power," or "resource allocation," in actively "optimizing precision expectations" or engaging in a "selective sampling of sensory data that have high precision (signal to noise) in relation to the model's predictions" (Feldman & Friston, 2010, p. 17). Rather, you directly experience *yourself* as, for example, actively selecting a new object for attention or trying to "see things more clearly." This is interesting because although during many types of mind-wandering episodes we do not have AA, these episodes can of course be *about* having been an attentional agent in the past, or *about* planning to control one's attention in the future.

Analogously, a closely related point can be made for CA. Conceptually, cognitive agency is not just a complex set of functional abilities such as the capacities for mental calculation; consciously drawing logical conclusions; engaging in rational, symbolic thought; and actively constructing new arguments. Again, there is a distinct phenomenology of currently being a cognitive *agent*, which can lead to experiential self-reports like "I am a thinking self in the act of grasping a concept," "I have just actively arrived at a specific conclusion," and "I am attempting to build an argument." There is a functional analysis ("autonomous cognitive self-control") and a phenomenological reading, based on verbal self-reports. The classical meta-theoretical issue, of course, is in what sense autophenomenological reports can or should inform the process of functional analysis and decomposition. But most important, what AA and CA have in common is that in both cases, we consciously represent ourselves as epistemic agents: According to subjective experience, we are entities that actively construct and search for new epistemic relations to the world and ourselves. We are information-hungry, and there is something we want to *know*.

Empirical research programs on spontaneous, apparently task-unrelated thought are interesting for philosophers, because they demonstrate (a) that epistemic mental agency is a *much* more vulnerable and *much* rarer phenomenon than many philosophers of mind may have intuitively assumed, and (b) that what we traditionally call "conscious thought" or "high-level symbolic cognition" may, more often than not, be a *subpersonal* process (as I have argued elsewhere; see Metzinger, 2013a, 2015). Such programs raise the need for conceptual demarcation criteria allowing us to distinguish between intentional mental action and unintentional mental behavior, as well as between personal-level thought, and forms of conscious cognitive processing that are better described as automatic, sub-personal chains of events. Nevertheless, the wealth of existing philosophical literature on action and thought may provide many helpful conceptual tools for empirical researchers to use to sharpen their hypotheses and predictions. For example, it would be excellent if empirical investigators always carefully distinguished between personal-level mentation and subpersonal processes, between properties of the person as a whole and properties of his or her brain. My own more specific positive proposal is this: the beginning of every mind-wandering episode is marked exactly by the collapse of our epistemic agent model (a conscious self-representation of *now* possessing the ability for epistemic self-control), and the end of every episode is marked by the re-emergence of a new epistemic agent model (the "meta-aware self"). How can we spell this point out on the functional level?

I think it could be heuristically fruitful to analyze mind-wandering as a *loss of mental autonomy*. The topic of mental autonomy (M-Autonomy hereafter; cf. Metzinger, 2015) is an excellent example of an area in which empirical research into mind-wandering makes a contribution to issues possessing great relevance in other fields, not only philosophy, but also law and psychiatry.[5] Very generally speaking, autonomy is the capacity for rational self-control, whereas the term "mental autonomy" refers to the specific ability to control one's own mental functions, like attention, episodic memory, planning, concept formation, rational deliberation, and decision-making. Mental autonomy includes the capacity to impose rules on one's own mental behavior and to explicitly select goals for mental action, as well as the ability for rational guidance and, most important, the intentional inhibition, suspension, or termination of an ongoing mental process. M-autonomy is a functional property,[6] which any given self-conscious system can either possess or lack. Its instantiation goes along with new epistemic abilities, a specific phenomenological profile, and the appearance of a new layer of representational content in the phenomenal self-model (Metzinger, 2003a). In humans, first insights into its neuronal realization are now beginning to emerge. From a philosophical perspective, this functional property is interesting for a whole range of different reasons. One of them is that it is directly relevant to both our traditional notions of a "first-person perspective" (1PP) and of "personhood" (Metzinger, 2015). If one cannot control the focus of one's attention, then one cannot sustain a stable first-person perspective, and for as long as one cannot control one's own thoughts, one cannot count as a rational individual. In other words, spontaneous thought is a subpersonal process, like respiration or heartbeat.

Biological systems produce different kinds of observable output, which can in turn be characterized by different degrees of autonomy and self-control. There are actions and behaviors, and both kinds of output are conceptually individuated by their satisfaction conditions—that is, they are directed at goal states. However, for actions, conscious goal-representation plays a central causal role: actions are typically preceded by a selection process; they can be terminated, suspended, or intentionally inhibited; and they exhibit a distinct phenomenological profile involving subjective qualities like agency, a sense of effort, goal-directedness, global self-control, and ownership. Behaviors, on the other hand, are purposeful, but possess no explicit form of conscious goal-representation. They are functionally characterized by automaticity, decreased context-sensitivity, and low self-control; we may not even notice their initiation, but they can be faster than actions. While their phenomenological profile can at times be completely absent, behaviors typically involve the subjective experience of ownership without agency, the introspective availability of goal-directedness varies, and there is frequently a complete lack of meta-awareness.

We find a parallel situation if we look at our inner life; some mental activities are not deliberately controllable, because one centrally important defining characteristic does not hold: they cannot be inhibited, suspended, or terminated. Let us call these activities "unintentional mental behaviors." Mind-wandering can therefore be conceptualized as a form of unintentional behavior, as an involuntary form of mental activity. Viewed in this way, research on mind-wandering is a subfield of human ethology; it belongs within the field of cognitive ethology for *Homo sapiens* (Allen & Bekoff, 1999; Marler & Ristau, 2013).

Of course, the fact that a given mental or bodily behavior is unintentional in no way implies that this behavior is unintelligent or even maladaptive. It is plausible to assume that many animals' minds wander, perhaps a lot of the time. For example, low-level, saliency-driven shifts in attentional focus are unintentional mental behaviors, not inner actions, and in standard situations, they cannot be inhibited. They are initiated by unconscious mechanisms, but may well result in a stable, perceptually coupled first-person perspective as their final stage. Stimulus-independent, task-independent thought, however, normally begins as a form of uncontrolled mental behavior, a breakdown of consciously guided epistemic autoregulation (the active control of one's own epistemic states on the level of high-level cognition). Just like an automatic, saliency-driven shift in the focus of attention, stimulus-independent, task-independent thought may be caused by unconscious factors like introspectively inaccessible goal representations that drive the high-level phenomenology of mind-wandering (Klinger, 2013), for example representations of postponed goal-states that have been environmentally cued by goal-related stimuli under high cognitive load (Cohen, 2013; McVay & Kane, 2009). Of course, quite often an episode of spontaneous thought will be *initiated* in a deliberate manner (see later discussion in this chapter and Seli et al., 2016), but as it unfolds it turns into unintentional mental behavior. Both low-level attention and uncontrolled, automatic thinking will frequently count as an intelligent and adaptive type of inner behavior. Nevertheless, as long as it is taking place, we seem to lack the ability to terminate or suspend it—we are fully immersed in an inner narrative and cannot deliberately "snap out of it." This highlights that perhaps the most relevant and hitherto neglected phenomenological constraint for a theory of mental autonomy is that, subjectively, we do not notice this fact. Therefore, on the functional level of analysis, my positive proposal is that mind-wandering is the graded loss of the ability for veto control on the mental level, which can be described as a graded loss of mental autonomy and epistemic self-control.

Epistemology of Mental Self-Knowledge

Mind-wandering is interesting for philosophers because it has important implications for theories of self-knowledge. First, every philosophical account of *conscious* self-knowledge now needs to do justice to the discovery that it is a highly discontinuous process, and that this discontinuity is only weakly reflected on the level of conscious experience itself. Second, unnoticed rationality deficits and self-deception from cognitive corruption are possible at any point in time (see Metzinger, 2013b, Example 4; Windt, 2015, p. 479). Clearly, we can have a specific epistemic ability, but we can also temporarily lose our knowledge of possessing this ability. In mind-wandering, the relevant ability is our potential for cognitive self-control, most importantly the very basic and fundamental capacity for what I have called "mental veto control." If this ability is not explicitly represented in our phenomenal self-model, then we—as a whole person—are not able to exert it. We suffer from an epistemic deficit, an absence of representation that is not represented *as* an absence—and the ensuing lack of conscious self-knowledge has well-documented causal consequences.

Recall the notion of having an internal model of "horizontal mental causation." For philosophers this means that one mental event causes another mental event. Closely related to this is the idea of "vertical mental causation," which typically means that a mental event could cause a *physical* event—say, a bodily movement—in a top-down fashion. Many contemporary philosophers think that something like this is not possible (we sometimes call this "the causal closure of the physical," assuming that every physical event that has a cause has a physical cause; see, e.g., Kim, 1993, 2000). But if we take our own phenomenology seriously, we discover that the human brain models mind–body interactions very differently, giving rise to Cartesian intuitions (Metzinger, 2003a, Section 6.4.1). However, there is a third possibility: *intramental* vertical causation, and this term may be another example of a potentially useful and heuristically fecund conceptual instrument for the mind-wandering community. Intramental vertical causation would be the case where one mental event causally influences another mental event, but not—as in the case of horizontal causation within the domain of mental events, as discussed earlier—in terms of continuing a chain of such events, but in terms of terminating such a chain, by top-down control. Let us ignore the philosophical metaphysics of the mind–body problem for now, and just look at the necessary functional architecture in our minds. My point is that in order to know about our ability for mental veto control (i.e., our capacity to terminate or suspend an ongoing train of thought or other mental process), we would first need an inner *model* of the possibility of top-down intramental causation, of one mental event terminating or modulating a chain of events on a lower level. A speculative empirical hypothesis would say that exactly this model disappears in our brains after the onset of a mind-wandering episode.

What makes this phenomenon interesting is that it does not seem to bother us very much, to the point that many of us initially doubt the empirical data on the frequency of attentional lapses and spontaneous, task-unrelated thought. There seems to be a widespread form of "introspective neglect," resembling a form of anosognosia or anosodiaphoria, related to the frequent losses of cognitive self-control characterizing our inner life. Obviously, "widespread" does not mean that *all* instances of task-unrelated thought involve introspective neglect—we know that there is intentional "tuning out" as well as "zoning out," as discussed earlier, that up to 41% of reported mind-wandering can be engaged with intention (Seli et al., 2016, p. 606), and that in certain memory, learning, and problem-solving contexts, reduced cognitive control can even provide a benefit (Amer et al., 2016, p. 907). That said, the phenomenon of mind-wandering is also clearly related to denial, confabulation, and self-deception. I once gave a talk about mind-wandering to a group of truly excellent philosophers, pointing out the frequent, brief discontinuities in our mental model of ourselves as epistemic agents, and one participant interestingly remarked, "I think only ordinary people have this. As philosophers, we just don't have this because we are intellectual athletes!" I think the truth of the matter may be just the opposite: high-performing intellectuals are particularly unaware of their own spontaneous, task-unrelated thoughts. The introspective experience and the corresponding verbal reports of one's own mind-wandering seem to be strongly distorted by overconfidence bias, illusions of superiority, and the introspection illusion (in which we falsely assume direct insight into the origins of our mental states, while treating others' introspections as unreliable). It is probably also influenced (and not only for philosophers of mind) by confirmation bias related to one's own theoretical preconceptions and culturally entrenched notions of "autonomous subjectivity," by self-serving bias, and possibly by frequent illusions of control on the mental level. This interestingly relates the field of spontaneous thought to other burgeoning and increasingly active areas of research like self-deception (Pliushch & Metzinger, 2015). One positive empirical prediction resulting from this discussion is that at least all of the biases I have listed as examples in the preceding should be considerably weakened in long-term practitioners of mindfulness meditation (Hölzel et al., 2011).

What Exactly Is a "Unit of Identification"?

On the level of content, every onset and every ending of an episode of mind-wandering are characterized by an unexpected shift or sudden switch in the phenomenal "unit of identification" (UI). Here is an example. Let us say that at first you identify with the conscious content of an internal model of the self as currently standing at a red traffic light, waiting for it to turn green. Then an internal simulation of yourself as buying tofu and bananas pops up, as you "remember" that you need to buy tofu and bananas. Now you identify with the protagonist of *this* inner narrative, with the virtual self that constitutes the center of an automatic inner action simulation. Phenomenologically, and for a short moment only, you literally "become someone else." For a brief moment you "zone out" completely, and this constitutes an involuntary and unexpected shift in the UI. Then perceptual coupling may quickly be restored and you re-identify with the "driver," a model of the self as an attentional agent, quickly checking if the lights have turned green. This is the end of your mind-wandering episode. Phenomenologically, the driver is real again, and the shopper is only virtual—the shopper is now *not* the UI any more, but just the retrospective content of a sudden memory leading to a decision and an action plan. Now you may decide to "tune out" again, perhaps to see if an active inner simulation of yourself as buying tofu and bananas "makes other things come to mind." In initiating this, you are an autonomous mental agent. However, in the very moment you "remember" that you also wanted to buy almond butter and raisins, the UI switches again and you quickly "zone out" for a fast update, an enriched mental simulation of the shopper and its now extended task list. This is the beginning of mind-wandering episode number two, and it is functionally characterized by another brief loss of mental autonomy—another bout of "involuntary mental time travel" (Song et al., 2012). This second episode may take less than a second to unfold, and as the light suddenly turns green you "snap back" into the driver model, hastily shifting gears. The "snapping back" is the shifting of the UI, and it is the end of your second mind-wandering episode. There have been two episodes and four switches in the UI.

Mind-wandering is interesting for philosophers because it has great potential for illuminating a deeper understanding of phenomenal self-consciousness and the supra-bodily mechanisms of phenomenal self-identification (Blanke & Metzinger, 2009). Furthermore, if the model I have sketched in the preceding is correct, then progress in empirical research into mind-wandering and the computational modeling of neuroscientific data decisively depend on a better understanding of what exactly a UI is.

Let us say that for every self-conscious system *S* there exists a *phenomenal unit of identification* (UI), such that

- *S* possesses a single, conscious model of reality;
- the UI is a part of this model;
- at any given point in time *t*, the UI can be characterized by a specific and determinate representational content *C*;
- such that *C* constitutes the system's phenomenal self-model (PSM; Metzinger, 2003) at *t*.

If we assume a "predictive processing" model of human brain activity (Clark, 2016; Friston, 2010; Hohwy, 2013), then, for all human beings, *C* is always counterfactual content. The UI ultimately represents the best hypothesis the system has about its own global state. For human beings, *C* is dynamic and highly variable, and it does not have to coincide with the physical body as represented (for an example, see de Ridder, van Laere, Dupont, Menovsky, & van de Heyning, 2007). There exists a minimal UI, which likely is constituted by pure spatiotemporal self-location (Blanke & Metzinger, 2009; Metzinger, 2013a, 2013b; Windt, 2010); and there is also a maximal UI, likely constituted by the most general phenomenal property available to *S* at any point *t*, namely, the integrated nature of phenomenality per se (Metzinger, 2013a, 2013b, 2016). *C* is phenomenally transparent. Internally, *S* models the representational content constituting the UI as neither counterfactual nor veridical, but simply real. Phenomenally experienced realness is empirical Bayes-optimality; it is an expression of successful prediction error minimization, high model evidence, and counterfactual richness (e.g., invariance under counterfactual manipulation). The UI is the transparent partition of the PSM.

Self-consciousness and the possession of a UI are what make verbal self-reports possible. For some *S*, if *S* has functionally adequate linguistic abilities, it can indirectly refer to itself by referring to *C*, and so generating autophenomenological reports of the type "I *am* this!" Mastery of the first-person pronoun "I" consists in successful linguistic self-reference via the UI. It is a form of displaced reference, because it only directly refers to *C* without *S* being able to experience this fact consciously at *t*. The possession of a UI is the central causally enabling factor for all forms of intelligent behavior, bodily or mental, which presuppose the ability for self-reference. The possession of a UI is conceptually necessary for self-consciousness because self-consciousness *is* phenomenally represented identification, based on counterfactual content, via transparency. Biological systems sustain organismic integrity by preserving the integrity of their UI, constantly trying to minimize PSM-related uncertainty. Thus confabulation, delusion, and functionally adequate forms of self-deception are attempts to sustain the integrity and stability of the UI across time, under exceptionally high degrees of uncertainty.

My last positive proposal for developing a novel conceptual framework is the following: mind-wandering and "spontaneous task-unrelated thought" can be conceived of as an unintentional form of mental behavior, centrally involving involuntary and initially unnoticed shifts in the UI. It is presently unknown whether such shifts serve a biological purpose in all or only in some cases, let alone if there is one general function or specific neurodynamical signature under which all instances of UI-switching can be subsumed. But the general principle would be that distinct episodes of mind-wandering, whether separated by a period of meta-awareness and a regaining of M-Autonomy or not, are always "bracketed" by UI-shifts. Isolating the neural correlates and the dynamic functional mechanisms constituting such "brackets" would constitute an important step forward in describing the temporal boundaries and conceptually individuating single occurrences of our research target. If this is correct, then the more fundamental conceptual insight is that phenomenal self-consciousness is a highly discontinuous process.

Notes

1. Some sections of this chapter strongly draw on Metzinger (2013a and 2015). I want to thank Kalina Christoff and Kieran Fox for helpful comments on an earlier version of this chapter, and Lucy Mayne for equally helpful comments plus excellent editorial help with the English version of this text.
2. The term "spontaneity" plays a role in a number of classical philosophical theories of mind, perhaps most prominently in the theory of Immanuel Kant. Unfortunately, this point would lead beyond the scope of the present contribution. Let me point, however, to an interesting link connecting Kant to our currently best mathematical models of brain function: Presupposing a predictive-processing framework, mind-wandering might also be seen as the expression of a very deep form of "neurocomputational creativity" inherent in the very generative model of reality, which our brains continuously create and update by minimizing free energy (Friston, 2010). Continuous free-energy minimization would then be the creative mechanism that implements what Kant had in mind, when he spoke of "spontaneity." As Robert Hanna writes about spontaneity in Kant, "A cognitive faculty is spontaneous in that whenever it is externally stimulated by raw unstructured sensory data as inputs, it then automatically organizes or 'synthesizes' those data in an unprecedented way relative to those inputs, thereby yielding novel structured cognitions as outputs (B1–2, A50/B74, B132, B152). So cognitive spontaneity is a *structural creativity* of the mind with respect to its representations. [. . .] Kant also uses the term 'spontaneity' in a somewhat different sense in a metaphysical context, to refer to a mental cause that can sufficiently determine an effect in time while also lacking any temporally prior sufficient cause of itself (A445/B473). Call this *practical* spontaneity. What is shared between the two senses of spontaneity, practical and cognitive, is the unprecedented, creative character of the mind's operations" (Hanna, 2016, Section 1.1) Free energy minimization would then be the transcendental condition of possibility for both knowledge and action (see Metzinger & Wiese, 2017).
3. Metzinger (2013a) was the first empirically informed sketch of an explicit, positive model of mind-wandering from the philosopher's camp. A substantial and careful criticism of this model can be found in Irving (2016).
4. "Transparency" is a property of conscious representations, namely, that they are not experienced *as* representations. Therefore, the subject of experience has the feeling of being in direct and immediate contact with their content. Transparent conscious representations create the phenomenology of naïve realism. An opaque phenomenal representation is one that is experienced *as* a representation, for example in pseudo-hallucinations or lucid dreams. Importantly, a transparent self-model creates the phenomenology of identification (Metzinger 2003a, 2008). There exists a graded spectrum between transparency and opacity, determining the variable phenomenology of "mind-independence" or "realness." Unconscious representations are neither transparent nor opaque. See Metzinger (2003b) for a concise introduction.
5. This section strongly draws on Metzinger (2015).
6. Functional properties are abstract properties referring to the *causal role* of a state (the set of its causal relations to input, output, and other internal states), without implying anything about the properties of its physical realization. Just like states described in a Turing machine table or computer software, they are multi-realizable. Since M-autonomy is a functional property, it could in principle also be implemented in a machine.

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CHAPTER

10

Spontaneity in Evolution, Learning, Creativity, and Free Will: Spontaneous Variation in Four Selectionist Phenomena

Dean Keith Simonton

Abstract

This chapter proposes that spontaneous variation has a central role in biological evolution, operant conditioning, creative thinking, and personal agency. But to support these advantageous outcomes, this spontaneity must be joined with some selection process or procedure that decides which alleles, behaviors, ideas, or choices are most adaptive or useful. The argument begins with spontaneous variations in evolutionary theory, and then turns to operant conditioning, with emphasis on the origins of spontaneous behaviors. That analysis leads directly to a discussion that introduces a three-parameter definition of both creativity and sightedness, two concepts that provide the foundation for the blind-variation and selective-retention model of creativity. The latter is then linked with the chance-then-choice theory of free will, a linkage that makes spontaneous choice generation the first of two steps leading to personal agency. In all four phenomena, spontaneity is defined as the production of variants in ignorance of their actual utilities.

Key Words: spontaneity, biological evolution, operant conditioning, creative thinking, free will

In this chapter I will argue that spontaneity, especially in the form of "spontaneous variations," plays an essential role in the acquisition of new adaptations and knowledge. Without such spontaneity, species never would have evolved, organisms would never learn, and new knowledge would never have been discovered or created. I will even go so far as to argue, toward the end of this chapter, that spontaneity has a critical role to play in personal agency or "free will." However, it will also become clear that spontaneity is a necessary but not sufficient basis for attaining all of these highly valued ends. By itself, spontaneous variation goes nowhere beyond the transient act of generating original and surprising alleles, behaviors, thoughts, or choices. To take the next step, the products of spontaneity must be subject to selection, a process or procedure that chooses a small subset of emitted effects—often only a single variant—to become a more enduring trait. Indeed, selection operates to construct a repertoire of non-spontaneous adaptations to the world, as well as established knowledge about the world (see also Cziko, 2001; Dennett, 1995).

Admittedly, I might have used other terms besides "spontaneous variation" and "environmental selection" to get this point across. Examples include "trial and error," "generate and test," "selection by consequences," "bold conjecture and refutation," or "blind variation and selective retention" (e.g., Bain, 1855/1977; Campbell, 1960; Nickles, 2003; Popper, 1963; Skinner, 1981). But I will retain the term "spontaneity" for three reasons. First, and most obviously, by using that term I can more easily justify my chapter's inclusion in this *Handbook*. Second, the concept of spontaneous variation has a pedigree going back more than 150 years, as will be discussed shortly. Third and last, even though the term "spontaneity" will briefly recede into the background in the middle portion of this chapter, it will again come in most handy toward the end by serving as an integrative concept. By then it will also become obvious why spontaneity probably provides a superior concept than "randomness," a somewhat related but distinct concept that is sometimes applied to the same phenomena.

I begin the chapter with a treatment of the selectionist theory of biological evolution. I next turn to a discussion of learning, with a special focus on Skinnerian operant conditioning. That discussion leads seamlessly to a more extended analysis of creativity, an analysis that will then be extended to a treatment of free will.

Evolution

The central thesis of Darwin's (1860/1952) theory of evolution by natural selection is that members of a species exhibit variation on a host of traits and that this variation is subject to selection, so that only the fittest variants survive and reproduce. For Darwin, this variability was an inevitable feature of organisms representing almost any species. One particular source of this variability was what he styled "spontaneous variation," a term used about a half dozen times in his *Origin of Species*. However, his usage is somewhat restricted to what could also be called "sudden" variations or "sports" (cf. "hopeful monsters" discussed in Johnson & Bouchard, 2014). Insofar as such variants could contribute to evolution by adding to the general variability of species subjected to natural selection, Darwin admitted that they had some place in evolution, an admission that increased over the course of his career. Nonetheless, Darwin emphasized that spontaneous variations were not uncaused, but rather that we did not have a complete understanding of how such variants came about. The essential point remains that all variations were generated without regard to their inherent fitness. Instead, their fitness had to be determined by each variant's interaction with the environment. If otherwise, selection would not be necessary because all organisms would be equally fit. The fact that not all or even most variants will survive "the struggle for existence" (the title of *Origin*'s third chapter) is ample evidence that variation is not prescient. Post hoc validation is mandatory.

From a contemporary perspective, Darwin's theory of evolution proves inadequate. Two major flaws stand out. First, he lacked a modern theory of inheritance. Although nearly contemporary, Mendel's genetics did not become well known until long after Darwin's death. Indeed, Darwin advocated a version of the now discredited theory of acquired characteristics, a version known as pangenesis. Second, Darwin could not possess a modern theory of how variations originate, spontaneous or otherwise. He certainly could not appreciate that these two inadequacies in his theory were closely related: Only after obtaining a valid theory of genetic inheritance could evolutionary theory obtain an adequate theory of variation.

Of course, these problems with evolutionary theory were resolved in the middle decades of the twentieth century with the advent of the movement variably styled as the New Synthesis, Modern Evolutionary Synthesis, or, somewhat inaccurately, Neo-Darwinism (see Mayer & Provine, 1998). Not only was inheritance rooted in the genes, but these genes could undergo unexpected mutations as well as genetic recombinations. The mutations could thus be said to provide the basis for the spontaneous variations mentioned in *Origin*. That is, new genetic traits could appear out of the blue. Although these genetic mutations were most often deleterious and thus quickly vanished from the gene pool, other mutations might confer superior fitness on the lucky organism. Natural selection can then operate to increase the relative frequency of these novel traits in the population. Selection remains necessary because, according to contemporary Darwinian theory, the mutations emerge without any foresight regarding their fitness values. That said, not all biologists accepted this view, some believing that mutations can be "directed" or "guided" to maximize fitness in advance (Lenski & Mittler, 1993). This dissenting position has inspired considerable debate. This controversy compels me to close this discussion by defining what it means for a mutation to be directed or guided rather than strictly "spontaneous."

A reasonable formal definition was provided by Sober (1992): "Let u be the probability of mutating from A to a and v be the probability of mutating from a to A. Mutation is directed if (i) u>v and (ii) u>v because w(a)>w(A), where w(X) is the fitness of X" (p. 39). The "because" in condition (ii) is critical as it indicates that the relative probabilities are *caused by* the relative fitness values of a and A. The organism somehow knows in advance that one trait has higher fitness than the other and adjusts the probabilities accordingly. In contrast, if condition (ii) proves invalid, then we can infer that variation and selection are "decoupled," meaning that the "twin sub-processes of variation and selection . . . take place quite independently, so that the factors responsible for the selective perpetuation of variants are entirely unrelated to those responsible for the original generation of those same variants" (Toulmin, 1981, p. 337). Stated yet differently, when a mutation fails to meet Sober's requirements for directedness, we can claim that the mutation is completely *spontaneous* in the precise sense that it occurs without any prior information about its adaptive value. The variant was not generated *because* it was already known to bestow higher fitness. The last possibility then requires that selection be introduced.

Notice that Sober's definition has two major features. First, it makes no reference whatsoever to chance or randomness. That is, it does not specify how variation and selection are decoupled, but rather just affirms what is required for the two processes to be considered decoupled, unguided, or undirected. This omission is important because chance and randomness are extremely difficult constructs to define precisely (Simonton, 2007). Indeed, given that computers routinely produce perfectly random numbers using deterministic algorithms (a.k.a. "pseudorandom number generators"), the distinction between determinism and indeterminism can become a bit fuzzy. To be sure, random variations would be expected to be undirected, yet undirected variations need not be random at all. The same holds for spontaneous variations.

Second, Sober's definition yields a discrete outcome. A mutation-based variation is either undirected or directed, spontaneous or not. This dichotomous outcome is consistent with standard Darwinian theory, which demands that variations always be undirected. Even so, as will become evident in the next section, not all variation mechanisms must impose this requirement. As a consequence, this attribute of variations can just as well be quantitative rather than qualitative. In particular, for certain phenomena, spontaneity may be a continuous variable ranging from totally spontaneous to perfectly unspontaneous (cf. Kronfeldner, 2010). This provision provides another reason to prefer "spontaneous variations" over "random variations." Unlike the concept of spontaneity, the distinction between random and determined events is most often viewed as qualitative rather than quantitative.[1]

Learning

Edward L. Thorndike was perhaps the first major psychologist to introduce selectionist principles into learning theory: his *law of effect* says that emitted behaviors will be either strengthened or weakened according to whether the environmental consequences are either positive or negative. He demonstrated this law using his puzzle boxes in which cats had to learn to escape. At first the trapped animals would just spontaneously emit *seemingly* random behaviors until by chance they pressed a lever that opened the door to the outside. As the poor cats endured repetitions of the experiment, the amount of time taken to escape would decrease until they eventually wasted no time getting out. One common criticism of these experiments is that the cat had no opportunity to display intelligent behavior. The situation was so novel, and the solution so arbitrary, that the cat had no other option but to engage in unintelligent trial and error: the cat could only emit spontaneous responses until it received a reward, after which the law of effect would take over until only the single adaptive behavior remained. Put differently, spontaneity was systematically extinguished until it totally disappeared. The cat had learned the one action that worked.

B. F. Skinner took over where Thorndike left off and vastly improved and expanded the experimental paradigm under the overall label of operant conditioning. At first his research had some of the same limitations as Thorndike's. A rat or pigeon in a Skinner box had a similarly restricted range of adaptive responses to acquire, such as pressing a lever or pecking at a disk. Yet he eventually expanded his research to incorporate *shaping*, in which ever closer approximations to a desired behavior were induced by a systematic application of reinforcement and extinction. Pretty soon he had conditioned pigeons to play a toy piano or compete at ping pong, among other amazing achievements. Whatever the particular end result, operant conditioning was again used to whittle a broad repertoire of spontaneous behaviors down to a well-defined and highly specific behavior or set of behaviors. The selectionist basis for this winnowing procedure was made explicit when he termed it "selection by consequences" (Skinner, 1981; see also Smith, 1983). Even so, Skinner devoted insufficient attention to the origins of the spontaneous behaviors on which selection had to operate.

This last deficiency was remedied by one of his students and collaborators, Robert Epstein (1991), who had earlier conducted experiments in which a pigeon displayed insight behavior very similar to that displayed by chimpanzees in Kohler's (1925) classic studies (Epstein, Kirshnit, Lanza, & Rubin, 1984). He then devised a formal explanation known as *generativity theory*, which he developed as a sophisticated computer model (Epstein, 1990, 2015). In simple terms, his theory offers a combinatorial model in which spontaneous behaviors entail recombinations of established behaviors. When faced with a routine situation in which the response with the highest probability is also the one most likely to receive reinforcement, the organism has no need to resort to behavioral spontaneity. Yet when the organism encounters a novel situation and quickly learns that the most probable responses do not work, then the probabilities are appropriately adjusted. Ineffective prior responses are eventually replaced with combinations of prior responses until one particular unforeseen combination emerges that would receive reinforcement. Spontaneity is then dramatically reduced for that situation, but the organism has also acquired an adaptation that it did not have before—such as a pigeon moving a small box under a "banana" hanging from above and then standing on the box to peck at the object to obtain a food pellet. Unlike standard learning, where the curves are gradual, the pigeon's switch to this new behavioral combination is quite abrupt, looking like a genuine insight—a Eureka experience!

Note that evolution also depends on combinatorial processes. Besides genetic recombination, which is explicitly combinatorial, spontaneous mutations most often depend upon the various ways that genetic material can recombine at the molecular level.

Creativity

Epstein's 1991 paper was entitled "Skinner, Creativity, and the Problem of Spontaneous Behavior" and his generativity theory was explicitly labeled a theory of creativity (Epstein, 1990, 2015), which allows a smooth segue into the topic of this section. Moreover, a strong case can be made that all forms of creativity are inherently combinatorial (Simonton, 2017). For example, Thagard (2012) showed that 100 top discoveries and 100 top inventions can each be identified as combinatorial products of various kinds. Furthermore, combinatorial models, both mathematical and computational, have provided effective simulations of key phenomena associated with creativity (Simonton, 1997, 2010; Thagard & Stewart, 2011). Yet it must be recognized that not all combinations are creative. On the contrary, highly creative combinations are very rare (Simonton, 2012a). Hence, we must devise a metric that assesses the creativity associated with any given combination. Before we can do so, we first must define three parameters. These definitions then permit us not only to define creativity, but also to define a second construct that can be considered the absolute inverse of spontaneity. Although the definitions are somewhat formal, the formalities have higher payoffs than trying to define the same concepts in more informal terms. Sometimes precision really is better than vagueness. Fortunately, the mathematics does not exceed that found in any introductory probability course.

The Three Parameters

Suppose someone generates k ideational or behavioral combinations, namely, x_1, x_2, x_3, . . . x_i . . . x_k, where $k \geq 1$ (e.g., k potential solutions to a given problem). These combinations can then be described by the following three parameters (cf. Simonton, 2013a, 2016):

1. The *initial probability* p_i (where $0 \leq p_i \leq 1$). This parameter can also be considered a response strength at the onset of an episode in which the combination may be generated.
2. The *final utility* u_i (where again $0 \leq u_i \leq 1$). Although technically a continuous variable, u_i can sometimes assume discrete all or none values, where 1 = useful and 0 = useless. The adjective "final" means that the combinatorial evaluations have been finalized.
3. The *prior knowledge* v_i of the utility (where once more $0 \leq v_i \leq 1$). If $v_i = 0$, the value of u_i is not known in advance of evaluation process or procedure, whereas if $v_i = 1$, the utility value is already known perfectly. If the prior knowledge value falls somewhere between the two outer values, such as $v_i = .5$, then the individual may only experience a "hunch" or a vague "feeling of knowing" state, lacking absolute confidence in the actual value of u_i.

The values of these three parameters are independent when any given pair is considered. For instance, the prior knowledge of the utility is orthogonal to the value of the utility. One might know with utter confidence that the combination is useful or useless; or one may be completely ignorant of whether the combination is useful or useless. Nevertheless, the specific parameter values assigned u_i and v_i taken together strongly constrain the most plausible parameter values for p_i. In particular, if $u_i = v_i = 1$, then a rational being would set $p_i = 1$, whereas if $u_i = 0$ but $v_i = 1$, then the same rational being would set $p_i = 0$. Indeed, these two constraints can be taken as a *definition* of rationality! Moreover, operant conditioning can be described as the phenomenon where p_i goes to 1 because $u_i = 1$ and v_i goes to 1. In other words, as an organism learns which response is most useful, the probability of the most adaptive response increases.

We can now define not just creativity, but also another important construct called *sightedness* (cf. Simonton, 2012b, 2013a, 2016).

Creativity and Sightedness

The creativity of any combination x_i is given by the following three-factor product:

$$c_i = (1 - p_i)u_i(1 - v_i), \quad \text{where } 0 \leq c_i \leq 1$$

Here $(1 - p_i)$ defines the *originality* of combination x_i (i.e., the inverse of its probability) and $(1 - v_i)$ represents the combination's *surprise* (i.e., the inverse of the utility's prior knowledge value). The combinations that most surprise are those that give us knowledge that we didn't have before. This third factor functions like the "non-obvious" criterion used as the third benchmark of the US Patent Office (Simonton, 2012c). According to this multiplicative integration, a combination's creativity must be zero if any one of the three factors is zero: Unoriginal, useless, and/or obvious combinations cannot be creative no matter what. Interestingly, if utility and surprise are held constant at unity values, then creativity will only approach unity if the initial probability approaches zero, where $(1 - p_i) = 1$ implies that $p_i = 0$. Hence, the maximally creative combinations are those that cannot be generated right away, but rather require an incubation period before they flash to mind in a brilliant insight!

Besides a combination's creativity, we must also define its sightedness, which is given as:

$$s_i = p_i u_i v_i, \quad \text{where } 0 \leq s_i \leq 1$$

In words, highly sighted combinations have high initial probabilities, are highly useful, and that usefulness is already known in advance. Indeed, for rational beings, as $u_i v_i \rightarrow 1$ then $p_i \rightarrow 1$, as noted earlier. The combination is then diametrically opposed to spontaneity; the combination is elicited precisely to accomplish some useful outcome. Significantly, as $s_i \rightarrow 1$ then $c_i \rightarrow 0$, indicating that highly sighted combinations cannot be creative because they represent routine, habitual, or reproductive thinking. But what happens as sightedness goes to zero? Does that mean that creativity goes to unity? No, not at all. The combination might have low sightedness because $u_i = v_i = 0$, which would make $c_i = 0$ as well. In short, low sightedness also applies to all combinations with low but unknown utilities.[2]

To get a better idea of what is happening here, Figure 10.1 provides a scatterplot describing the hypothesized relation between creativity and sightedness (Simonton, 2012a). Observe that as we advance from the most sighted to the least sighted combinations, we get the following outcomes: (a) the maximum possible creativity increases in an accelerated function; (b) the minimum possible creativity stays constant at zero; and (c) the conditional distribution of creativity for a given level of sightedness becomes more skewed, with uncreative combinations vastly outnumbering creative combinations—meaning that the most creative combinations are located where the most uncreative combinations are found. This paradox raises the question: How does one separate the wheat from the chaff, especially when the biggest kernels are hidden among the most chaff?

Blind Variation and Selective Retention

Donald Campbell (1960) put forward a solution to the last problem: the *blind variation and selective*

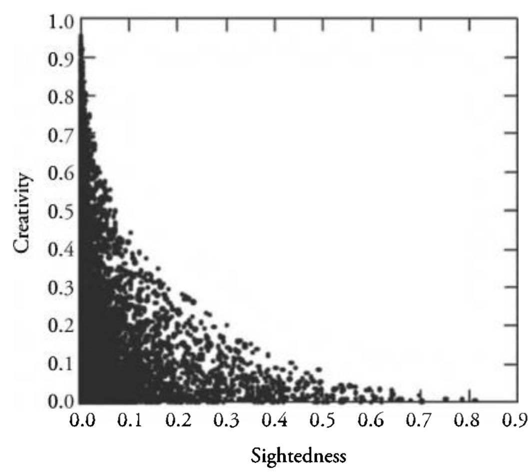

Figure 10.1. Scatter plot showing the relation between sightedness and creativity for Monte Carlo generated combinations, where sightedness is just the inverse of blindness (viz. $b_i = 1 - s_i$). The most creative combinations are found on the left side of the graph, where the most uncreative ideas are also located, thus requiring the implementation of BVSR, generation and test, or trial and error. The graph is adapted from Figure 4 in D. K. Simonton (2012a), Combinatorial creativity and sightedness: Monte Carlo simulations using three-criterion definitions, *The International Journal of Creativity & Problem Solving, 22*, 5–17.

retention theory of creative thought and "other knowledge processes." Often abbreviated BVSR, this theory says that creativity and the acquisition of new knowledge requires that the person generate blind variants that are then tested against the real world (whether in the environment directly or via internal representations of that reality). Unfortunately, Campbell's presentation of this theory was a bit too informal and anecdotal, with little attention given to defining the key constructs (Martindale, 2009). These communication issues have led to numerous misunderstandings, such as thinking that BVSR required combinations to be produced randomly or that the combinations be equiprobable, neither of which is true (Campbell, 1960; Simonton, 2011b). Instead, the combinations only have to be generated blindly, which most often just means that the person spontaneously conceives the combination without complete prior knowledge of its utility, and thus requiring a subsequent test. Expressed in terms of our current formalisms, high blindness is equivalent to low sightedness because any combination's blindness $b_i = 1 - s_i$. In other words, the creator must produce "spontaneous variations" and then subject them to evaluation, retaining only those that satisfy the given utility criterion. BVSR operates at the left "blind" side of Figure 10.1 because that is the only place where the most creative combinations are located.

It should be obvious that BVSR operates approximately the same way as operant conditioning, as argued by Epstein's (2015) generativity theory. At the same time, BVSR and operant conditioning work somewhat differently from the combinatorial processes seen in biological evolution. Although blindness and sightedness define two ends of a continuum for both learning and creativity (Simonton, 2011a), natural selection only operates with totally blind genetic combinations and mutations. That is, if biological variants are undirected, according to Sober's (1992) definition, then it necessarily follows that $v_i = 0$ and hence $s_i = 0$. Only operant conditioning and creativity can function somewhere in the middle of the bipolar continuum defining the horizontal axis in Figure 10.1.

Free Will

This updated BVSR theory of creativity is largely isomorphic with a major theory of free will: the *chance then choice* theory (Simonton, 2013b; cf. Doyle, 2011). The latter theory attempts to find a solution to the fundamental problem that both determinism and indeterminism are antithetical to genuine free will (Dennett, 1984). Choices are obviously not free if they are utterly determined, but they are also not free if they are generated randomly because they would no longer indicate anything representative of the person making a bona fide choice (cf. James, 1884). The theory's solution is to conceive free will as a two-step process, just as BVSR entails a two-step operation. More specifically, the "two-stage model effectively separates chance (the indeterministic free element) from choice (an arguably determinate decision that follows causally from one's character, values, and especially feelings and desires at the moment of decision)" (Doyle, 2010, p. 8). Saying that the decision is "determinate" just means that the individual determines the choice, rather than the decision being imposed from outside the person, by extraneous forces, and thereby not representing a genuine choice. The individual thus remains an agent.

Admittedly, the BVSR theory of creativity and the chance-choice theory of free will have some differences, too. Yet while some of these differences are essential, others are peripheral and can thus be modified. In the former category is the fact that BVSR aims at identifying the most creative combination, whereas chance-choice endeavors to identify the most useful one, at least in the sense of fitting the individual's personal disposition at the time the choice is made. Only in the case of highly creative persons might the most favored choice also prove less useful. For instance, an avant-garde artist might deliberately sacrifice some utility for originality, producing a highly shocking work that only appeals to a tiny group of cognoscente.

In the category of peripheral differences is the contrast between the "blindness" of BVSR theory and the "chance" of the chance-choice theory. Because this contrast is superficial, it can easily be removed. Just as BVSR does not require the random generation of combinations, free will really should not demand that choices be generated by chance. Instead, the choices only need to be produced blindly, meaning that they are produced without prior knowledge of their utility values (i.e., $v_i = 0$), thereby requiring the second stage in the process, the selection or decision stage. For example, if a person contrives a grid containing all possible options using combinatorial procedures, then those choices are blind without being random. The second step is still required to separate the wheat from the chaff, just as in BVSR. Expressed differently, choices must be spontaneously generated, without regard to potential utilities, and then the utilities evaluated at a later stage.

The preceding argument implies that free will might itself be viewed as often involving a combinatorial process or procedure, just like creativity and operant conditioning (Simonton, 2013b). Indeed, this particular theory has been called "Valerian free will" (Doyle, 2011; cf. Dennett, 1978) after the words of the French poet, Paul Valéry: "It takes two to invent anything. The one makes up combinations; the other one chooses, recognizes what is important to him in the mass of things which the former has imparted to him" (Hadamard, 1945, p. 30). Yet Valéry's assertion concerns creativity ("invention"), not free will per se. By implication, creativity can be used to make people freer by using combinatorial processes or procedures to generate more choices. Personal freedom or agency depends on the capacity for spontaneity, that is, the capacity for generating options without prior knowledge of which will later be considered most useful (i.e., the final utility u_i).

One remarkable feature of this new version of the chance-choice theory is that it provides new insights into the nature of free will. These insights all ensue from the fact that choices that come from the blind end of the choice combinations in Figure 10.1 will operate to increase personal freedom (Simonton, 2013b). Already this leads to the striking implication that free will itself is not an all-or-nothing psychological event, but rather is situated on a continuous dimension from minimally to maximally free. In addition, any factors that enable the individual to operate at the blind end will enable the person to be freer. For example, as the number of choices increases (i.e., as k increases), so will freedom, all other factors held constant. Moreover, as the choices become more equal in their initial probabilities (i.e., as $p_i \rightarrow 1/k_i$ for all i), free will correspondingly increases in a nonlinear but monotonic fashion, again with all other factors held constant.

Besides those logical implications, I can also argue that factors that empirical research has found to enhance creativity would also serve to increase free will. Given that argument, we can say that personal agency or autonomy will be higher for those individuals for whom certain cognitive processes, personality traits, developmental experiences, and environmental conditions support the generation of highly unsighted ideational or behavioral combinations (Simonton & Damian, 2013; Simonton, 2003). These supportive factors include openness to experience (McCrae & Greenberg, 2014); reduced latent inhibition, defocused attention, or cognitive disinhibition (Carson, 2014); psychoticism (Eysenck, 1994; Stavridou & Furnham, 1996; cf. Acar & Runco, 2012) or schizotypy (Nettle, 2006; cf. Acar & Sen, 2013); divergent thinking and remote or rare associations (Gough, 1976; Guilford, 1967; Mednick, 1962; Rothenberg, 2015); multicultural experiences (Godart, Maddux, Shipilov, & Galinsky, 2015; Leung & Chiu, 2008; Leung, Maddux, Galinsky, & Chiu, 2008; Maddux, Adam, & Galinsky, 2010; Saad, Damian, Benet-Martinez, Moons, & Robins, 2013); and varied kinds of novel, incongruous, random, or chaotic environmental stimuli (Damian & Simonton, 2014; e.g., Ritter et al., 2012; Rothenberg, 2015; Vohs, Redden, & Rahinel, 2013). Both separately and together, these factors enable the individual to conceive combinations located toward the left side of the scatter plot shown in Figure 10.1. Because these spontaneous combinations are generated without prior knowledge of their utilities, and hence without awareness of whether the choices will be selected, the resulting decision enjoys far less psychological predictability.

Conclusion

I have just discussed biological evolution, operant conditioning, BVSR creativity, and a modified version of the chance-then-choice theory of free will. Permeating all four sections was the concept of spontaneity, although that concept's explicit involvement was not uniform. I started with spontaneous variation in Darwin's theory of evolution. Although this concept had a more limited role in his theory, its importance was expanded in the New Evolutionary Synthesis with the advent of spontaneous genetic mutations. I then turned to learning, and especially operant conditioning, ending with a treatment of the origins of spontaneous behavioral variants. The latter discussion led quite naturally to the section on creativity, and its concentration on the blind variation and selective retention theory (BVSR). I argued that "blind" variation might just as well be called "spontaneous" variation. That notion was then carried over to the final analysis of free will, a phenomenon that can be analyzed in BVSR terms. Spontaneity then becomes a source of personal autonomy.

The use of the noun "spontaneity" or the adjective "spontaneous" may seem highly variable across these four contexts. But they do share a single conceptual basis. The words were used in all four situations to describe when variants—whether alleles, behaviors, thoughts, or choices—are emitted without prior knowledge about their ultimate fitness or utility values. Hence, the outcomes cannot possibly be generated *because* they are useful. That prior ignorance then requires the imposition of a second selection stage, whether evolution's natural selection, operant conditioning's selection by consequences, BVSR's selection and retention, or free choice's decision phase. Naturally, the latter necessity implies that many, if not most, of these variants will feature no fitness or utility whatsoever. Many mutations will be maladaptive; many behaviors initially emitted in a Skinner box will yield no food pellet; many combinations produced during creative thought will end up being rejected; and many options pondered in life will not be chosen. In that respect, spontaneous variants are awfully wasteful. Yet without the capacity for such spontaneity, species could not evolve, organisms would never learn, individuals could not be creative, and persons could not construct their own lives. Those four adverse consequences should suffice to explain why spontaneity pervades such diverse phenomena!

Notes

1. In truth, one can argue that randomness and determinism represent opposite ends of a quantitative bipolar dimension. To provide an everyday illustration, if I put a wadded up piece of paper into the wastebasket right next to my desk chair, the event can be considered totally deterministic. It was inevitable that the event would happen. But if I toss the same ball of paper into a wastebasket at the other end of my large office, and it goes straight in without even touching the rim, most observers, including me, would attribute that perfect toss to pure luck. Yet if I decided to move the target closer to my desk to avoid the accumulation of failed shots on the surrounding floor, it would be absurd to specify that precise distance between me and the wastebasket where this event switches from random to deterministic. If an NBA player makes 80% of his free throws but 20% of his 3-point attempts, is the former deterministic but the latter random?
2. I am deliberately oversimplifying here. If a blind combination is defined as one in which $s_i = 0$, then there are seven different types of blind combinations, only four having $v_i = 0$ (viz., creative ideas or responses, fortuitous response bias, problem finding, and blissful ignorance, discussed in Simonton, 2016). Excluding creative combinations, six of these seven types are represented by the data points in the lower left-hand corner of Figure 10.1 (albeit not all types are equally probable, at least for rational creatures). Discussing these complications would take us too far from the current goal of formally representing spontaneity.

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CHAPTER

11

How Does the Waking and Sleeping Brain Produce Spontaneous Thought and Imagery, and Why?

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Abstract

Although mind-wandering and dreaming often appear as trivial or distracting cognitive processes, this chapter suggests that they may also contribute to the evaluation, sorting, and saving of representations of recent events of future value to an individual. But 50 years after spontaneous imagery—night dreaming—was first compared to concurrent cortical EEG, there is limited hard evidence on the neural processes that produce either visual dreaming imagery or the speech imagery of waking spontaneous thought. The authors propose here an outline of a neurocognitive model of such processes with suggestions for future research that may contribute to a better understanding of their utility.

Key Words: mind-wandering, dreaming, imagery, neural process, cognition, neurocognition

Cognitive Utility

Whether daydreaming and mind-wandering are a cognitive disability or whether they have some value for an individual has been hotly debated over the past century. Given that spontaneous imagery and thought occupy a substantial part of everyone's waking day and sleeping night, the question deserves attention. Industrial psychologists in the service of assembly-line efficiency continue to see daydreaming as the enemy of productivity—which Charlie Chaplin hilariously parodied in *Modern Times* (1936). And the factory ethic has been vigorously carried over into school classrooms, where teachers see mind-wandering as inattention, incompatible with learning. Woodworth (1921, pp. 496, 499) suggested that a person lacking in "the personal force needed in dealing with other people, may take refuge in daydreams as a substitute for real thing." Indeed, the very words "daydreaming" and "mind-wandering" have a pejorative quality that is incompatible with any positive function. Expanding this negative viewpoint, some moralists associated dreaming and daydreaming to sexual and other taboo ideation. But Jerome L. Singer saw the positive side of daydreaming. Although professionally trained as a clinical psychologist, his liberal arts background constantly reminded him of the value of a rich inner life described by novelists and poets. His argument for that positive value persuaded the National Institute of Mental Health (NIMH) in 1958 to award him the first research grant to study the "Dimensions of Fantasy: Imagination Aspects of Internally-Produced Cognitive Processes Production." Starting as his first graduate assistant, we actively collaborated for many years as we moved from Teachers College, Columbia University, to City College, City University of New York, and Jerome moved on to Yale University. To distinguish imaginal thought from perceptual cognition, we called it "stimulus-independent thought" which had the convenient acronym "SIT." However, as we show in the following, the neurocognitive processes that generate the speech portion of thought are significantly different from those that produce the visual image portion. So we now prefer "spontaneous thought and imagery (STI) to represent their collective production.[1]

"I've got to . . . wash the dishes, . . . call my mother, . . . go to the bank, . . . gas up the car, . . . make a date for Friday night, . . . pick up the groceries, . . . finish the paper, . . ." illustrate the positive contribution of STI to personal planning and personal concern (Andrews-Hanna, Smallwood, & Spreng, 2014; Klinger, 1971, 1999, 2009; Singer, 1966, 1970; Spreng & Andrews-Hanna, 2015). But note that the external perceptual processes that compete with STI (reading this text, listening to the teacher, watching the car in front of yours, checking the output on the assembly line, etc.) are *also* of personal concern. The personal concerns of STI and external sensory perception are in continuous competition. Whether the cognitive system produces STI or attends to external stimuli requires the comparison of the relative estimated value of the two, and this comparison is continuous across time and space. If processing current visual or auditory stimuli is of greater value than STI, STI production should stop. But if the external world holds little interest, one may switch to his or her private thoughts, whether for entertainment or personal concerns. In the framework of *utility* theory (payoff minus cost), the utility of sensory perception is continuously weighed against the utility of STI (Antrobus, 1999; Antrobus, Singer, & Greenberg, 1966). The ideal cognitive system maximizes utility by estimating the utility of each and choosing the alternative that offers the best payoff minus cost. And since STI can be generated while one is brushing one's teeth, walking down a crowded street, driving to work, and even in a drowsy or sleep state, the cost of generating STI may be so small that it is easily offset by the value of generating the small everyday reminders that we scarcely notice, such as "turn on the kettle, . . . where is my cell phone, . . . time to go to class."

This competition between STI and sensory perception provides a convenient way to determine how the interacting networks of executive processes within the cognitive system compare with the value of STI versus sensory perception and how they accomplish the deft switching back and forth between the two. In order to measure the conditions under which the cognitive system chooses STI, we employed a one-hour STI versus information-processing task in which subjects, sitting in a light- and sound-attenuated room, were cued every 15 seconds to indicate (Yes/No with a toggle switch) whether any STI occurred in that prior interval (15-sec intervals were optimally sensitive to STI because the probability of STI in longer intervals was close to 1; Antrobus, Singer & Greenberg, 1966). To our surprise, we found that, unlike the popular stereotype, daydreaming, i.e., STI, is not limited to intervals of extended boredom. When we systematically varied the "free time" interval between response and next sensory stimulus within 15-second trials, STI was reported in "free" (inter-response-stimulus) intervals as short as 1 second! Perhaps we never notice these brief moments of STI in our everyday life, but they may nevertheless have a useful function. As William James noted, the mind never goes blank: ". . . we must simply say that thought goes on" (1890, Vol. 1, p. 225).

The 1966 experiments support the basic STI utility model. As predicted, increasing the payoff for processing the task stimuli significantly increases task performance and does so at the expense of decreasing STI production. But note that the cognitive system does not wait until its sensory-processing resources are idle to produce STI. In order to ensure that task performance and STI production do not compete for the processing resources that they share, the cognitive system learns to anticipate when cognitive resources may be free, even if for a second, to produce STI. As evidence, holding task information rate per 15-second interval constant, Drucker showed that STI production was substantially higher when task stimuli were presented at a constant and therefore predictable inter-stimulus intervals, compared to variable and therefore unpredictable inter-stimulus intervals (see Antrobus, Singer, Goldstein, & Fortgang, 1970).

The personal concerns that dominate such a large part of STI are represented in the continuous evaluation of memories of recent events. This evaluation process functions to identify memories that are, indeed, of personal concern or threat, and should be saved for further attention, or consolidated in a more stable frontal cortex memory, versus those which can be safely ignored and discarded. In order to determine whether the STI increases in response to real threat, we exposed subjects, in 1965, to a (fake) radio broadcast reporting a major escalation in the Vietnam War and a likely draft call of all college-age males. As predicted, relative to the control group, subjects exposed to the fake broadcast produced significantly more STI throughout the entire hour. Although the war threat broadcast slightly decreased task performance, as predicted by the utility model, the decrease was short of statistical significance. We suggest that the different time distributions of the task and STI payoff saved task performance from being sacrificed to STI. The cognitive system had only 1 second to recognize each task stimulus, but the response to the war threat could be postponed for at least an hour. Now, like Woodward, you might ask, what is the utility of STI regarding an impending war if there is nothing you can do about it?

I suggest that the first job of the cognitive system is to compute and "read out" STI—in this case, the implicit threats in the radio war broadcast and the names of friends vulnerable to the draft—so the cognitive system can determine if the STI does indeed describe a potential threat. If so, the cognitive system may move out of the STI mode and activate deliberate thought to determine the utility of possible overt alternative responses to the threat. And many of our subjects started to do just that! In the experiment debriefing session, prior to telling them it was a fake broadcast, many subjects described vivid images of being cruelly tortured by enemy soldiers. Until we intervened by telling them that the war threat broadcast was a fake, they planned to immediately notify all their friends who were vulnerable to the draft, and some recommended leaving for safety in Canada (Antrobus, Singer, & Greenberg, 1966). Note how the cognitive system simultaneously maximizes the utility of the task and STI production. It weighs the benefit minus cost of the information-processing task, STI production, and an overt response to threat to maximize overall utility. Since subjects were penalized at different rates for information-processing errors and STI is produced in the "free time" between successive responses and next stimuli, utility for task and STI were in conflict. So as we increased the financial cost of a task error, the rate of generating STI decreased. Since the danger of one's friends who might be drafted would not be affected by a one-hour delay, the utility of overt response to the draft threat, the utility of task performance, and the utility of STI production appear to be jointly maximized.

The role of the STI response in initiating overt responses to the war threat does not imply that the utility of STI is limited to eliciting behavioral solutions to personal concerns. I suggest that the cognitive system continually scans through recent memories to determine which require more deliberate problem-solving attention, which need to be saved in a more permanent form, which suggest revision of earlier memories, and of equal importance given the finite storage capacity of our brains, which are of such little personal concern that they can be discarded. These rather different values are illustrated when we systematically sample STI in waking individuals over an extended time, as described in the preceding. STI is initially concerned exclusively with recent novel external events—thinking about the purpose of the study, whether they are performing well, and whether they are liked by the experimenter. But over the course of an hour, STI progressively turns almost entirely to prior familiar matters—college and family issues that had been thought about many times before (Reinsel et al., 1992). Novel current events, such as participating in the experiment, top the list, but over time the value of continued "rehashing" of the same information decreases (Andrews-Hanna, Reidler, Huang, & Buckner, 2010). These processes may include problem-solving, planning, sorting out trivial information, and consolidating useful information (a cortical-hippocampus process) of personal value (as represented in the medial prefrontal cortex) into long-term memory (see Brokaw, Tishler, Manceior, & Wamsley, 2016; Spreng, & Andrews-Hanna, 2015).

Absent a serious threat, each STI topic is soon replaced by the "readout" of another concern. What accounts for these shifts in STI? In neural networks such as the *emergent* model of O'Reilly and Munakata (2010, 2014), competition plays on until the networks "settle" into a solution—the neural representation of an object or event sequence (a state where further interaction produces little further change—the neural network version of boredom). At that point, other issues—mismatches among existing person, object, event, and goal representations—that had been suppressed (inhibited) by production of the prior STI production may begin to dominate the personal concern arena and initiate competition for the production of the next STI. Indeed, one STI (e.g., "I've got to study for tomorrow's math test") may cue associated concerns, "I've got to get groceries for dinner tonight . . . I should leave here by 5. . . ." The process never ends because there is no limit on the size of the personal concern arena. Note that the so-called executive management of this process is widely distributed across competing neural networks within competing cortical regions, most with ultimate connections to the medial prefrontal cortex.

We assume that spontaneous subvocal speech is the dominant part of STI. Nevertheless, subvocal speech itself represents only a fraction of the complex interrelated meanings and competing concerns, plans, and values associated with the production of each subvocal speech STI. What, then, is the particular function of the spontaneous subvocal speech "read out" itself? We suggest that because fluent speech production and recognition are the most effective way one has of communicating with other people, it is also the most effective way of communicating with oneself, for example, for different memories, intentions, and values represented in different cortical locations to be compared (see Spreng & Andrews-Hanna, 2015). Perhaps transforming a complex abstract representation into subvocal speech enables the frontal cortex to save the representation in a more simplified form, and also one that shares features (i.e., words) with other memories. That's a hard one to test! It may be helpful to compare the pattern and magnitude of activation in the temporal, parietal, and dorsomedial frontal cortices that is produced by spontaneous subvocal speech with deliberate subvocal speech as a reference (see Amunts & Catani, 2014; Horikawa, Tamaki, Miyawaki, & Kamitani, 2013; Spreng & Andrews-Hanna, 2015).

Spontaneous Subvocal Speech Versus Spontaneous Visual Imagery I

By discussing STI as though it consists exclusively of spontaneous subvocal speech, we ignore the quite different process by which spontaneous visual imagery, possibly a minor part of waking STI and the primary part of dreaming STI, is produced. Given that we have no visual image generator comparable to our vocal speech generator, the processes that produce spontaneous visual imagery may vary considerably from those that generate spontaneous subvocal speech. Frontal and prefrontal default cortical processes may play a large part in generating both, but those cortical processes must be distinguished from the quite different processes that create visual imagery and subvocal speech. And since the utility of spontaneous subvocal speech may differ substantially from that of spontaneous visual imagery, understanding those differences may help us determine their utility.

We assume that spontaneous subvocal speech is produced by many of the same cortical vocal production circuits as vocal speech, especially the temporal, parietal, and dorsomedial frontal cortices. Note that waking speech production is closely tied to auditory feedback from vocal speech. If normal auditory feedback from one's speech is suppressed, the speaker begins to stutter in the attempt to recover the expected auditory feedback. Indeed, the production and recognition portions of spontaneous subvocal speech are so closely interrelated that people often find it difficult to distinguish acoustic speech imagery from the meaning of the thought that it expresses. They can't confidently distinguish between whether they "heard" themselves speak, or simply that they knew what they were saying.

One reason for the apparently weaker role of visual imagery in STI production is that the visual recognition cortex lacks the interacting production-recognition system of the auditory brain. While spontaneous subvocal speech is produced by many of the same structures and processes as vocal speech, the processes that produce spontaneous visual imagery are not well known. Although we seem to have little difficulty generating the spontaneous subvocal speech of STI while simultaneous listening to the radio, or to a friend or classroom teacher (see Wammes, Seli, Cheyne, Boucher, & Smilek, 2016), spontaneous visual imagery seems unable to survive the illumination in normal waking environments. Supporting this assumption, we found that increasing the task information rate suppressed spontaneous visual imagery much more severely than spontaneous subvocal speech. Nevertheless, *both* STI imagery modalities are weaker when task stimuli are presented in the same sensory modality; that is, even spontaneous subvocal speech is weaker when the task stimuli are auditory rather than visual (Antrobus, Singer, Goldstein, & Fortgang, 1970).

Spontaneous Visual Imagery

Given the modest role of spontaneous visual imagery in waking STI, we might have dropped it from further consideration but for the discovery by Aserinsky of the association of rapid eye movements (REM) in sleep with reported visual dream imagery (Aserinsky & Kleitman, 1953). No experimental psychologists had ever dared to publish verbal reports of subject's private experience, and the solid/stolid behavioral American Psychological Association journal, *Experimental Psychology*, refused to publish Aserinsky's findings because reports of mental activity were not the stuff of science! Hailed as the strongest cognitive-neurophysiological association ever discovered, the REM–dream imagery association initiated a flood of research designed to find out if the REMs were actually scanning a visual image of the dream. No definitive evidence was ever found! Oddly enough, no one proposed a brain model of how and where in the brain the visual dream image was produced. Instead, the research focus turned on an observation by Jouvet (1962) that pontine neurons in the rat fire randomly in REM sleep, and this phasic activity is transmitted via the lateral geniculate to the occipital cortex (PGO spikes), and coincides with the eye movements of REM sleep. Hobson and McCarley (1977) then proposed that in the absence of sensory input, the brain reads this PGO input as though it is sensory input, and its random distribution in time and neural space accounts for the bizarreness of REM dream imagery! Their model of how the visual dream image is produced was limited to the single word "modulation," and their subcortical brain model for the generation of REM versus non-REM (NREM) sleep was later found to be built on flawed data (Foulkes, 1985; Foulkes & Domhoff, 2014; Reinsel, Antrobus, & Wollman, 1992). Nevertheless, their detailed subcortical account of the basis of bizarre visual imagery as a process unique to REM sleep again distracted many of us from realizing that we still had no model for the generation of the visual image itself.

Our own evaluation of the REM-PGO model was based on the analysis of bizarreness in the dream reports (Reinsel et al., 1992). Contrary to the PGO model, we found that imagery reports were *not* more bizarre after active REM than after ocular quiescence. And while Stage 1 REM reports were significantly more bizarre than Stage 2 reports, we also found that bizarreness is closely associated with the length of the mentation report. When report length was partialled out, REM reports were no more bizarre than Stage 2 mentation reports. In other words, the longer the mentation report, the more likely it included a bizarre element. REM reports were more bizarre than Stage 2 reports simply because the longer the report, the more likely that some elements will be inconsistent with earlier elements (Wollman & Antrobus, 1984).

That bizarreness is not unique to REM sleep prodded us to examine the widely held, but untested, claim that *waking* STI is free of bizarre, vivid waking mentation (Reinsel, Antrobus & Wollman, 1992). And that required that we sample STI in the *identical* dark bedroom environment used for sleep research, while monitoring EEG to ensure wakefulness. STI samples were obtained at random intervals (mean, 9 min.; N reports = 257) over a one-hour period. On the assumption that normal college environment ambient sound might attenuate remote fantasy, we established two acoustic environments: one with intermittent environmental sounds and one with minimal environmental sound except for a low amplitude white noise mask—both with low illumination. Given the high-sensory thresholds of REM sleep, that state should be simulated more closely by minimal environmental sound and illumination. For each mentation report, we estimated a global bizarre score and three subclasses of bizarreness: discontinuities in the report sequence narrative; improbable combinations; and improbable identities.

Much to our surprise, STI reports from both conditions were even *more* bizarre than those reported from REM sleep! Improbable continuities was the largest subclass of bizarreness, and reports from the intermittent sound condition had twice as many bizarre reports as those from REM sleep—with the minimal sound condition reports coming in a close second. Improbable identities were rare—accounting for only 7% of the bizarreness of REM dreams. In short, despite the widespread reputation of dreams, dreams reported directly from REM sleep are not particularly bizarre. The primary distinction between waking STI and REM dreams is that daydreamers *always know* that that the bizarre feature of their STI is fantasy, whereas in REM sleep the high sensory thresholds pretty much compel the dreamers to assume that every bizarre element in their imagery is real.

Despite these minor differences, their common features suggest that both waking and sleep STI must be produced by similar brain structures and processes. Further, given that the synapses in the neural networks that execute these processes must be learned primarily in the waking state, these structures and processes must be a subpart of those that accomplish waking perception and speech, but are also active *in the absence* of sensory input and motor output. Those regions, now called the *default network* (actually default mega-network*s*), consist of multiple interacting networks located throughout the prefrontal, frontal, and medial temporal cortices and the posterior cingulate cortex (Buckner & Carroll, 2007). Their role in both active planning and passive anticipation of future events is the subject of active research by Buckner, Andrews-Hanna, and Schacter (2008), Andrews-Hanna, Reidler, and Buckner (2010), and Andrews-Hanna, Smallwood, and Spreng (2014). Given the enormous complexity of the default mega-networks and the assumption that they must operate somewhat differently to produce spontaneous visual imagery and spontaneous subvocal speech, our goal here is to exploit our knowledge of waking visual recognition, to suggest how default mega-networks might produce dreaming and waking spontaneous visual imagery.

As noted earlier, the features of spontaneous subvocal speech are so similar to those of vocal speech that we may assume that they are produced by many of the same brain structures and very similar processes. But lacking a visual projection facility comparable to vocal speech, spontaneous visual imagery is clearly produced by a somewhat different process. We start with the assumption that the neural structures and processes that produce spontaneous visual imagery are accomplished by neural network pathways that have been previously well-learned in the course of prior visual perception. The traditional visual object recognition model assumed that recognition is accomplished in a bottom-up sequence of recognition-processing structures, moving the retinal image through the optic tract, thalamus, and primary visual cortex to high-level recognition locations such as the infero-temporal and temporal cortices. The representation of the recognized object is then passed on through recurrent hub connections to a wide array of interactive frontal cortical networks that represent the multiple meanings of the object and, by their interactions with medial prefrontal networks, linked to the amygdala, also represent the value of the recognized object in its particular context. That is, the representation of the visual *image* of an object or person is represented in closely related temporal and/or parietal neural networks, while its more abstract meanings, names, and values are represented in an array of temporal and frontal cortex networks.

But visual perception is a two-way process! Bottom-up activation of the parietal image of a visual object (e.g., house, face, car, or tree) activates the temporal and frontal representations associated with that object in that particular *context* (see Klinger's meaning complex, 1971). But these temporal and frontal context networks also act back, "top-down" on the parietal networks that are competing to recognize the image. This reciprocal bottom-up-top-down interaction may occur many times in a fraction of a second until the two representations settle on a winner. The top-down context activation part of this largely bottom-up recognition process so greatly facilitates the activation of the parietal object activation that sometimes only a fraction of the bottom-up input is needed to complete recognition of the parietal image. For example, the context of the preceding sentence so strongly anticipates the final word "image" that the bottom-up recognition of the first letter "i" is sufficient to "see" the full word.

Given that spontaneous visual imagery is produced when bottom-up input to the parietal representation is absent, as in sleep, or minimal, as in reduced stimuli waking environments, the top-down frontal cortex context networks may be the primary, if not only, input to the parietal visual image representations that produce spontaneous visual imagery. In short, this frontal, top-down source of activation is available to the visual image representations in the parietal cortex *because* it was previously learned as part of the "bottom-up" visual perception process.

This activation source has been ignored for several reasons. First, there is the widely held belief that the multiple steps in waking perception from line detectors to object recognition are exclusively bottom-up, and therefore that STI must also originate from a bottom-up input source (i.e., retina → lateral geniculate → V1). If we use temporal windows as long as 1 second, and large cortical regions to view this perceptual process, visual perception does indeed *appear to be* a bottom-up process. But at the fine-grain level of neural networks in millisecond intervals, there is no such thing as the classical bottom-up process. Stepping from one macro-cortical region up to the next in the visual recognition pathways is accomplished by extremely fast, *recurrently interactive* neuronal interactions, often with more top-down and lateral input than bottom-up.

Another impediment to building an STI model is *the implicit assumption that the visual image is the final step in perceptual object/image "recognition."* But it is only the *penultimate* step. As a result of visual perception learning over the course of one's childhood (see Foulkes, 1985), visual "recognition" in the parietal cortex is capable of activating a large array of frontal and temporal circuits that represent an enormous array of abstract meanings, contexts, names, and appropriate responses to each image. Complete recognition of the visual object or event is therefore represented by the joint collaborative activation of all context-appropriate temporal, parietal, and frontal representations. By means of the connections of these representations with the medial prefrontal cortex, they also represent the personal significance, and the utility, of various responses to a perception. In contrast to the local visual object identity recognition in the parietal cortex, this larger, distributed collaborative representation represents *conscious* recognition of the visual representation (as implied by the Latin *con*, meaning "together," and *scio*, meaning "I know, understand"). By extension, spontaneous thought and imagery are conscious neurocognitive processes produced by the same collaboration, but minus sensory bottom-up input. (For a similar model of consciousness, see Flanagan, 1996.)

Spontaneous Subvocal Speech Versus Spontaneous Visual Imagery II

As suggested earlier, the similarity of vocal speech production to subvocal speech suggests that spontaneous subvocal speech has strong frontal cortex speech production sources that are unavailable to spontaneous visual imagery production. In addition, spontaneous subvocal speech may have a frontal-to-temporal cortex activation source similar to the frontal-to-parietal input for spontaneous visual imagery. So, while we have located the one source of input for spontaneous visual imagery, there are at least two for spontaneous subvocal speech, which implies that spontaneous subvocal speech is a more resourceful generator of STI than spontaneous visual imagery.

On the assumption that a comparison of a threat, like our fake war threat, with a control condition will facilitate identification of its cortical and cognitive processes and our understanding of STI utility, I strongly recommend that future experiments

1. include a stress threat condition, and
2. systematically evaluate the effect of time since introduction of the stressor.

Recall that STI reports are significantly *more* bizarre in both waking conditions than in REM dream reports! The reason is that the cortical EEG indicates higher cortical activation in the waking condition, associating bizarreness with higher cortical activation. The class of bizarreness accounting for this difference is discontinuities—discrete changes in topic units—in the STI reports. Discontinuities increased with report length and were more common in the intermittent environmental sounds than the minimal environmental stimuli STI environment (Reinsel et al., 1992; Wollman & Antrobus, 1984). The data are consistent with several assumptions. Greater frontal activation supports longer STI sequences, but the lower sensory thresholds associated with increased cortical activation allow external sensory stimuli, whether associated with higher personal concern (i.e., utility) or not, to interrupt the current train of STI. In addition, the higher frontal cortical activation could support faster, more efficient review of trivial STI topics so they are discarded more quickly, producing more frequent topic change. However, more precise research is needed. Wollman and Antrobus (1987) found no association of STI report length with any EEG index of cortical activation, so the role of frontal networks in determining STI duration and consistency over time remains undefined.

3. Although the magnitude of auditory and visual stimuli in the STI environment may have a major effect on STI, it is often unreported. We can't draw inferences about the differences between visual imagery and subvocal speech within waking STI and REM if the data are obtained in different sensory and temporal environments.
4. I recommend that we attempt to get much more information from our verbal reports of SIT—specifically, that we attempt to distinguish different subclasses within conventional STI labels:
   a. *Bizarreness*: Given that the large array of frontal networks that produce STI are acquired over a lifetime of visual perception learning, their participation in STI should reflect a very accurate representation of expected bottom-up visual perception. And indeed, despite popular assumptions to the contrary, even dream STI features are largely consistent with the features of waking perception. Nevertheless, *infrequent* bizarre features may tell us more about how STI is generated than those features that are consistent with waking perception. For example, bizarre combinations of objects or people, such as "it was my brother, but he was a girl in my dream . . ." could never occur in waking perception. As a dream STI, it suggests that the parietal⇔frontal (⇔ symbolizes recurrent two-way connections) cortex gender representations that strongly inhibit one another in waking may be weaker during STI production. The gender confusion might be influenced by some feminine characteristics associated with her brother's waking behavior, but that hypothesis would need independent evidence. The brother-girl STI is an example of *improbable identities*. That they are more common in REM sleep (7% of bizarre REM reports) than in in minimal environmental stimuli waking STI (2% of bizarre reports) supports the assumption that parietal-frontal cortex neural networks are less activate in REM sleep than minimal environmental stimuli waking.

However, a weakening of familiar inter-network connections learned during waking does not easily account for *bizarre combinations* (see preceding discussion) of objects or people, such as ". . . nuns wildly driving in red cars . . ." because waking experience may never have included anyone wildly driving in red cars, let alone nuns. Bizarre combinations make up about 16% of all bizarre STI) events. They imply competing parietal⇔frontal⇔parietal cortex biases that are incompatible in normal waking, but neither of which is able to suppress the other in sleep or low-sensory waking STI. Future research needs to examine the prior STI context of such bizarre combinations to determine if either is a carry-over lag from an earlier STI context.

b. *Visual imagery and subvocal speech*: We need to estimate the relative *amount of information* in visual versus speech imagery and the extent to which one acts as the context of the other. Note that our estimate of the relative strength and utility of spontaneous subvocal speech and spontaneous visual imagery is based on our convenient study pool of college students. But the utility of spontaneous visual imagery may be much larger for carpenters, architects, and painters, and if we include motor imagery, for choreographers and dancers. If we distinguish words from music, the ratio might go differently for singers versus musical instrumentalists. To the extent that an individual's vocation is differentially dependent on visual versus verbal fluency, comparison of these ratios across vocations might inform us about their utility in SIT.

c. *Thought*, or "knowing" versus sensory features of speech: STI reporters rarely distinguish knowing what the imaged speaker means from the sensory features of speech image. Making that distinction will help us identify the different cortical regions that generate the two.

d. *Visual image brightness and clarity*: If scaled relative to waking vision, we may be able to estimate the contribution of parietal image to that of the frontal cortex to the creation of the image.

e. *Rate of STI production*: STI rate should increase with the utility of STI. It may be possible to insert real-time markers, such as a click, to help estimate the amount of STI per unit time. I assume that it is much slower in REM sleep than waking.

f. *Effect of report latency*: Difference between the initial STI and that made by the fully awake cortex will inform us about the difference between the STI-producing networks of the default cortex and those of the fully engaged brain. The assumption that the frontal cortex is somewhat deactivated during sleep is supported by comments made by dream reporters as they move toward full awakening. For example, ". . . he must have been my uncle Henry because (in the dream) we were at his summer boat dock . . ." implies that recurrent connections between the frontal networks that generated the original spontaneous visual image and those that represented the identity of the uncle were weak while dreaming, but became re-engaged upon awakening.

The Promise and Limits of Functional Magnetic Resonance Imaging (fMRI)

Introducing these experimental treatments and improved STI measures will greatly enhance the value of information we obtain from cortical activation fMRI blood-oxygen-level-dependent (BOLD) measures. Although I have emphasized the role of interacting frontal and prefrontal cortex neural networks and pathways, we have at this point in time only a vague understanding of the mega-neural networks within those massively complex cortical regions. As Fox et al. (2015) have demonstrated in their meta-analysis of the literature, functional neuroimaging, whether by MRI or fMRI, are the most promising procedures available for estimating the cortical regions that generate STI. But they note that in MRI and fMRI, magnet noise is extremely distracting and bound to interfere with the production of STI and dreams. However, using substantial ear plugs, Horikawa, Tamaki, Miyawaki, and Kamitani (2013) have reported successful links between fMRI and waking and sleeping visual imagery. And one of my fMRI colleagues says that he has been under the magnet so many times that he doesn't even notice the noise. But as noted earlier, environmental noise does affect STI (Reinsel et al., 1992). So at this point we do need a careful measure of the effects of magnet noise on the verbal and visual components of both STI and sleeping dream reports, perhaps on novice and seasoned magnet users. I also recommend that we assess the effect of the magnet and EEG sleep stage on subjects' report of whether they judged they were actually asleep or awake when called to make a report.

My other suggestion is that STI cognitive data implies that STI production is normally a low neuronal energy process. Therefore, we should not interpret low cortical energy (e.g., BOLD signal) as *the absence* of STI (see Buckner, Koutstaal, Schacter, & Rosen, 2000; Szpunar, St. Jacques, Robbins, Wig, & Schacter, 2014). The process of recognizing novel words or pictures activates the parietal, temporal, and frontal cortices. The particular cortical regions activated depend on the properties of the stimulus and the characteristics of the required recognition response (Wig, Buckner, & Schacter, 2009). Recognition of successive repetitions of the same stimulus gradually decreases the levels of activation, particularly in the parietal and temporal cortices as well as in the frontoparietal control system regions. It follows that low frontal activation is *not necessarily* evidence of a lack of cognitive processing in the frontal cortex. *Familiar* sustained frontal-supported spontaneous visual imagery may be sustained for short intervals with no detectable increase in regional cortical activation, while the more parietal BOLD fMRI signal found by Horikawa et al. (2013) may be produced by more *novel* parietal spontaneous visual imagery sequences initiated by a more stable frontal network activity.

Neural Network Modeling

Perhaps the greatest challenge to understanding spontaneous subvocal speech and visual imagery is the sheer magnitude of the frontal and prefrontal neural networks that represent the expression of personal concerns. The massive size, complexity, and long learning history represented in the frontal and prefrontal cortices defy any attempt at comprehensive description. Nevertheless, we may begin to model some of their salient properties. The most interesting of these are the processes that continuously activate representations of recent events, estimating their value, discarding those of little value, and saving those of value (by means of hippocampus-cortex interactions). I recommend modeling STI with the neural network emergent model of O'Reilly and Munakata (2010, 2014). An STI model must be based on a recognition model, which in turn requires a high-dimensional learning model. Consider a multilayered object or word recognition model starting with features represented in dot matrices, going on to successive interacting layers—lines, angles, object features, to letters, to words or objects (represented in the temporal or parietal cortex). It then moves on to dorsolateral frontal cortex layers representing more abstract features such as the properties and characteristics dog, cat, mother, teacher, money, gun, and so on. Finally, after all that, it makes value representations (in the medial prefrontal) such as friendly people and dangerous people. One of the many merits of the emergent model is that it allows the model to be trained (i.e., externally reinforced by the programmer), simultaneously at several levels (e.g., letters, words, object category, value category). The effect of high value on recognition, whether positive or negative, therefore, can be simulated by biasing the resting activation of selected items in the prefrontal cortex layer. But even the outline of that project is beyond the scope of this chapter.

The publication of *The Oxford Handbook of Spontaneous Thought* marks a landmark in research that describes STI and its many possible functions in our lives. Describing that research in one volume provides all of us with a well-informed base from which to create better models of STI and design even better research in the future.

Note

1. We have also used the term "task-unrelated imagery and thought" (TUIT).

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CHAPTER

12 Spontaneous Thinking in Creative Lives: Building Connections Between Science and History

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Abstract

Scientists have only recently begun to explore spontaneous thinking. It might appear that as elusive a phenomenon as it is in the laboratory, it would be impossible to detect in the historical record. This essay argues that it is possible to make space for accounts of spontaneous thinking in historical accounts of creativity and discovery. It argues that historians can use scientific work on daydreaming, mind-wandering, and other forms of spontaneous thought to illuminate the history of ideas. It explains how historical research informed by science could generate new insights in the history of writing and thinking, the history of attitudes towards reason and inspiration, the daily practices of creative thinkers, and even elusive phenomena like sensory perception and sleep. With diligence and imagination, it will be possible to reconstruct the place of spontaneous thinking in the history of ideas.

Key Words: spontaneous thinking, creativity, insight, work, history, psychology

Historians of ideas and cognitive psychologists have long shared a common interest in creativity, but little else. Historians interested in the genesis of new ideas and scientific theories have been divided on efforts to apply psychoanalysis or cognitive psychology to intellectual history. Cognitive psychologists, meanwhile, have preferred to develop rigorous studies of creative activity in the laboratory, and have largely avoided the richer but more ambiguous data offered by the lives of noted scientists, artists, and inventors. Both fields, however, have shared a common focus on conscious cognition over spontaneous thought. Intellectual history has been the history of conscious cognition, of directed effort. Likewise, psychologists interested in studying convergent or divergent thinking have generally been interested in conscious efforts to solve problems, see associations, or generate novelty.

The recent rise of interest in spontaneous thinking, the recognition of the importance of mind-wandering in creative thinking, and the discovery of the default mode network have renewed interest in the role of unconscious cognition in creative activity; likewise, the development of tools like positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have raised the prospect that we can begin to identify the brain mechanisms at work during moments of insight. These discoveries present an opportunity to build new bridges between historical and scientific research. Historians should take up the challenge of expanding our accounts of creative lives by explaining the role of spontaneous thinking in the lives of famous thinkers and the history of ideas. At the same time, scientists interested in creativity could make good use of archival and other primary historical materials to better understand how spontaneous thinking operates.

In this chapter I explore how historians of ideas and cognitive psychologists might draw on and inform each other's work. I show how historians can use scientific work on daydreaming, mind-wandering, and other forms of spontaneous thought to illuminate the history of ideas, and in particular to understand how creative thinkers construct the relationship between conscious and spontaneous thinking.

History and the Problems of Spontaneous Thought

Traditionally, historians have ignored mind-wandering and spontaneous thought. Why? The simple answer is that everyone has underrated its importance, including psychologists. But that doesn't mean that recent work on mind-wandering and spontaneous thinking will automatically find its way into historians' agendas. We need to look a little deeper into why spontaneous thinking would receive little attention, and how to build a case for paying attention to it.

Previous efforts to use psychology to inform history and biography have had a mixed reception. "Psychohistory" has never reached the status of other historical specialties, and works like Erik Erikson's *Young Man Luther* (1958), Peter Gay's biography of Sigmund Freud (1998), and Lloyd de Mause's (1995) studies of child-rearing and national culture have remained controversial. Most biographies avoid explicit psychological explanation and theorizing; even those that offer nuanced and perceptive views of a subject's personality, motivations, and fears tend not to invoke psychology. Adrian Desmond and Jim Moore's (1991) magnificent biography of Charles Darwin, for example, provides a wealth of detail about Darwin's health problems, his agony over the death of his beloved daughter, and his blend of outward modesty and ferocious, ambitious curiosity. Yet *Darwin* avoids explicit reference to psychology: instead, Desmond and Moore build a "defiantly social" account that draws on sociology and social studies of science to explain how Darwin's work and thinking developed.

Another source of reluctance is that stories of "aha!" moments, or sudden inspiration, have an uncomfortable echo of "Great Man" history, or sound too much like an invocation of *Deux Ex Machina*. The hard-to-fathom character of these moments sits uneasily with scholars intent on explaining, rather than mystifying, their subjects. This aversion is reinforced by a deep-seated belief that insights apparently arrived at through spontaneous thinking must by definition be less trustworthy than those that come at the end of hard work. Josef Pieper (1952) argued in *Leisure, The Basis of Culture* that since the 1800s we have downplayed the role of spontaneous thinking in the creation of new ideas, have distrusted ideas that aren't clearly the result of labor, and have eliminated revelation as a source of new knowledge. Ancient and medieval European philosophers had argued that knowledge required the marriage of *ratio*, logical and discursive methods, and *intellectus*, described by Pieper as "an attitude of non-activity, of inward calm" that allowed the philosopher to perceive the world's deep truths. During the Enlightenment and the Industrial Revolution, however, this organic vision was upended. The German philosopher Immanuel Kant argued that "reason acquires its possessions through work," and that "herculean labor" was necessary to arrive at the truth (Kant, quoted in Pieper [1952], p. 26).

For scholars, then, the history of ideas has been the history of *laboring over* ideas. Many biographies, for example, describe themselves as studies of the "life and work" of their subjects, a framing that subtly directs their attention away from rest and spontaneous thinking. An illustrative example is Roy Jenkins's (1995) brilliant biography of William Gladstone. Gladstone was a tireless writer and the towering political figure of the Victorian era, and Jenkins does a masterful job of explaining Gladstone's rise, work, and legacy. Gladstone also spent long weekends at his country estate at Hawarden, took long vacations on the Continent, and relaxed by reading Greek and Latin (indeed, he was the first to note that the *Iliad* and the *Odyssey* never use the word "blue," but instead use terms like "wine-dark" to describe the sea). Yet Jenkins treats these episodes as a break in the main narrative, not as factors that help explain Gladstone's success; a four-week tour of Italy, for example, is dispatched in a short paragraph between long accounts of parliamentary debates or cabinet maneuvers.

This is not to say that *Gladstone* is a bad book. Far from it; it's easily one of the best English-language biographies published in the last 20 years. But it illustrates how biographers gloss over their subjects' vacations and downtime, and don't consider that how their subjects *rested* could be as interesting a topic as how they *worked*. Instead, they treat the daily habits or annual vacations of their subjects as narrative interruptions to be dealt with quickly and dismissed (an impatience that reflects modern assumptions about the irrelevance of leisure to productivity).

Finally, and most important, it feels like spontaneous thinking doesn't have a history. A psychological activity doesn't change over time in the way that political structure, ideas, or civilizations do; there is no rise and fall in spontaneous thinking. The problem is reinforced by the absence of primary sources, which makes writing the history of spontaneous thought impossible. Spontaneous thought leaves no direct records, even in the memories of individuals. Much of the time it's difficult for people to remember the contents of their wandering minds even seconds later, and only a vanishingly small number of people have bothered to record the contents of their spontaneous thoughts, or have described the role of spontaneous thinking in their creative processes. While instances of spontaneous thought have been connected to the production of significant works of art, scientific theories, and religious epiphanies, accounts of such "aha!" moments are usually retrospective, published in memoirs and biographies, recounted in commemorative addresses, or recorded by students or followers. As compelling as they are, these retellings are shaped by cultural norms, religious precepts, or ideas about genius; they tell us as much—perhaps more—about the era that produces them as the people and ideas that are their subject.

An Outline of Spontaneous Thinking in History

I contend that spontaneous thinking has a history; it can be told; and both history and science would benefit from telling it.

While historians interested in spontaneous thinking cannot work with the directness of military or political historians, they should not give up all hope. Several generations of historians and anthropologists have shown how to use previously overlooked but conventional materials, as well as novel materials—for example, court documents, medical and police files, property records, welfare case records, photographs, provincial archives, and many other kinds of material—to illuminate the lives of women, the working classes, children, servants and slaves, minorities, dispossessed groups, and others (see, for example, Boyer and Nissenbaum, 1974; Darnton, 1985; Scott, 1974; Thompson, 1963). Scholars working with either overlooked records or applying new methods to familiar sources have reconstructed the histories of everyday senses and emotional experiences, like smell, noise, and silence; friendship and family ties; and information overload (Boyarin, 1993; Classen et al, 1994; Kern, 1983; MacCulloch, 2013; Martin, 1995; Schivelbusch, 1986).

Other experiences that were long thought to be biologically determined and unchanging turn out to have a history, or to contribute decisively to human history. Sleep, Roger Ekirch argues, became a single uninterrupted break in consciousness only relatively recently; for centuries, it turns out, Europeans were biphasic sleepers, regularly waking in the middle of the night to read, pray, or engage in other activities (Ekirch, 2005, 2015). Evolutionary biologists David Samson and Charles Nunn (2015) argue that the unique properties of human sleep may have helped give rise to human society, intelligence, and culture. Compared to other primates, humans sleep less, but their sleep is richer in slow-wave and REM sleep, a combination that supported the growth of "enhanced cognitive abilities in early humans," gave them more time to develop complex social ties and culture, and encouraged nocturnal innovations like beds, shelters, controlled fires, and larger social groups.

One can begin by using recent intellectual histories, and studies of intellectual practices, as a scaffold for building a history of spontaneous thinking. In order to understand how spontaneous thought might have been used or harnessed by thinkers in earlier centuries, or how everyday life presented opportunities for spontaneous thinking, it's necessary to have a sense of what other kinds of cognitive challenges people faced. In fact, the history of spontaneous thought probably cannot be written without contextualizing it in the history of intellectual practices and cognitive activities.

Work

Studies of the cognitive load required by work and workplaces provide an obvious starting point. According to archaeologist Lyn Wadley (Wadley et al., 2009), 70,000 years ago or earlier, our humanoid ancestors cooked ingredients into adhesives to secure sharpened flints to spears and arrows, a process that required careful planning, attention, and a capacity for multitasking. Monica Smith (2010) argues that many ancient complex activities, such as farming, weaving, and pottery, required a capacity for keeping in short-term memory several simultaneous activities. Cognitive archaeologists Colin Renfrew and Lambros Malafouris (Renfrew & Zubrow, 1994; Malafouris, 2009) have reconstructed ancient Mycenaean mental states of ancient peoples from burial chambers, holy sites, and artifacts. The more recent efforts of scientists like Gloria Mark (Mark, Voida, & Cardello, 2012) and Larry Rosen (2012) to measure levels of distraction in the workplace, classroom, or daily life, and of technology writers and critics like Sherry Turkle (2011), Nicholas Carr (2011), and Andrew Keen (2015) to assess the impact of technologies on thinking, distraction, and mind-wandering, all provide a basis for mapping how conscious and unconscious thought would be harnessed to solve problems and complete tasks.

Writing and Cognition

Studies of the relationship between writing and cognition offer another foundation for a history of spontaneous thinking. A host of historians and anthropologists have traced the impact of alphabets and writing on ancient Greek thought, starting with Albert Lord's (2000) and Milman Parry's (1987) work on Homeric epics and the shift from oral to literate culture, to the work of Jack Goody and Ian Watt (1963), Eric Havelock (1986), and Walter Ong (1982). Paul Saenger's (1997) work on word spacing in ancient and medieval Latin offers an especially stimulating study that could inform work on medieval conscious and spontaneous cognition. Saenger argues that the adoption of word spacing from the 1100s to 1400s had titanic effects on the ease with which people could read, and by implication the cognitive resources available for spontaneous thinking. Ancient Romans read books without punctuation, upper or lowercase letters, or word separation. This meant that readers had to labor to sound out words, and had to focus hard to make sense of an author's argument. Early Christians, particularly those in non-Latin speaking lands, struggled with this regime. For Saxon and Celtic priests, word spacing was a necessary innovation to make reading from Latin easier. Arabic texts translated into Latin also adopted word spacing (borrowed from Arabic itself). But what began as an aid to reading aloud soon gave rise to new practices, most notably silent transcription and silent reading. Scribes who copied texts worked in silence, and had developed means of copying in silence, such as breaking texts into lines of 10–15 characters, which could be remembered in their entirety. Adding word spacing allowed scribes to abandon these methods, and instead to copy out texts word by separated word.

The rise of silent reading drove changes in the design of spaces for reading, particularly a shift from providing monks with cubicles where they could sound out texts without disturbing others, to central halls that brought all readers together in silence. Books that were meant to be read silently differed from those meant to be read aloud: they were more visually complex, and their design could incorporate metadata and visual cross-references that wouldn't make sense in books that were read aloud. But the most interesting and elusive consequences of silent reading were psychological. Silent reading changed the ways in which both heresy and devotion were practiced, making challenges and obedience to heterodoxy more of a personal matter. Earlier heretical movements had been social movements that spoke to collective spiritual needs; by the thirteenth century, heretical thought was more personal and individual. Spiritual literature in the fourteenth century was read alone, turning reading itself into a kind of meditation. Silent reading made easier the cultivation of individual opinions and subversive thoughts. It also made religious feeling into a more private matter—an essential foundation for the Renaissance and the Reformation.

Physical Spaces

The design of physical spaces, particularly spaces intended to support creative activity and deep thinking, is another source for reconstructing the history of spontaneous thought. Spaces enable certain kinds of social and intellectual activity, and discourage others; they bring people together or keep them apart, encourage sociability or support solitude. Several works illustrate how these historical studies can throw light on the history of spontaneous thinking. Gadi Algazi's (2003) study of the medieval and early modern scholarly *habitus* examines how changes in scholarly life in Europe affected the design of private spaces for scholarly work and contemplation, and how the location of those spaces in larger enterprises—households, lecture halls, and so on—reflect the evolving social and professional identity of the scholar. The private office or chamber for scholarly study, it turns out, became an important part of scholarly work and identity in the thirteenth century, as scholars moved from monasteries and scriptoria, and the scholarly production shifted from a highly communal to a more private mode. In a now-classic article, Owen Hannaway (1986) showed how ideas about the powerful and secret nature of scientific knowledge are reflected in the design of Tycho Brahe's Uraniborg, built in 1576 to support Brahe's astronomical and alchemical research.

More recently, the rise of the contemporary open office reflects a re-socialization of creative work and spontaneous thinking. The open office is often defended on the grounds that it encourages a particularly social form of spontaneous thought. Workers who might keep to themselves in traditional offices or sealed in their laboratories are encouraged by the space to mix at the café or water cooler, generating a series of random social collisions and interactions that yield new collaborations, projects, or products (Saval, 2014). How well such spaces work is a matter of debate, but these offices are notable for reflecting a notion of creativity as an essentially social and stochastic phenomenon, as the product of a collision of people with different perspectives and expertise, rather than the result of long periods of individual, solitary thinking (Brown & Duguid, 2000).

Attitudes Toward Spontaneous Cognition

Another factor affecting spontaneous cognition and its use are ideas about the benefits or dangers of spontaneous thinking. As Pierre Hadot argued, ancient Greek philosophy constituted a set of practices aimed at sharpening perception and focus, an enterprise that simultaneously improved a student's intellectual and moral character (Hadot, 2004). Inbar Graiver argues that early Christian monastics cultivated a state of "continual attentiveness" that saw mind-wandering as morally suspect (2016). Likewise, Buddhist contemplative practices that aim to calm the jittery, undisciplined "monkey mind," replacing it with a more placid, self-controlled mind, downplay the value of mind-wandering (for a detailed discussion of various contemplative attitudes toward spontaneous thought, see Eifring, Chapter 38 in this volume). In contrast, medieval thinkers came to see insights generated in moments of leisure as divinely inspired. However, as Pieper argued, in the eighteenth century philosophers came to see real knowledge as the product of "an active, discursive labor of the *ratio*" alone, and banished *intellectus* and leisure from philosophical life (Pieper, 1952, p. 28). The rise of industry and technology, growth of the modern bureaucratic state, emergence of the modern office, rise of the labor movement, and triumph of the marketplace completed the transformation of knowledge from a product of leisure to a product of routinized production. By the mid-twentieth century, Pieper lamented, "intellectual activity [has been] overwhelmed by the modern ideal of work and is at the mercy of its totalitarian claims," he wrote, while space for contemplation and leisure had been eliminated in the name of "planned diligence and 'total labor.' " (Pieper, 1952, p. 20)

The Discovery of Deliberate Rest

Nineteenth- and twentieth-century sources are detailed and plentiful enough to allow historians to reconstruct the relationship between spontaneous thinking and creativity in greater detail, and to map how ideas about creativity, culture, and work shape how people organize their days, and manage the relationship between formal, structured work and unruly, unpredictable inspiration.

In my book *Rest* (Pang, 2016), I argue that some of history's most prolific writers, artists, and scientists developed daily practices that allow them to exploit the creative benefits of spontaneous thinking. By looking at autobiographies, diaries, recollections from family and servants, and other sources, I found it was possible to reconstruct the daily lives and schedules of figures as diverse as naturalist Charles Darwin, composer Ludwig von Beethoven, artist Salvador Dali, neurologist Charles Sherrington, and author Raymond Chandler. The first notable feature of their lives was a paradox. While they organized their lives around their work, they didn't seem to work as long or as hard as we do: most spent about four or five hours a day working. The second was that they had common patterns in what they did in their ample leisure time: lots of walks, afternoon naps, and unstructured time each day, atop which they layered serious hobbies and lengthy vacations. Indeed, many would literally stop in mid-sentence to go outdoors, and take up again early the next morning.

So how did they manage to get so much done while apparently working so little? For those of us living in an era in which overwork is treated as a virtue, and long hours are assumed to be a prerequisite for success (and increasingly, are necessary simply to stay competitive in the job market), four hours seems entirely inadequate to do a day's work, much less write *The Origin of Species*.

The route to understanding how they got so much done while working comparatively few hours, I argue in *Rest*, runs through the scientific literature on mind-wandering and the psychology of creativity. The discovery of the default mode network (DMN) opened a new era of research on unconscious, undirected thought. At the very least, the discovery that the brain maintains high levels of activity during periods of apparent inactivity suggests that there is a reserve of cognitive capacity that can be accessed by the mind during rest, leisure, and periods of undirected mental activity. At its best, work on the DMN offers a way to observe the brain's activity when we're apparently "doing nothing," and to begin to see how new ideas are assembled, tested, and made visible to the conscious mind—in other words, to understand the processes that lead to "aha!" moments when new ideas seem to spontaneously appear. Likewise, scientists interested in mind-wandering have made a compelling case that there are significant psychological benefits to spontaneous, undirected thought. Far from being wasted or psychologically damaging, it offers the mind opportunities to reflect on past experiences, explore future scenarios, and work unconsciously on problems. Scientists examining the role of breaks in creative thinking have conducted experiments that show that when participants know they will return to a particular type of problem (a divergence thinking test, for example), their unconscious minds continue working on it, even as they work consciously on other tasks. Others have shown that people appear to benefit from a creative boost when they work against their chronotype. Mareike Wieth and Rose Zacks, for example, found that night owls perform best on insight problem-solving tests in the early morning, while early birds turned in their best performances late at night (Weith & Zacks, 2011). Another body of research has documented the positive effects of exercise on creativity. In the short run, activities like walking and swimming can provide opportunities for mind-wandering and put the mind in a state where it's more receptive to new ideas; in the long run, exercise and other activities that are both physically strenuous and mentally absorbing provide an essential respite from work, and help people deal better with the (usually underappreciated) physical challenges of working at a high creative level.

In other words, if you use insights from the latest neuroscience and psychology to design a daily schedule, habits, and routines that allowed the creative mind to exploit both conscious and spontaneous cognition, maximized time for mind-wandering, and improved the odds that your creative career would last for decades, the result would look like Charles Darwin's life, or Ray Bradbury's, or Peter Ilyich Tchaikovsky's.

What Scientists Have to Learn from History

What can scientist learn from more attention to the history of spontaneous thinking? First, there are many understudied accounts of moments of insight that could deepen our understanding of the role of spontaneous thinking as a catalyst for creative thinking. Historians have tended to focus on a few famous cases: among scholars, Kekule's account of dancing snakes revealing the structure of benzene and Henri Poincare's sudden insights into Fustian functions are nearly as famous as Archimedes' "eureka" moment. But there are many other accounts that are more detailed and less well-examined, and there is a great deal to be learned by looking at things like diaries, letters, appointment books, and so on— the primary documents that record the ebb and flow of creative lives, and can help us piece together the role of spontaneous thought in creative work. Making good use of these materials, however, requires the scholar to know what she's looking for, to have an awareness of the traces that spontaneous thinking might leave behind, and to be able to see the clues of its operation in the stories people tell about their work. Here is where scientific work like Mihalyi Czikszentmihalyi's interviews on flow and creativity (2002), or Édouard Toulouse's (1897) survey of French scientists and artists, can be helpful in helping scholars spot the signals of spontaneous thinking drawn into the creative process.

Second, historical studies could help scientists interested in the role of spontaneous thinking in other important human activities. In particular, historical accounts of contemplative practices, of efforts to tame the monkey mind or fight distraction, and to cultivate states of mental quiet, could greatly enhance our understanding of the cognitive dimensions of religious experiences. For all their theological differences, a comparative study of contemplative practices across religions reveals a number of tantalizing similarities, and since at least the Axial Age, almost all the world's major religions have struggled to construct a place for spontaneous thinking in monastic practices and worship (Pang, 2013).

Finally, historical studies can help us see how creative people learn to harness spontaneous thought to be more creative. While it sounds contradictory to argue that spontaneous thinking can be treated as a skill that we can learn, and learn to harness more effectively, the fact that many creative people organize their days in similar ways, mixing periods of work and leisure, as well as that they rest in similar ways, suggests that we can. The experience of geneticist Barbara McClintock (Keller, 1983) provides a vivid example of this ability becoming suddenly accessible to one of the twentieth century's most noted scientists. In the early 1940s, McClintock was a visitor at Stanford University, trying to identify the chromosomes in the bread mold *Neurospora*. After a few fruitless days in the lab, McClintock went for a walk. "I sat out there, and I must have done this very intense, subconscious thinking" on the problem for half an hour. Then, suddenly, she literally saw the solution: she visualized how to identify the chromosomes and follow them through

Neurospora's life cycle. "I jumped up, I couldn't wait to get back to the laboratory. I knew I was going to solve it—everything was going to be all right." According to a colleague, McClintock's insight "did more to clean up the cytology of *Neurospora* than all other cytological geneticists had done in all previous time," and made it possible for *Neurospora* to join *Drosophila melanogaster* and *Escherichia coli* as a model organism in genetics research. What's interesting is that McClintock had taken walks when working on tricky problems for years; but after her walk at Stanford, she reported being able to regularly use walking to get out of the lab and clear her head, confident that part of her mind would continue working on a problem—and often would come up with an answer.

This suggests that while it may be difficult to teach, techniques for harnessing spontaneous thinking for creative purposes can in fact be learned. Just as we learn language or how to walk, the process of learning how to use spontaneous thinking proceeds slowly and fitfully, through lots of experiments and trial and error. Even if we never learn to "summon it when needed," as Barbara McClintock claimed she learned to do after her Stanford experience, we can learn what practices or conditions are likely to support spontaneous thinking and yield creative insights.

Conclusion

The "history of spontaneous thinking" may sound at first like an oxymoron. How can a neurological function have a history, and how can its history be told? But as histories of walking (Gros, 2015; Solnit, 2001), sleep (Ekirch, 2005), and childbirth (Leavitt, 1988) have shown, natural activities are often influenced by culture and society, and the ways we practice them, think about them, or integrate them into our daily lives may change. For historians, paying attention to the role of spontaneous thinking in creativity would enliven and enrich the history of ideas. It would throw new light on the ways designed spaces like studies, laboratories, and libraries have supported both formal cognitive activity, and contemplation and reflection. It would encourage scholars to be more attuned to the role everyday practices like walks play in creating space for spontaneous thinking. It would provide a richer view of the lives of significant thinkers. And it would help us reconstruct the history of attitudes toward hard-to-control but highly creative mental states like dreams, visions, and hypnagogic and hypnopompic states. For neuroscientists, historical studies of spontaneous thinking could deepen our understanding of the role of spontaneous thinking as a catalyst for creative thinking, help scientists chart the role of spontaneous thinking in other important human activities, and help us see how creative people learn to harness spontaneous thinking,

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PART IV

Mind-Wandering and Daydreaming

CHAPTER

13

The Neuroscience of Spontaneous Thought: An Evolving Interdisciplinary Field

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Abstract

An often-overlooked characteristic of the human mind is its propensity to wander. Despite growing interest in the science of mind-wandering, most studies operationalize mind-wandering by its task-unrelated *contents*, which may be orthogonal to the *processes* constraining how thoughts are evoked and unfold over time. This chapter emphasizes the importance of incorporating such processes into current definitions of mind-wandering, and proposes that mind-wandering and other forms of spontaneous thought (such as dreaming and creativity) are mental states that arise and transition relatively freely due to an absence of constraints on cognition. The chapter reviews existing psychological, philosophical, and neuroscientific research on spontaneous thought through the lens of this framework, and calls for additional research into the dynamic properties of the mind and brain.

Key Words: spontaneous thought, mind-wandering, task-unrelated, dreaming, creativity

An Introduction to an Evolving Interdisciplinary Field

A mere 10 years ago, the idea of an edited volume on spontaneous thought might have seemed far-fetched. Yet fast-forward to 2018, and the topic—once considered a "fringe" or "pseudo" science—has begun to thrive in mainstream research. This growing scientific interest in spontaneous mental activity was sparked by several independent findings from psychology and neuroscience research that have recently been synthesized under the heading of a new field: *the neuroscience of spontaneous thought* (see Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016, for a recent review).

Beginning in the 1960s, findings from the psychology literature demonstrated that cognition often unfolds independent from the here and now (Singer & McCraven, 1961; Kane, Brown, & McVay, 2007; Killingsworth & Gilbert, 2010; Klinger & Cox, 1987), and subsequent studies have shown that these *task-unrelated* or *stimulus-independent thoughts* exhibit complex relationships with attention (Antrobus, Singer, & Greenberg, 1966; McVay & Kane, 2010; Smallwood & Schooler, 2006; Teasdale et al., 1995) and well-being (Giambra & Traynor, 1978; McMillan, Kaufman, & Singer, 2013; Watkins, 2008). In parallel, neuroscientists discovered that a set of regions known as the *default network* becomes more active when participants disengage from a wide variety of tasks (Raichle et al., 2001; Shulman et al., 1997a), leading to a plethora of studies attempting to uncover the network's functional roles (reviewed in Buckner, Andrews-Hanna, & Schacter, 2008). Subsequently, the introduction of *resting state functional connectivity* (RSFC) into mainstream neuroscience research (i.e., Fox et al., 2005; Greicius, Krasnow, Reiss, & Menon, 2003) demonstrated that intricate maps of the brain's functional network architecture could be derived from an fMRI scan while individuals rested quietly in the scanner (reviewed in Fox & Raichle, 2007). Collectively, these findings revealed that a set of brain regions becomes engaged in coordinated ways when individuals are left alone undisturbed.

Neuroscientists therefore started to question: "What is so special about periods of rest?"

In this chapter, we highlight how our understanding of the neuroscience of spontaneous thought has benefited greatly from integrating these parallel findings across psychological and neuroscientific levels of analysis, as well as related fields such as the philosophy of mind-wandering (Carruthers, 2015; Dorsch, 2015; Irving, 2016; Irving & Thompson, Chapter 8 in this volume; Metzinger, 2013; Metzinger, 2015; Sripada, Chapter 3 in this volume; Sripada, 2016). Realizing that the mind is always active—spontaneously associating, simulating, remembering, predicting, mentalizing, and evaluating—suggests that the default network's coordinated activity during periods of wakeful rest may be neither a coincidence nor indicative of a state of idleness. Similarly, the recent discovery that regions associated with executive control become engaged during mind-wandering[1] (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015) sheds important light on the complex behavioral relationships between mind-wandering and executive function. Here we discuss how interdisciplinary cross-talk led to evolving views on how to define, measure, and understand the significance of spontaneous thought, and how these inquiries continue to spark new questions for future research on this elusive phenomenon.

Evolving Definitions of Spontaneous Thought

Although the phrase "spontaneous thought" is often equated with "mind-wandering" throughout the literature, we recently proposed that mind-wandering is but one member of a larger class of spontaneous processes that also includes nighttime dreaming, as well as aspects of creativity (Christoff et al., 2016; Figure 13.1). We defined spontaneous

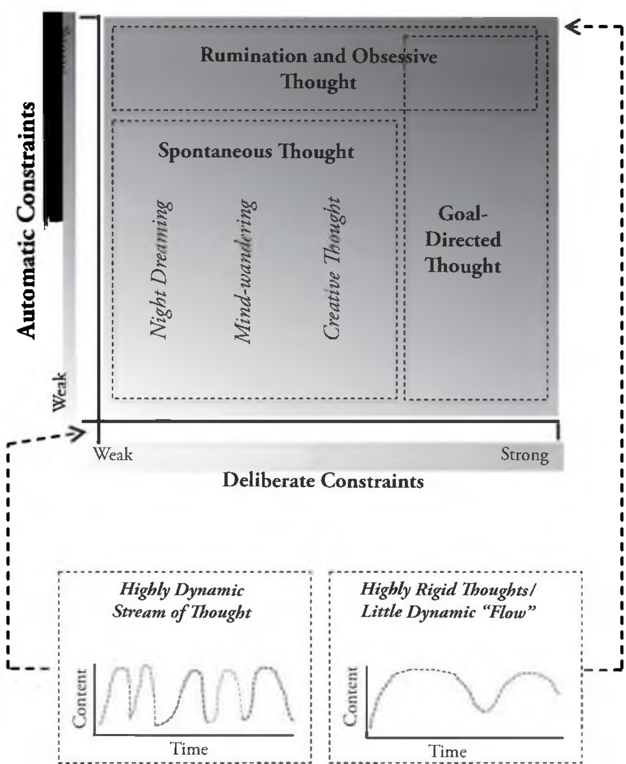

Figure 13.1. A dynamic model of spontaneous thought. Spontaneous thought spans a conceptual space, inclusive of night dreaming, mind-wandering, and creative thought, that is relatively free from two kinds of constraints: (1) deliberate constraints (x-axis), and (2) automatic constraints (y-axis). According to this model, adapted and extended from Christoff and colleagues (2016), ruminative and obsessive thought are not truly spontaneous in nature due to strong bottom-up, "automatic" constraints that bias their content. The dynamics of thought—the way thoughts unfold and flow over time—represent an important element of this model. As shown in the bottom left box, thoughts that are free from both kinds of constraints should transition relatively quickly and span different phenomenological content (represented by different gray colors). Conversely, excessively constrained thoughts should have longer durations with similar content (bottom right box). (See Color Insert)

thought as "a mental state, or a sequence of mental states, that arise relatively freely due to an absence of strong constraints on the contents of each state and on the transitions from one mental state to another" (p. 719). Three key components of this definition are largely overlooked by prior research (see also Irving, 2016, for a philosophical theory that incorporates similar developments). First, the definition suggests that thoughts arising in a spontaneous or unintentional fashion should not be equated with thoughts arising deliberately, even when such thoughts have similar (e.g., task-unrelated) contents. Second, this definition contrasts thoughts that arise spontaneously from those that are constrained through automatic sources, such as perceptual and affective salience. Third, if spontaneous thoughts unfold relatively free from constraints, they should flow in a flexible and dynamic manner.

Although these principles may seem inherent to the term "spontaneity," the bulk of the mind-wandering literature characterizes the phenomenon by its *contents*, rather than the *processes* by which thoughts are evoked (i.e., Smallwood & Schooler, 2006). For years, mind-wandering has been defined as being either unrelated to the task at hand (as a *task-unrelated thought*) (e.g., Giambra, 1989), or as independent from external stimuli (as a *stimulus-independent thought*) (e.g., Teasdale et al., 1995). While more recent taxonomies suggest that true episodes of mind-wandering are thoughts that are both task-unrelated *and* stimulus-independent (Stawarczyk et al., 2011a), such definitions do not consider the manner in which thoughts are evoked, nor how they unfold over time (but see Christoff, 2012; Irving, 2016; Irving & Thompson, Chapter 8 in this volume; Klinger, 1971; McMillan et al., 2013; Seli, Carriere, & Smilek, 2015a; Smallwood & Schooler, 2015; Stan & Christoff, Chapter 5 in this volume).

The distinction between spontaneous versus deliberate thought is critical in many respects. For one, recent research suggests that unintentional versus intentional task-unrelated thoughts show dissociable effects across a variety of behavioral and clinical contexts (Seli, Risko, Purdon, & Smilek, 2016a). For example, intentional task-unrelated thoughts are most frequent in easy compared to difficult tasks, while unintentional thoughts are most frequent in difficult compared to easy tasks (Seli, Risko, & Smilek, 2016b). Further, greater endorsement of unintentional thinking, as measured with a trait questionnaire, positively predicts symptoms of both deficit hyperactivity disorder (ADHD; Seli, Smallwood, Cheyne, & Smilek, 2015b) and obsessive-compulsive disorder (OCD; Seli, Risko, Smilek, & Schacter, 2016c), despite the finding that intentional task-unrelated thoughts do not show significant relationships with symptoms of these disorders. Moreover, intentional task-unrelated thoughts positively predict aspects of trait mindfulness, while unintentional thoughts negatively predict the same mindfulness construct (Seli et al., 2015a). The distinction between unintentional and intentional task-unrelated thinking may also prove important when interpreting existing neuroscience research, as discussed later in this chapter.

Another key dimension of spontaneous thought, foreshadowed by William James as the flowing "stream" in the *stream of consciousness* (James, 1890), is the manner in which thoughts unfold over time. According to the definition of Christoff and colleagues (2016), thoughts that concern a narrow topic, and remain fixated on this narrow topic over time, are not spontaneous in nature because of the excessive constraints that influence how one transitions from one thought to another. As discussed earlier, a train of thought can be constrained in two ways (Christoff et al., 2016; Irving, 2016). One type of constraint that can limit the flow of thought is deliberate in nature—that is, evoked intentionally using top-down control, as when one chooses to remain focused on a particular topic for an extended period of time. Another type of constraint is automatic in nature—as when a habitual thought pattern or salient perceptual stimulus biases one's thoughts toward a specific topic in a bottom-up manner. This temporal variability, largely overlooked by prior research, has important clinical relevance. For example, excessive automatic constraints could characterize ruminative thoughts (see DuPre & Spreng, Chapter 36 in this volume)—a common symptom of depression and anxiety (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008). In contrast, thoughts with excessive variability may characterize ADHD or aspects of psychosis (Christoff et al., 2016). The dynamics of spontaneous thoughts may have additional implications for recent neuroscientific findings (see discussion later in this chapter).

Although this section has given much weight to *process* models of spontaneous thought, the *content* of spontaneous thought is also key, and variability in thought content over time is an important manifestation of its dynamic flow. Additionally, numerous studies have shown that task-unrelated thoughts can have a diverse array of content, including emotional, temporal, and social content that may differ within and between individuals in ways that relate to well-being (Klinger, 2009; Singer & Antrobus, 1966; Smallwood & Andrews-Hanna, 2013). For example, although meta-analyses of behavioral studies show that task-unrelated thoughts have a slightly positive bias on average (Fox et al., 2014; Fox et al., in preparation), symptoms of depression have been linked to more negative and self-focused thoughts (Andrews-Hanna et al., 2013; Giambra & Traynor, 1978). Additionally, while task-unrelated thoughts can sometimes predict worse subsequent mood (Killingsworth & Gilbert, 2010, but see Mason, Brown, Mar, & Smallwood, 2013; Poerio, Totterdell, & Miles, 2013), task-unrelated thoughts pertaining to the future predict *better* subsequent mood (Ruby, Smallwood, Engen, & Singer, 2013). According to the *content regulation hypothesis* proposed by Smallwood and Andrews-Hanna (Smallwood & Andrews-Hanna, 2013; Andrews-Hanna, Smallwood, & Spreng, 2014), an ability to limit one's task-unrelated thoughts to largely positive, constructive content is thought to be a critical factor governing its costs and benefits.

Evolving Approaches to Measuring the Neuroscience of Spontaneous Thought

Thus far, this chapter has introduced a new field—the neuroscience of spontaneous thought—and has discussed how the definition of spontaneous thought (and mind-wandering, in particular) has evolved in recent years. Before synthesizing findings from research on this topic, it is worth discussing how the neural underpinnings of spontaneous thought are commonly measured. The element of spontaneity poses a unique challenge inherent to its experimental study. How can one measure a process that, by definition, cannot be directly experimentally induced, as doing so would introduce deliberate constraints on cognition that conflict with spontaneity? And how can one isolate stretches of spontaneous thought, when they arise at unpredictable times, independently of immediate perceptual input and experimental demands, and often unbeknownst to the person having those thoughts? This section reviews evolving approaches to measuring the neural underpinnings of spontaneous thought, and evaluates such approaches in light of the definitions discussed in the previous section.

Early Neuroscience Research Measured Spontaneous Thoughts Accidentally and Indirectly

Although the field of psychology had begun to address the challenges inherent to the measurement of spontaneous thought by the 1990s, historical biases and demands for rigorous experimental control pressured the neuroscience field to focus on externally-oriented processes with measurable behavioral manifestations (Callard, Smallwood, & Margulies, 2012). As a result, the neuroscience of spontaneous thought trailed behind for decades (but see early efforts by Ingvar, 1979; Andreasen et al., 1995; McGuire et al., 1996; Binder et al., 1999). Given these biases, it may not seem surprising that the *default network*, a brain system now widely appreciated for its role in internally directed thought (Buckner, Andrews-Hanna, Schacter, 2008), was discovered entirely accidentally. This groundbreaking discovery followed a meta-analysis of nine different positron emission tomography (PET) studies of "human visual information processing," each with passive control conditions in which participants fixated on a crosshair or passively viewed the same stimuli (Shulman et al., 1997a, 1997b). To the surprise of the researchers, relatively few regions would exhibit common patterns of blood flow increases across the experimental tasks (Shulman et al., 1997b), while a robust set of regions would show the opposite contrast of *passive fixation > active tasks* (Shulman et al., 1997a). The network that emerged in this second comparison was coined the "default mode of brain function" by Raichle and colleagues in 2001 (Raichle et al., 2001).

Although these two manuscripts brought initial attention to the default mode and introduced several hypotheses regarding the default network's functional significance during periods of awake rest, including the generation of "unconstrained verbally-mediated thoughts" (Shulman et al., 1997a), the studies did not assess the frequency or nature of ongoing thoughts during periods of rest. Despite the efforts of these groups, many subsequent studies assumed the default network and the resting state reflected an idle state with little contribution to active forms of cognition. This assumption was perhaps most apparent throughout the literature on resting state functional connectivity MRI (rs-fcMRI), a technique that examines temporally correlated fMRI activity patterns during extended periods of awake rest (reviewed in Fox & Raichle, 2007). In 2003, fMRI activity time courses from key regions of the default mode were shown to temporally correlate at low frequencies during the resting state, forming a brain system known as the *default mode network*, or *default network* (Greicius et al., 2003; Greicius, Srivastava, Reiss, & Menon, 2004). Several other large-scale brain systems have been subsequently identified using principles of rs-fcMRI (Yeo et al., 2011; Power et al., 2011; Doucet et al., 2011). A commonly held assumption of rs-fcMRI was that patterns of connectivity are *intrinsic* in nature, reflecting a long history of firing and wiring (Fox & Raichle, 2007). Periods of awake rest were used to evoke resting state correlations because cognition was assumed to be at a minimum during this unconstrained state, and low temporal frequencies were isolated partially to ensure that task-related activity was filtered out, despite later findings that unconstrained thoughts unfold at similar frequencies (Klinger, 2009; Vanhaudenhuyse et al., 2010).

Thus, groundbreaking discoveries from neuroscience research in the first decade of the 2000s revealed that periods of awake rest were associated with increased activity in a set of regions that came to be known as the default mode network. Scientists became curious about periods of rest, prompting a synthesis of the psychological literature on unconstrained cognition and mind-wandering. These initial efforts revealed that the absence of experimental tasks should not be equated with the absence of cognition (Andreasen et al., 1995; Binder et al., 1999; Buckner, Andrews-Hanna, & Schacter, 2008; Christoff, Ream, & Gabrieli, 2004), and set the stage for an explosion of research to come.

Measuring the Neuroscience of Spontaneous Thought in the Modern Age

The appreciation that thoughts frequently unfold in the absence of internal and external constraints on cognition led to a plethora of neuroimaging and electrophysiological studies attempting to more precisely characterize their neural underpinnings. Here we review mainstream methods to measure the neuroscience of spontaneous thought (Figure 13.2).

One common method examines individual difference relationships between covert neurocognitive measures (such as fMRI activity, strength of rs-fcMRI correlations between brain regions, structural MRI, neurophysiological/occulometric measures, electroencephalography [EEG] and event related potentials [ERP]) and participant scores on *trait questionnaires* assessing the typical nature of spontaneous thoughts in daily life. Examples of such questionnaires include the Imaginal Process Inventory (Singer & Antrobus, 1966), the Mind-Wandering Questionnaire (Mrazek et al., 2013), and the recent Mind Excessively Wandering Scale (Mowlem et al., 2016). Scores on these and other trait questionnaires are correlated across participants with individual differences in brain activity or connectivity during experimental tasks (Mason

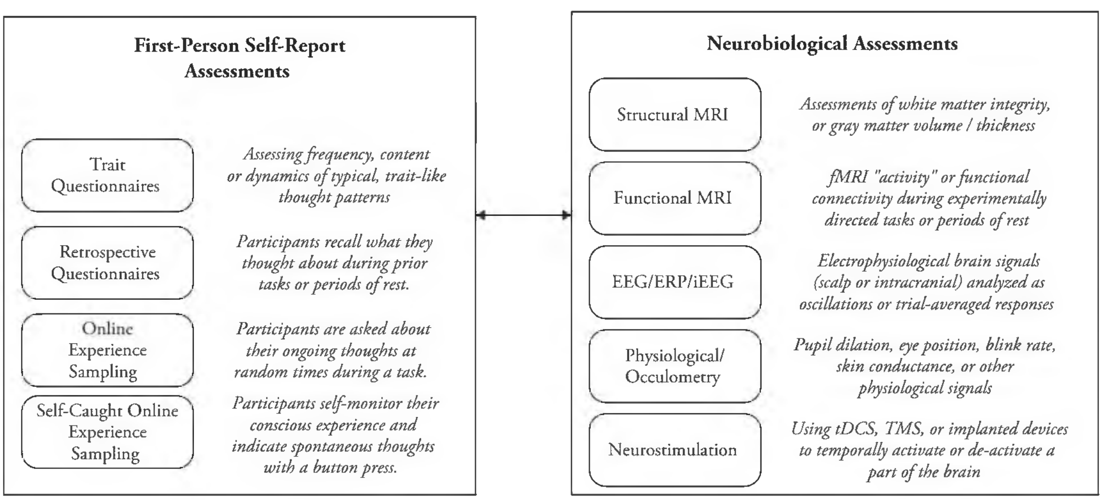

Figure 13.2. Methods to assess the neuroscience of spontaneous thought in humans. Left panel: Many different first-person approaches are used to assess the nature of trait- or state-like thought patterns, although most existing studies do not differentiate between spontaneous and constrained forms of thinking. Right panel: Neuroimaging, psychophysiological, and occulometric approaches are increasingly being employed to covertly assess the neurocognitive correlates of spontaneous thought. MRI = magnetic resonance imaging; EEG = electroencephalography; ERP = event-related potential; iEEG = intracranial EEG; tDCS = transcranial direct current stimulation; TMS: transcranial magnetic stimulation.

et al., 2007) or periods of rest (Kucyi & Davis, 2014). Of particular interest given evolving definitions of spontaneous thought are two additional scales that separately assess the tendency for individuals to engage in intentional and unintentional forms of thought: the Mind-Wandering Deliberate Scale and the Mind-Wandering Spontaneous Scale (Carriere et al., 2013; Seli, Carriere, & Smilek, 2015a). Additionally, the "Mentation Rate" and "Absorption in Daydreams" subscales of the Imaginal Process Inventory (Singer & Antrobus, 1966) focus on the dynamics of spontaneous and deliberate thought (e.g., how quickly one's thoughts transition from topic to topic versus how likely thoughts are to remain focused on a specific topic). Several clinically oriented questionnaires may indirectly measure the dynamics of thought, insofar as they plausibly measure automatic constraints on thought processes. These inventories include the Ruminative Response Scale (Roberts, Gilboa, & Gotlib, 1998; Treynor, Gonzalez, & Nolen-Hoeksema, 2003), the Rumination-Reflection Questionnaire (Trapnell & Campbell, 1999), the Cognitive Intrusions Questionnaire (Freeston, 1991), and the Intrusive Thoughts Questionnaires (Edwards & Dickerson, 1987). Recent studies have begun to examine relationships between these clinically focused traits and individual differences in brain activity or connectivity (Hamilton et al., 2011; Kaiser et al., 2015; Ordaz et al., 2017).

Relating neurobiological measures to trait questionnaires has the advantage of allowing researchers to assess more stable properties of mind-wandering, but may not provide an accurate assessment of participants' thoughts during the tasks or rest periods for which neurobiological measures are derived. For example, Berman et al. (2014) found that group differences in functional connectivity between depressed and non-depressed individuals were much more substantial following a rumination induction period than during a baseline resting state, suggesting that spontaneous cognition may not always track trait measures. To overcome this limitation, researchers commonly administer *retrospective questionnaires* after task paradigms or periods of rest in which neurobiological measures are simultaneously recorded. Retrospective questionnaires require participants to retrospectively reflect on their phenomenological experience during those paradigms, and answer a series of self-report questions characterizing the nature of their thoughts during that time. This approach was originally implemented in conjunction with neuroimaging on an informal verbal basis, prompting Andreasen and colleagues to coin the ironic acronym *Random Episodic Silent Thought* (REST) to emphasize that periods of rest often involve autobiographical memory recall and future thought (Andreasen et al., 1995). In 1996, McGuire and colleagues (McGuire et al., 1996) used a retrospective questionnaire to assess participants' frequency of task-unrelated thoughts following task and rest conditions, and examined which brain regions tracked individual differences in the frequency of task-unrelated thoughts (see also Andrews-Hanna, Reidler, Huang, Randy, & Buckner, 2010a). More than a decade later, a retrospective Resting State Questionnaire was developed to quantify the content and form of thoughts during resting state scans (Delamillieure et al., 2010), and a similar questionnaire was administered in a different study that linked individual differences in thought content to individual differences in functional connectivity during rest (Andrews-Hanna et al., 2010a; see also Doucet et al., 2012; Gorgolewski et al., 2014). Across these studies, participants reported spending a large proportion of time engaging in stimulus-independent thoughts, with thoughts about the future being especially frequent. Retrospective questionnaires have also been used in conjunction with methods assessing pupillometry (Smallwood, Brown, Baird, & Schooler, 2012a) and EEG (Barron, Riby, Greer, & Smallwood, 2011). Collectively, retrospective questionnaires have the potential to reveal the frequency and content of spontaneous thoughts without disrupting ongoing cognition or biasing subsequent attention. A drawback of this approach is that participants may not remember the contents of their thoughts when assessed minutes later, and reported thoughts might be influenced by biases in memory. Additionally, since retrospective questionnaires often ask participants to average multiple thoughts across extended periods of time, they are not ideal approaches to examine the way in which thoughts precisely unfold over time.

Online experience sampling approaches have the potential to overcome many of the limitations of retrospective questionnaires by assessing the nature of thoughts at different moments throughout a task. This approach had gained popularity in psychology (Giambra, 1989; Teasdale et al., 1995), and had initially been adopted for use in simulated scanning environments to approximate the frequency of task-unrelated thoughts in identical paradigms conducted in the scanner (Andrews-Hanna et al., 2010a; Binder et al., 1999; McKiernan, D'Angelo, Kaufman, & Binder, 2006). It was not until 2009, however, that experience sampling probes were incorporated directly into neuroimaging paradigms, allowing researchers to compare patterns of brain activity associated with epochs of on-task versus off-task thought, and examine correspondences with disruptions in behavioral performance (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009a). Since then, additional studies have adopted similar online experience sampling approaches during periods of rest (Tusche, Smallwood, Bernhardt, & Singer, 2014; Van Calster et al., 2016; Vanhaudenhuyse et al., 2010) or external tasks (Kucyi, Salomons, & Davis, 2013; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011b), and the approach has also gained popularity in the EEG (Baird et al., 2014; Kam et al., 2011; Kam et al., 2013; Kirschner et al., 2012; Smallwood et al., 2008) and structural MRI literature (Bernhardt et al., 2014). Note, however, that while most studies ask participants whether they characterized their thoughts as on-task or off-task, some studies have additionally asked about participants' meta-awareness of their thoughts (i.e., Christoff et al., 2009a), or whether their thoughts were dependent or independent of external stimuli (Kucyi, Salomons, & Davis, 2013; Stawarczyk et al., 2011b). These questions, as well as questions assessing other measures of phenomenological content, are important because participants are often unaware of their ongoing mental activity (Fox & Christoff, 2015; Schooler et al., 2011). Furthermore, a sizable proportion of off-task thoughts pertain to external distractions and involve unique neural underpinnings (Stawarczyk et al., 2011b). Critically, to our knowledge, no neuroscientific study has directly assessed, using online experience sampling approaches, whether participants' thoughts arose in a spontaneous or constrained fashion. Thus, as discussed in the next section, existing neuroimaging research may present an incomplete picture, and resolving the neuroscience of spontaneous versus deliberate (and automatically constrained) thought marks an important direction for future research.

One twist on the online experience sampling approach allows participants to press a button the moment they become aware of a spontaneous thought arising. Participants then answer questions characterizing their thought, and subsequently return their attention back to the ongoing task (e.g., focusing on one's breath). This *self-caught online thought sampling* approach gives researchers the opportunity to analyze patterns of brain activity before, during, and after moments of awareness of thought, differentiating brain regions involved in the generation and awareness of task-unrelated and/or spontaneous thoughts (Ellamil et al., 2016; see also Hasenkamp et al., 2012, and Hasenkamp, Chapter 39 in this volume). Related approaches have been adopted for non-meditators as well (Vanhaudenhuyse et al., 2010), offering additional insight into the dynamics of thinking.

Evolving Insight into the Neurobiological Basis of Spontaneous Thought

As discussed in the previous section, neurocognitive research over the last several years has witnessed evolving methodological approaches to characterizing brain systems and tracking the frequency and phenomenology of spontaneous thought. Indirect or inferential approaches have begun to be complemented by real-time assessments that are less influenced by biases and failures of memory. Avenues for future research include novel approaches that could assess spontaneous thoughts covertly without interrupting the participant or relying on self-report, as well as methods that could examine the causal role of brain regions in the generation or dynamics of spontaneous thought (see discussion later in this chapter). In this section, we ask what can be gleaned from the research outlined in the preceding on the neuroscience of spontaneous thought (see also Kam & Handy, Chapter 19 in this volume, for a summary of ERP research).

The Role of the Brain's Default Network in Mind-Wandering

As discussed previously, early neuroimaging studies observed that short breaks in between blocks of externally directed tasks led to blood flow increases in brain regions that would be come to be known as the default network.[2] Subsequent rs-fcMRI studies determined that activity fluctuations within these structures are temporally correlated during rest (i.e., Fox et al., 2005; Greicius et al., 2003). Clustering the magnitude of interregional associations during rest and tasks revealed that the default network can be further parceled into two *subsystems* that converge on *core hubs* (Andrews-Hanna et al., 2010b; Yeo et al., 2011). A ventrally positioned medial temporal subsystem includes the hippocampal formation and parahippocampal cortex, as well as two cortical regions that exhibit direct anatomical connections with the medial temporal lobe: ventral angular gyrus and retrosplenial cortex. A dorsal medial subsystem includes structures spanning the dorsal medial prefrontal cortex (mPFC), the temporoparietal junction, the lateral superior and inferior prefrontal gyrus, and the middle temporal gyrus extending into the temporal pole. These subsystems are strongly interconnected with a set of core hubs centered on the anterior mPFC, the posterior cingulate cortex, the dorsal angular gyrus, the superior frontal sulcus, and right anterior temporal cortex. The default network also includes aspects of Crus I and II of the cerebellum (Buckner, Krienen, Castellanos, Diaz, & Yeo, 2011), and subcortical regions such as aspects of the dorsal and ventral striatum (Choi, Yeo, & Buckner, 2012). Thus, structural and functional MRI research suggests that the default network is a large brain system with interacting components that converge on key association cortices.

Although early neuroimaging studies did not explicitly assess participants' mental states during periods of "rest" that give rise to default network activity, links between unconstrained thinking and the default network were observed across several subsequent studies employing a variety of methodological approaches (but see Raichle, 2016). For example, retrospective questionnaires and online experience sampling approaches revealed that conditions in which participants reported high frequencies of task-unrelated thought were associated with greater default network activity (Andrews-Hanna et al., 2010a; Mason et al., 2007; McKieran et al., 2006), that off-task trials activated the default network to a greater degree than on-task trials (Christoff et al., 2009a; Stawarczyk et al., 2011b), and that stimulus-independent thoughts during the resting state activated the default network to a greater degree than epochs in which participants were focused on external perceptions (Preminger, Harmelech, & Malach, 2011; Stawarczyk et al., 2011b; Van Calster et al., 2016; Vanhaudenhuyse et al., 2010). Additionally, individual difference analyses revealed positive associations between default network activity during ongoing tasks and mind-wandering as assessed with trait questionnaires and retrospective measures (Mason et al., 2007). Conversely, experienced meditators, as compared to novices, show less default network activity and experience fewer task-unrelated thoughts while meditating (Brewer et al., 2011). Links between task-unrelated thinking and the default network also extend to individual differences in rs-fcMRI measures (Andrews-Hanna et al., 2010a; Doucet et al., 2012; Gorgolewski et al., 2014; O'Callaghan, Shine, Lewis, Andrews-Hanna, & Irish, 2015; Smallwood et al., 2016; Wang et al., 2009), and structural MRI measures such as cortical thickness (Bernhardt et al., 2014; Golchert et al., 2017). In 2015, much of the work outlined in the preceding was synthesized in two formal fMRI meta-analyses of mind-wandering (Fox et al., 2015; Stawarczyk & D'Argembeau, 2015). These meta-analyses revealed that several regions throughout the default network—particularly regions associated with the default network core—were reliably associated with mind-wandering across studies employing diverse populations and methodological approaches (Figure 13.3), but also regions outside the DN (see the following).

Although the default network is now widely appreciated for its role in spontaneous thought, the precise functional contributions of the specific regions involved remain unclear, particularly because the studies included in the meta-analysis defined mind-wandering by its task-unrelated and/or stimulus-independent nature, rather than by its spontaneous dynamic processes. One intriguing possibility is that different regions, subsystems, or multivariate patterns within the default network support the conceptual content and/or form characterizing spontaneous thoughts (Andrews-Hanna et al., 2010; Andrews-Hanna, Smallwood, & Spreng, 2014; Gorgolweski et al., 2014; Smallwood et al., 2016; Tusche et al., 2014). For instance, specific patterns of default network activity might differentiate a positive spontaneous thought about one's upcoming wedding from a negative memory about an ex-partner, or a thought of any other conceptual nature. This possibility is supported by evidence from a variety of task-related and rs-fcMRI studies suggesting that the medial temporal subsystem might support contextual, visuospatial, and temporal aspects of memory and imagination—important for constructing a mental scene (Addis, Pan, Vu, Laiser, & Schacter, 2009; Andrews-Hanna et al., 2010b; Bar, 2007; Bar, Aminoff, Mason, & Fenske, 2007; Hassabis & Maguire, 2009)—whereas the dorsal medial subsystem may support a variety of socio-emotional content (Andrews-Hanna, Saxe, & Yarkoni, 2014; Hyatt, Calhoun, Pearlson, & Assaf, 2015; Lieberman, 2007; Spreng & Andrews-Hanna, 2014). The widespread connectivity of core hub regions, combined with their involvement in a variety of self-generated processes, well position these regions to integrate disparate conceptual information when computing the overarching significance or importance of a particular thought (Andrews-Hanna, Smallwood, & Spreng, 2014; Smallwood et al., 2016)—a process that may

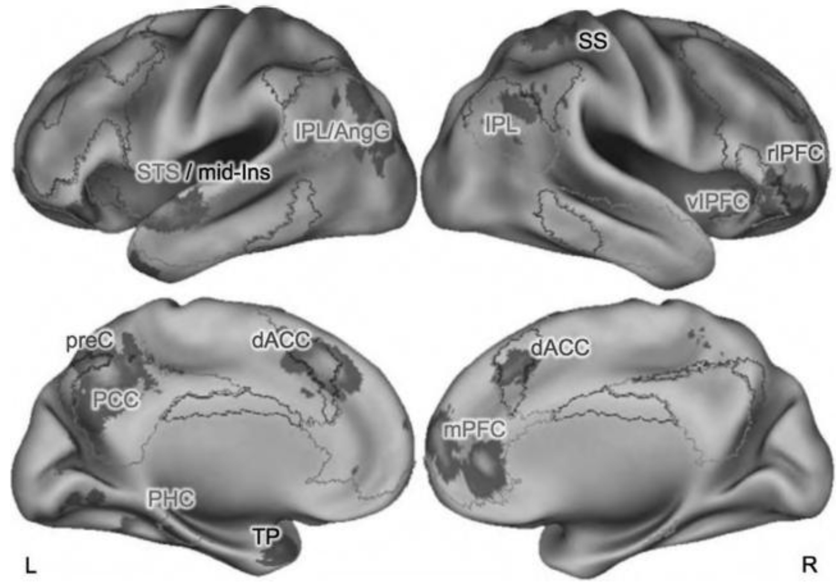

Figure 13.3. Meta-analytic findings reveal neuroimaging correlates of task-unrelated and/or stimulus-independent thought. A meta-analysis of 10 fMRI studies demonstrates that many regions within the brain's default network (outlined in light gray, using 7-network parcellations from Yeo et al., 2011) and the frontoparietal control network (outlined in dark gray) are reliably engaged across studies of task-unrelated and/or stimulus-independent thought. Regions within the default network include: medial prefrontal cortex (mPFC), posterior cingulate cortex (PCC), parahippocampal cortex (PHC, a part of the medial temporal subsystem; see Yeo et al., 2011), inferior parietal lobule (IPL), angular gyrus (AngG), superior temporal sulcus (STS), and ventral lateral PFC (vlPFC). Regions within the frontoparietal control network include: rostral lateral prefrontal cortex (rlPFC), dorsal anterior cingulate cortex (dACC), and precuneus (preC). Regions spanning other networks include mid insula (mid-Ins), somatosensory cortex (SS), and temporal pole (TP, extending into the dorsal medial subsystem of the default network). Note that the fMRI studies included in the meta-analysis do not differentiate between spontaneous and constrained forms of thinking, so it is unclear which regions are involved in spontaneous thought, and which are involved in exerting constraints on those thoughts (see text). (See Color Insert)

partly determine the thought's dynamics, or the way in which it unfolds over time.

It is also possible that specific components of the default network directly contribute to the generation of spontaneous thoughts in a more domain-general manner, yet interact with other default regions, such as the lateral temporal cortex, to elaborate thoughts with specific conceptual content (e.g., Szpunar, Jing, Benoit, & Schacter, 2015). Evidence from human neuroimaging, intracranial recordings, rodent neurophysiology, and lesion work suggests that the hippocampus and nearby medial temporal structures may be prime candidates for such components (for reviews, see Christoff et al., 2016; Fox, Andrews-Hanna, & Christoff, 2016). In particular, activity in the hippocampus, parahippocampal cortex, and other aspects of the medial temporal subsystem emerge early in the dynamics of spontaneous thought—just prior to the moment of subjective awareness—consistent with a role in the initiation, as opposed to the elaboration and/or evaluation, of spontaneous thought (Ellamil et al., 2016; Gelbard-Sagiv, Mukamel, Harel, Malach, & Fried, 2008). Additionally, reviews of human intracranial recording studies suggest that spontaneous thoughts, memories, and other dreamlike experiences are elicited more than half the time following electrical stimulation of regions within the medial temporal lobe—considerably more than any other cortical region assessed (reviewed in Selimbeyoglu & Parvizi, 2010; Fox et al., 2016). In rats, hippocampal place cells—neurons with spatial receptive fields that track where a rat is in its environment (O'Keefe & Nadel, 1978)—also spontaneously fire independent of immediate perceptual input, including during brief epochs of "rest" when the rat stops navigating its environment (Foster & Wilson, 2006). This spontaneous hippocampal firing has been linked to replay of prior experiences (Diba & Buzsaki, 2007; Foster & Wilson, 2006), pre-play of upcoming experiences (Dragoi & Tonegawa, 2011, 2013), and even to patterns suggestive of simulations of entirely novel experiences (Gupta, van der Meer, Touretzky, & Redish, 2010). In humans, spontaneous hippocampal activity and connectivity during periods of rest following periods of learning predict the degree to which studied material is encoded into long-term memory (Tambini, Ketz, & Davachi, 2010), and periods of rest as well as sleep are considered critical for memory consolidation and problem-solving (Dewar, Alber, Butler, Cowan, & Della Sala, 2012; Dewar, Alber, Cowan, & Della Sala, 2014; Stickgold, 2005; Wagner, Gais, Haider, Verleger, & Born, 2004). Finally, damage to the medial temporal lobe in hippocampal amnesia and Alzheimer's disease is associated with profound deficits in both memory and imagination (Hassabis, Kumaran, Vann, & Maguire, 2007; Irish & Piolino, 2016), although the effect of such lesions on spontaneous thought has yet to be investigated, to our knowledge. In sum, multiple sources of evidence from human and nonhuman animals suggest that the medial temporal lobe may play a key role in the initiation of a spontaneous thought. The medial temporal lobe is densely interconnected with cortical structures throughout the medial temporal subsystem as well as several core default network regions such as the lateral temporal cortex (Lavenex & Amaral, 2000; Suzuki & Amaral, 1994), thought to play an important role in conceptual knowledge and elaboration (Patterson, Nestor, & Rogers, 2007; Rice, Lambon Ralph, & Hoffman, 2015). Thus, it is likely that the medial temporal lobe does not operate in isolation, and we suspect its connectivity with distant cortical regions within and outside the default network are important determinants of the phenomenological content, form, dynamics, and conscious awareness of spontaneous thought.

The Role of the Frontoparietal Control Network in Mind-Wandering

Although the role of the default network in spontaneous thought has now gained support from a considerable body of research, neuroimaging meta-analyses of mind-wandering also reveal reliable involvement of several regions *outside* the default network (Figure 13.3) (Fox et al., 2015; but see Stawarczyk & D'Argembeau, 2015). Most notable are aspects of the frontoparietal control network (FPCN), a set of regions spanning association cortices such as the lateral prefrontal cortex, dorsal anterior cingulate/pre-supplementary motor area, and anterior inferior parietal lobe (Vincent, Kahn, Snyder, Raichle, & Buckner, 2008; Yeo et al., 2011). The FPCN is thought to allow individuals to flexibly allocate attentional resources toward external stimuli and/or internal representations (i.e., thoughts, memories, and emotions), and to integrate relevant information from external and internal sources of information in the service of immediate and long-term goals (Cole et al., 2013; Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013; Vincent et al., 2008). While the involvement of the FPCN in task-unrelated and/or stimulus-independent thought may seem surprising given that mind-wandering is often assumed to reflect a failure of control (Kane & McVay, 2012; McVay & Kane, 2010), a closer look at the data points to many possible explanations that mark important avenues for future research.

First, the majority of studies define mind-wandering by its task-unrelated and/or stimulus-independent contents, and consequently lump spontaneous and deliberate thoughts together when conducting analyses. It is therefore possible that the FPCN comes online only when individuals experience deliberate task-unrelated thoughts. There are two ways to interpret this claim, which arise from the two ways to distinguish spontaneous from deliberate thoughts. First, it is possible that the FPCN comes online only when participants deliberately disengage from ongoing tasks, and that thoughts arising without intention may not involve the FPCN at all (Seli et al., 2016b). Second, it is possible that the FPCN comes online only when participants deliberately constrain the course that their thoughts take as they unfold over time. In this sense, transient FPCN activity may reflect the deliberate re-allocation of attention away from the task at hand and/or the sustained pursuit of internal goals that are irrelevant to the task at hand. Similarly, sustained patterns of FPCN activity may help participants shield their internal thoughts from less personally-significant distractions, including the sounds of the scanning environment, other thoughts deemed less important, or even the task itself. Despite the injunctions to participants to stay alert and focused on external stimuli in paradigms, such as the Sustained Attention to Response Task (SART), participants may consider real-world issues such as an upcoming exam, a weekend trip, or an unresolved conflict with a friend as more pressing "tasks," which may therefore vie for attention in potentially adaptive ways (Andrews-Hanna, 2012; Baars, 2010; McMillan et al., 2013). Nevertheless, recent findings provide support for the idea that the FPCN might play an important role in deliberate (but not necessarily spontaneous) task-unrelated thinking. Golchert and colleagues (2017) used a trait questionnaire to assess the frequency with which participants engaged in deliberate and spontaneous forms of task-unrelated thought. Participants who engaged in more frequent deliberate thinking exhibited greater functional integration between the FPCN and the DN, and greater cortical thickness in aspects of the FPCN.

Another explanation for the FPCN's involvement in spontaneous and/or deliberate task-unrelated thought concerns the phenomenological content characterizing periods of spontaneous or deliberate thought. Behavioral and neuroimaging studies exploring the content of task-unrelated thoughts suggest that adults spend a considerable proportion of time engaged in prospectively oriented thoughts, including thoughts about future goals, and in planning how to achieve those goals (Andrews-Hanna et al., 2010a; Andrews-Hanna et al., 2013; Baird, Smallwood, & Schooler, 2011; Song & Wang, 2012; Stawarczyk et al., 2011a; Stawarczyk et al., 2013). Support for this idea comes from neuroimaging studies using task paradigms in which participants are explicitly asked to plan for their future. In these autobiographical planning contexts, both the default network and the FPCN become engaged in a tightly coordinated manner (Gerlach, Spreng, Gilmore, & Schacter, 2011; Gerlach, Spreng, Madore, & Schacter, 2014; Spreng & Andrews-Hanna, 2015; Spreng, Stevens, W. D., Chamberlain, J. P., Gilmore, A. W., & Schacter, 2010). One intriguing question is whether thoughts pertaining to upcoming goals can occur and/or unfold in a spontaneous fashion, as suggested by Klinger's *current concern hypothesis* (Klinger, 1971, 2009). If so, would such thoughts recruit activity within the FPCN?

The nature of the task paradigms employed in mind-wandering studies may also partly explain why activity within the FPCN is often associated with task-unrelated thoughts. Most neuroscience research assesses mind-wandering retrospectively or with online experience sampling probes during easy behavioral paradigms in which participants can maintain a minimal level of performance while *simultaneously* allocating their attention toward the task at hand and their (potentially) spontaneous thoughts. Thus, easy tasks—including resting state paradigms and the SART task—may encourage dual-task situations where participants simultaneously direct their attention externally and internally, or rapidly switch between internal and external modes of attention. Both types of processes may recruit the FPCN in a regulatory manner to help coordinate attention across tasks. Conversely, maintaining reasonable levels of performance during difficult behavioral paradigms may require that participants be continuously focused on the task at hand. In these scenarios, occasional off-task trials may be more likely to manifest as decreases in FPCN activity, reflecting lapses in attention marked by a failure of control. Paralleling these findings, behavioral studies of mind-wandering reveal complex relationships between mind-wandering and executive function that appear to partly depend on the difficulty of the ongoing task (Smallwood & Andrews-Hanna, 2013). For example, participants who frequently experience task-unrelated thoughts during easy tasks have higher working memory capacity (Levinson, Smallwood, & Davidson, 2012), suggesting that they are simultaneously able to have task-unrelated thoughts while maintaining acceptable performance on the task. Conversely, participants who frequently experience task-unrelated thoughts during difficult tasks tend to exhibit poorer working memory capacity (Kane & McVay, 2012; Unsworth & McMillan, 2013). These findings prompted Smallwood and Andrews-Hanna to propose the *context regulation hypothesis*, suggesting that the costs and benefits of mind-wandering partly depend on an individual's ability to constrain task-unrelated thoughts to easy or unimportant contexts (Andrews-Hanna, Smallwood, & Spreng, 2014; Smallwood & Andrews-Hanna, 2013). In light of these observations, future studies could consider examining patterns of activity associated with task-unrelated thoughts across tasks that vary in difficulty.

Finally, it is important to note that not all regions within the FPCN are reliably engaged across studies of mind-wandering: Whereas rostral lateral PFC (rlPFC) and dorsal anterior cingulate cortex (dACC)/pre-SMA are among those present, meta-analyses of mind-wandering show that the dorsolateral prefrontal cortex (dlPFC), posterior PFC, and anterior inferior parietal lobe are not reliably engaged across studies (Fox et al., 2015). The rlPFC has been linked to metacognitive awareness of one's thoughts, attention, and performance (Fleming & Dolan, 2012; McCaig, Dixon, Keramatian, Liu, & Christoff, 2011), so activity in the rlPFC could reflect the monitoring processes encouraged by online experience sampling tasks (but see Christoff et al., 2009a). Furthermore, dACC/pre-SMA may play an important role in the detection of internal conflict elicited when mind-wandering during the presence of an ongoing task, or in computing trade-offs in the expected values of being on-task versus off-task.

Intriguingly, according to some theories of prefrontal cortex function, the prefrontal cortex is organized along a rostro-caudal gradient, where more anterior regions become engaged by more abstract or temporally extended conditions that often rely on internal processes such as episodic memory and maintenance of long-term goals (Badre & D'Esposito, 2009; Christoff & Gabrieli, 2000; Christoff, Keramatian, Gordon, Smith, & Mädler, 2009b; Christoff, Ream, Geddes, & Gabrieli, 2003; Dixon, Fox, & Christoff, 2014; O'Reilly, 2010). Conversely, posterior PFC regions tend to respond to more specific task demands, such as learning specific stimulus-response contingencies, biasing attention toward one stimulus attribute and away from another, or flexibly adjusting one's attention following errors in performance (Badre & D'Esposito, 2009; Christoff et al., 2009b; O'Reilly, 2010). It is therefore possible that the FPCN activation during mind-wandering represents a form of abstract control that is compatible with a considerable degree of dynamic spontaneity. Because abstract goals (e.g., "do well as an academic") place few constraints on *how* one is to achieve or think about them, one's thoughts may be directed toward such a goal, while still spontaneously wandering to a broad range of ideas (Irving, 2016). This hypothesis makes testable predictions: Periods of spontaneous task-unrelated thought (measured through online thought sampling) that are loosely constrained to an abstract goal should be associated with more anterior PFC activation, whereas periods of task-unrelated thought that are deliberately constrained to a specific goal should be associated with more posterior PFC activation. In sum, although the functional contributions of the FPCN are unclear, different regions or patterns within and across regions likely play different roles and are likely influenced by a variety of factors (see Christoff et al., 2016, for a similar point).

The Role of Additional Brain Regions

A synthesis of existing neuroscience research on mind-wandering would be incomplete without discussing the involvement of additional regions outside the default and frontoparietal networks, including the lingual gyrus, somatosensory cortex, and posterior insula (Figure 13.3). Collectively, these regions may be associated with the sensory and embodied perception of task-unrelated thoughts. Many individuals characterize their thoughts during awake rest as unfolding in the form of mental *images* (Delamillieure et al., 2010), and the lingual gyrus may support the visual nature of such thoughts. The lingual gyrus is reliably observed during a variety of visual and mental imagery tasks—including when individuals are dreaming (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013), or asked to recall their past and imagine their future (Addis et al., 2009)—and lesions to this region are associated with an impaired ability to engage in visual imagery and reduced levels of dreaming (Solms, 1997, 2000). Similarly, the somatosensory cortex and posterior insula, associated with tactile sensation, tactile imagery, and interoceptive awareness (Craig, 2003; Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004; Yoo et al., 2003), could relate to the frequently reported thoughts about the body (Delamillieure et al., 2010; Diaz et al., 2013) and/or distracting external sensations. Interestingly, there is some evidence from rs-fcMRI that individuals who characterize their thoughts as having more visual imagery during periods of rest show heightened connectivity between visual regions, including the lingual gyrus, somatosensory cortices, and posterior insula (Doucet et al., 2012), perhaps reflecting attention toward sensorimotor and perceptual characteristics of unconstrained thinking.

The Role of Default and Frontoparietal Networks in Dreaming and Creative Thought

In this section, we have synthesized research investigating the neuroscience of spontaneous thought, focusing on studies defining mind-wandering largely by its contents (since studies defining mind-wandering by its spontaneity are scarce). Whereas some expected findings have emerged from this synthesis—namely, the involvement of the default network—other findings—namely, the involvement of the FPCN—are more surprising, inviting several distinct hypotheses regarding their precise role in spontaneous thought. We now turn to neuroscience research examining two cognitive processes closely related to spontaneous thought—namely, dreaming and creative thinking—and ask whether our knowledge of these mental states can shed light on the role of the FPCN in mind-wandering and spontaneous thought more broadly.

According to the dynamic process model of spontaneous thought illustrated in Figure 13.1, dreaming is considered more spontaneous than mind-wandering due to an absence of many constraints on the contents and flow of mental states during this period, resulting in the bizarre, improbable, and highly dynamic characteristics of dreams (Hobson, Pace-Schott, & Stickgold, 2000). Conversely, creative thought is considered less spontaneous than mind-wandering because it usually unfolds in the service of a specific goal (e.g., to generate a creative idea, solution, or product), and involves more deliberate processes of selecting a creative solution, evaluating its utility, and revising it if necessary (Beaty, Benedek, Kaufman, & Silvia, 2015). Creative insight also involves aspects of metacognitive awareness (Armbruster, 1989), as individuals who lack awareness of their creative ideas may be unable to benefit from them. Consequently, assuming that activity within the FPCN during mind-wandering at least partially reflects the deliberate nature of task-unrelated thoughts, and/or the metacognitive awareness that often accompanies them, one might expect that dreams would show activity reductions in the FPCN (consistent with lack of cognitive control and metacognitive awareness), while creative thinking might evoke increases in FPCN activity, particularly during later evaluative stages of the creative process.

A synthesis of neuroimaging literature on dreaming supports the role of the FPCN in deliberate constraints and metacognitive awareness (Fox et al., 2013). Compared to periods of relaxed wakefulness, REM sleep is associated with enhanced activity throughout the default network's medial temporal subsystem, and reductions in activity throughout the FPCN, consistent with the bizarre nature of dreams and a lack of awareness while dreaming (Figure 13.4A). Interestingly, lucid dreamers—individuals

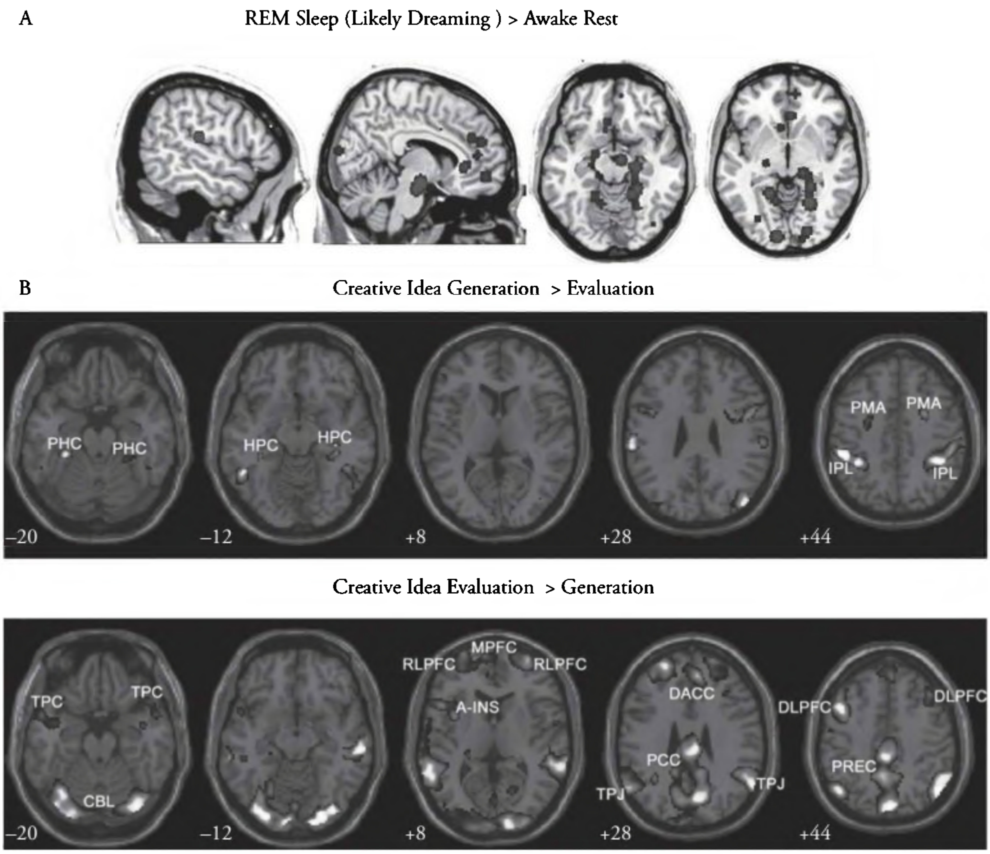

Figure 13.4. Neural underpinnings of night dreaming and creative thought. (A) A meta-analysis of neuroimaging studies on REM sleep (a sleep stage characterized by dreaming) reveals greater activity in a number of brain regions compared to awake rest. Among others, these include medial temporal and medial prefrontal regions within the default network, and visual cortex. (B) Creative thinking is associated with distinct temporal activity dynamics. The medial temporal lobe becomes engaged to a greater degree early in the creative process while generating a creative idea. Other regions within the default network, as well as key frontoparietal control network regions, become engaged to a greater degree during later stages of creative thinking, when evaluating creative ideas.

A-INS = anterior insula; dACC = dorsal anterior cingulate cortex; DLPFC = dorsal lateral prefrontal cortex; CBL = cerebellum; HPC = hippocampus; IPL = inferior parietal lobule; MPFC = medial prefrontal cortex; PHC = parahippocampus; PMA = premotor area (PMA); PCC = posterior cingulate cortex; PREC = precuneus; TPC = temporopolar cortex; TPJ = temporoparietal junction. Figures adapted from Fox et al., 2015 (A), and Ellamil et al., 2011 (B). (See Color Insert) who are aware of their dreams while dreaming, and are often able to deliberately control how their dreams unfold—have enhanced gray matter volume throughout rostrolateral and medial PFC (Filevich, Dresler, Brick, & Kühn, 2015), and also exhibit enhanced rlPFC activity during tasks in which participants are explicitly asked to monitor the contents of their thoughts (Filevich et al., 2015). The FPCN is also widely recruited during lucid REM sleep as compared to non-lucid REM sleep (Dresler et al., 2012).

Conversely, many creative tasks, including tasks of divergent thinking, poetry generation, and creative idea generation, show initial activity within the medial temporal subsystem and the posterior cingulate cortex, followed by enhanced activity and connectivity of FPCN regions when deliberate constraints must be implemented to hone in on creative ideas, or evaluate and revise creative products (Figure 13.4B) (Beaty et al., 2015; Beaty, Benedek, Silvia, & Schacter, 2016; Ellamil, Dobson, Beeman, & Christoff, 2011; Liu et al., 2015). Thus, evidence from neuroscience research on dreaming and creative thinking suggests that the involvement of the FPCN in mind-wandering—and spontaneous forms of thinking more broadly—might reflect deliberate control processes that serve to constrain the content and flow of mental states by guiding and suppressing their spontaneity (Fox & Christoff, 2014). In short, the growing body of neuroscience findings on mind-wandering may reflect an intricate balance of spontaneous and deliberate cognitive processes, and it remains a task for future research to unravel the common or distinct neural underpinnings of each.

New Promises for Future Inquiry into the Neuroscience of Spontaneous Thought

In this chapter, we have synthesized an interdisciplinary field of inquiry—the *neuroscience of spontaneous thought*—and have discussed how definitions of spontaneous thought, approaches to measure spontaneous thought, and knowledge of brain systems supporting such thoughts have rapidly evolved in a few short years. New definitions rely less on the task-unrelated and stimulus-independent content that had long dominated the literature, and more on the processes that govern their initiation, as well as the temporal dynamics that characterize their flow; measurement approaches have shifted from indirect to more direct approaches in which thoughts are assessed much closer to the time at which they occur; and recent neuroscience findings emphasize the importance of regions outside the default network—such as the FPCN, sensorimotor networks, and posterior insula.

With exciting theoretical and methodological progress come many new questions and avenues for future research. One timely research direction regards assessing the forgotten dynamics of spontaneous thought (Christoff et al., 2016; Irving, 2016). To this end, online experience sampling approaches could be used in conjunction with dynamic rs-fcMRI (Calhoun, Miller, Pearlson, & Adalı, 2014) to elucidate how spontaneous thoughts and their corresponding neural underpinnings unfold and change over time (Zabelina & Andrews-Hanna, 2016). These approaches may also shed light on key mechanisms underlying a variety of mental health disorders (e.g., Kaiser et al., 2015).

Another direction for future research includes differentiating between spontaneous and deliberate thoughts at both the behavioral and neural level, and re-synthesizing existing research in light of subsequent findings. Relatedly, there is some suggestion that spontaneous thoughts can be further characterized by the unintentional manner in which they are *initiated* (i.e., Seli et al., 2016b), as well as the unconstrained nature in which they *unfold* over time (Christoff et al., 2016; Irving, 2016; see also Stan & Christoff, Chapter 34 in this volume). Although the initiation and dynamics of spontaneous thought are likely correlated, they are conceptually distinct (Smallwood, 2013). They are likely correlated because top-down constraints on thought are typically (perhaps always) initiated with deliberate intent. Yet they are conceptually distinct for two reasons. For one, it seems possible to unintentionally initiate automatic constraints on the spontaneous dynamics of thought. For example, a depressed patient might unintentionally begin to ruminate. Furthermore, it seems possible to intentionally initiate a thought process with spontaneous dynamics. During a boring lecture, for example, one might intentionally let one's mind wander in an unconstrained manner. To help determine the relationship between these two ways of characterizing spontaneous thought, future research could design questionnaires that directly assess the tendency to have thoughts whose *dynamics* are unconstrained, compared to the tendency to *initiate* thoughts unintentionally. Researchers could then relate both forms of spontaneity to individual differences in brain activity and connectivity.

Additionally, although this chapter has largely focused on the role of deliberate constraints in restricting the contents and flow of thought, another type of constraint can also limit its spontaneity. Affective and perceptual biases in attention are examples of *automatic constraints* that serve to capture and hold one's attention on specific sources of information (see earlier discussion in this chapter; Christoff et al., 2016; Irving, 2016; Irving & Thompson, Chapter 8 in this volume; Todd et al., 2012). Although little is known about the relationship between automatic constraints and spontaneous thought, preliminary evidence from clinical literature on depression and anxiety implicates an important role of the brain's salience network (McMenamin, Langeslag, Sirbu, Padmala, & Pessoa, 2014; Ordaz et al., 2017; Seeley et al., 2007; reviewed in Christoff et al., 2016).

Future research would also benefit from developing new methods to covertly assess spontaneous thoughts without relying on self-report. Despite the usefulness of the introspective approaches discussed in the preceding, self-report assessments come with several limitations. Participants are sometimes unaware of their own mental activity, and most studies do not assess participants' subjective level of awareness. Participants may also interpret questions and use self-report scales in different ways, sometimes being sensitive to perceived experimenter expectations. Additionally, the act of requiring participants to introspect about their mental activity may interfere with the natural course of cognition, and may bias participants to think in particular ways. To overcome some of these limitations, analysis methods such as machine learning algorithms could be applied in future work to covertly predict the nature of mental activity based on voxelwise patterns of brain activity (i.e., with *multivoxel pattern analysis*; Kragel, Knodt, Hariri, & LaBar, 2016; Tusche et al., 2014), and/or concurrent behavioral, occulometric, neurophysiological, or neuroendocrine measures. Additionally, these approaches could eventually be used in conjunction with real-time fMRI to train people to become more aware of their thinking patterns (e.g., McCaig et al., 2011; McDonald et al., 2017; see also Garrison et al., 2013a; Garrison et al., 2013b), and improve their ability to stay on task, or engage in productive forms of spontaneous thought.

Finally, although neuroimaging and behavioral approaches can offer insight into the neural underpinnings of spontaneous thought, these approaches are correlational at best, and are unable to reveal whether patterns of brain activity play a causal role in the initiation or dynamics of spontaneous thought. Future research should therefore make use of methods such as transcranial magnetic stimulation (TMS) or transcranial direct current stimulation (TDCS) to transiently disrupt or enhance activity in certain brain regions (Axelrod, Rees, Lavidor, & Bar, 2015), and neuropsychological studies should consider assessing if and how spontaneous thoughts become altered in patients with focal cortical or subcortical lesions. Toward this end, intracranial electroencephalography also marks a promising area of future research (reviewed in Selimbeyoglu and Parvizi, 2010; Fox et al., 2016).

An old sufi parable attributed to Mulla Nasrudin might serve as an analogy for the history of research on spontaneous thought. A police officer approaches a drunk man who's searching for something beneath a lamppost, "What are you looking for?" "My keys, Sir," the drunk man replies. The police officer helps to look for a few minutes. Finding nothing, the officer asks, "Are you sure you lost them under the lamppost?" "No," says the drunk, "I lost them in the park." "Then why are you searching here?!?" "Because there's a light." Like the drunk man, the field of psychology may have neglected spontaneous thought for over a century because it is shrouded in darkness. From Behaviorism through the Cognitive Revolution, the field looked for psychological processes under the light of experimental tasks. Methodological innovations in neuroscience and psychology moved our gaze a little further, but still we look only at those forms of "mind-wandering" that can be illuminated by their contents. Now it's time to break out the flashlights, to step into the darkness wherein lies the dynamics of spontaneous thought.

Acknowledgments

We extend our gratitude to Evan Thompson, Randy Buckner, Jonathan Smallwood, Matt Dixon, Rebecca Todd, Chandra Sripada, and Dasha Zabelina for helpful feedback and scholarly discussion on our teams' recently published manuscripts featured in the present chapter. A Brain and Behavioral Research Foundation Grant supported J. R. A.-H. while preparing this chapter. K. C. was supported by grants from the Natural Sciences and Engineering Research Council (NSERC) (RGPIN 327317–11) and the Canadian Institutes of Health Research (CIHR) (MOP-115197). Z. C. I. was supported by a Social Sciences and Humanities Research Council of Canada (SSHRC) postdoctoral fellowship, the Balzan Styles of Reasoning Project, and a Templeton Integrated Philosophy and Self

Control grant. R. N. S. was supported by an Alzheimer's Association grant (NIRG-14-320049). K. C. R. F. was supported by a Vanier Canada Graduate Scholarship.

Notes

1. In the first section, we discuss how the definition of mind-wandering varies throughout the literature, leading to disparate interpretations of existing experimental findings. Note that while we use the term "mind-wandering" loosely in this chapter, we are sensitive to these different interpretations and discuss them at length when possible.
2. Strictly speaking, we have argued that mind-wandering is a form of spontaneous thought, and so we cannot be sure that these studies are measuring mind-wandering properly defined (as we discuss throughout this section when interpreting current findings).

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CHAPTER

14

Neural Origins of Self-Generated Thought: Insights from Intracranial Electrical Stimulation and Recordings in Humans

Kieran C. R. Fox

Abstract

Functional magnetic resonance imaging (fMRI) has begun to narrow down the neural correlates of self-generated forms of thought, with current evidence pointing toward central roles for the default, frontoparietal, and visual networks. Recent work has linked the arising of thoughts more specifically to default network activity, but the limited temporal resolution of fMRI has precluded more detailed conclusions about where in the brain self-created mental content is generated and how this is achieved. This chapter argues that the unparalleled spatiotemporal resolution of intracranial electrophysiology (iEEG) in human epilepsy patients can begin to provide answers to questions about the specific neural origins of self-generated thought. The chapter reviews the extensive body of literature from iEEG studies over the past few decades and shows that many studies involving passive recording or direct electrical stimulation throughout the brain point to the medial temporal lobe as a key site of thought-generation.

Key Words: self-generated thought, functional magnetic resonance imaging, fMRI, medial temporal lobe, default network, intracranial electrophysiology, iEEG

An enormous amount of scientific interest has recently begun to focus on spontaneous and self-generated forms of thought (Andrews-Hanna, Smallwood, & Spreng, 2014; Christoff, 2012; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Seli, Risko, Smilek, & Schacter, 2016). As experience sampling studies (see Stawarczyk, Chapter 16 in this volume) and questionnaires develop an understanding of the associated subjective content (Delamillieure et al., 2010; Diaz et al., 2013; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; Fox, Thompson, Andrews-Hanna, & Christoff, 2014; Stawarczyk, Chapter 16 in this volume; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011), functional neuroimaging research over the past two decades has delineated a rough but increasingly refined picture of general brain recruitment associated with these self-generated forms of thought (Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015). Throughout this chapter, by "self-generated thought" I will simply mean mental content that is relatively independent of and unrelated to the immediate sensory environment (Andrews-Hanna et al., 2014; Fox, Andrews-Hanna, & Christoff, 2016); taken broadly, self-generated thought includes mental processes such as stimulus-independent thought (McGuire, Paulesu, Frackowiak, & Frith, 1996), task-unrelated thought (Dumontheil, Gilbert, Frith, & Burgess, 2010), spontaneous thought (Spiers & Maguire, 2006), mind-wandering (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009), creative thinking and insight (Ellamil, Dobson, Beeman, & Christoff, 2012), and dreaming (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013).

Now that a general picture of the subjective content and neural correlates of self-generated thought is emerging, deeper and subtler questions are being posed: for instance, whether specific neural correlates are associated with specific self-generated content (Gorgolewski et al., 2014; Tusche, Smallwood, Bernhardt, & Singer, 2014); whether differences in brain morphology are associated with individual tendencies toward certain types of self-generated thinking (Bernhardt et al., 2014; Golchert et al., 2017); what the relationship of self-generated thought is to various psychiatric and neurodegenerative conditions (Christoff et al., 2016); and whether specific neural origin sites of self-generated thought can be identified (Fox et al., 2016). It is this final question that I will focus on throughout this chapter: What brain structures are the primary initiators, drivers, and creators when the brain decouples from its sensory environment and self-generates its own experiences? Is this question even valid? Can there be a specific answer?

First, I will very briefly review what is known about the broad neural correlates of self-generated thought from functional neuroimaging investigations. These studies point to the primacy of the default network in initiating self-generated thought, but cannot seem to go beyond this level of specificity and offer a more detailed answer due to their inherently poor temporal resolution. Next, I will delve into the relatively smaller (but fast-growing) human intracranial electrophysiology literature to explore the neural origins of self-generated thought in more detail. Starting with the broad set of regions identified by functional neuroimaging as being involved in self-generating thought, I synthesize data from human electrophysiology to hone in on the most likely origin/initiation sites and to tentatively exclude other areas from a primary generative role.

Functional Neuroimaging of Self-Generated Thought: The Importance of Default Network Regions

Noninvasive neuroimaging modalities, particularly functional magnetic resonance imaging (fMRI), have been instrumental in exploring the broad neural correlates and large-scale network dynamics associated with self-generated forms of thought (Christoff et al., 2016; Ellamil et al., 2016; Fox et al., 2013; Fox et al., 2015; Wise, Ide, Poulin, & Tracey, 2004; Zabelina & Andrews-Hanna, 2016). A recent quantitative meta-analysis of neuroimaging studies investigating various forms of self-generated thought (including mind-wandering, stimulus-independent thought, and spontaneous mentalizing) found that a wide variety of brain regions appear to be recruited by these processes, including multiple nodes of the default, frontoparietal, and visual networks (Fox et al., 2015; Figure 14.1). Although this meta-analysis demonstrated the importance of brain regions and networks beyond the default network to self-generated thought, it was unable to answer more specific questions about the functional roles of each network, or of their temporal primacy in initiating self-generated forms of thinking.

Two specific neuroimaging studies of the origins of self-generated thought are interesting not only for the light they shed on this problem, but also because they exemplify the limitations of fMRI when it comes to identifying specific neural origin sites. Briefly, these studies point to the involvement of default network regions in the initial self-generation of thought, but have not been able to identify which specific components of the network are most important.

First, a study by Ellamil and colleagues in 2012 recruited visual artists at a local fine arts university to create visual art while in the scanner using an MRI-compatible drawing tablet and pen (Ellamil et al., 2012). The artists were then asked to reflect on and evaluate the quality of the artwork they had created. The "generation" phase of artwork creation was contrasted with a control condition where the artists simply traced the pen around the drawing tablet, therefore controlling for motor effects associated with the act of drawing itself. Among the residual activations associated with the process of generating the artistic ideas themselves, recruitment was observed in the medial temporal lobe (including hippocampus and parahippocampus), inferior and superior parietal lobule, premotor areas, and other regions (Figure 14.2). This study helped narrow down the possible regions implicated in self-generation of creative ideas, but nonetheless the widespread recruitment observed made it difficult to determine which regions, if any, were specifically involved in generating creative thoughts, as opposed to being recruited shortly thereafter to participate in this generation process or its communication to other brain regions. (Note that a similar emphasis on the role of the default network in creative generation has been found in a recent study involving participants generating poetry, as opposed to visual artwork; Liu et al., 2015.)

A related study examined brain activation surrounding the spontaneous arising of everyday

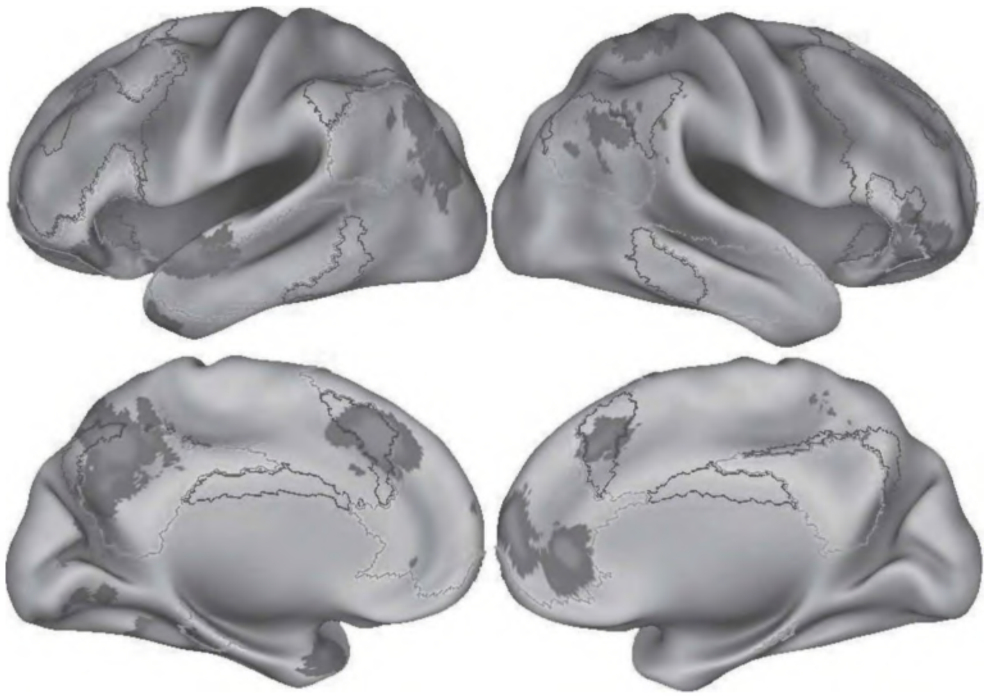

Figure 14.1. Meta-analysis of brain areas consistently recruited by self-generated forms of thought. Meta-analytic clusters indicating brain regions consistently recruited across various forms of spontaneous and self-generated thought. Outline of the frontoparietal (black) and default (blue) networks are shown for comparison. Reproduced with permission from Fox et al. (2015). (See Color Insert)

thoughts when participants' minds wandered while in the MRI scanner (Ellamil et al., 2016). The participants were highly experienced mindfulness meditation practitioners accustomed to monitoring the arising of distracting thoughts and identifying their contents. While they practiced mindful attention to their breathing, they indicated with a button press when they noticed the arising of a spontaneous, unbidden thought into consciousness. The time-course of brain recruitment before, during, and after this button press was then examined in detail. When these time-courses were explored, it was found that certain brain regions showed peaks of activation slightly *before* the subjective awareness of a thought (as indicated by the button press; see Figure 14.3). Various other regions showed peak activations that either coincided with the button press, or followed it (only figures for peak activations *prior* to arising thoughts are shown here; for details of later activation peaks, see the original figures in Ellamil et al., 2016). Regions showing peak activation antecedent to the arising of thought included the medial temporal lobe bilaterally, the inferior parietal lobule, the posterior cingulate cortex, and others (Figure 14.3).

Notably, almost all of these regions are considered components of a broadly defined default

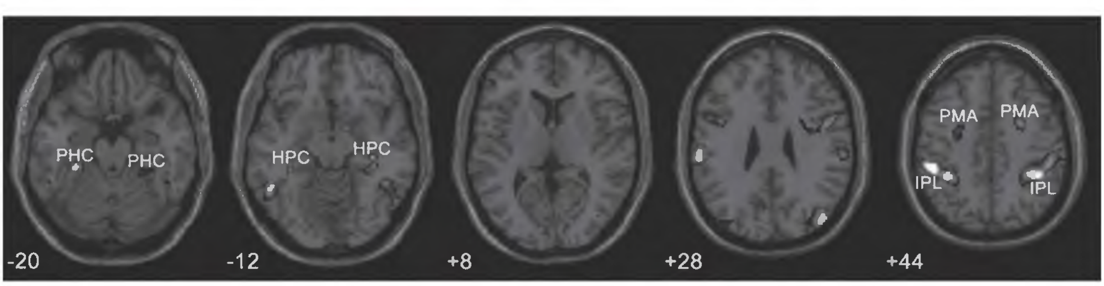

Figure 14.2. Brain regions recruited during the self-generation of creative ideas. Activations throughout the brain during the generation of visual artwork. Numbers indicate z-coordinates in MNI space. HPC: hippocampus; IPL: inferior parietal lobule; PHC: parahippocampus; PMA: premotor area. Reproduced with permission from Ellamil et al. (2012). (See Color Insert)

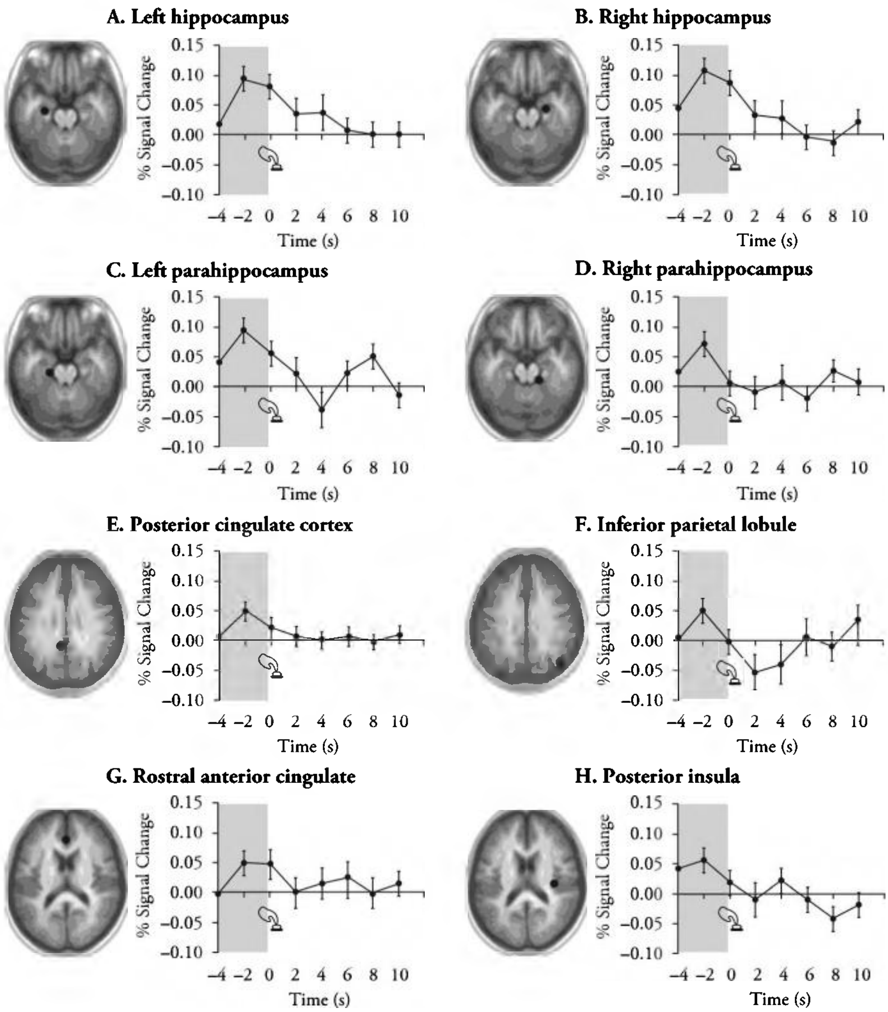

Figure 14.3. Time-course of brain regions where activation peaks just prior to awareness of spontaneously arising of thoughts. Brain regions where activation peaked prior to the conscious awareness of a spontaneous thought arising are indicated by the button-press icon. Note that although the results suggest an important role for the medial temporal lobe, the temporal resolution of fMRI could not distinguish these early activations from those in other brain regions, such as the posterior cingulate cortex and rostral anterior cingulate. Reproduced with permission from Ellamil et al. (2016). (See Color Insert)

network (Buckner, Andrews-Hanna, & Schacter, 2008; Raichle et al., 2001), which (as noted earlier) is widely agreed to be essential to self-generated and self-referential cognitive activity (Fox et al., 2015; Northoff et al., 2006; Stawarczyk & D'Argembeau, 2015). Beyond this focus on the default network, however, the coarse temporal resolution of fMRI was unable to differentiate between the regions showing antecedent activations, leaving important questions unanswered. Are these various default network or other regions equally involved in generating mental content—or might their dispersed but synchronized activity (functional connectivity) be the explanation? Or are specific areas preferentially involved in generating novel patterns of brain activity corresponding to self-generated mental content?

Where Are Thoughts Generated in the Brain? Insights from Human Intracranial Electrophysiology

Direct recording of the electrical activity produced by single neurons and neuronal populations provides unparalleled spatial and temporal resolution (at the scale of single neurons and in the millisecond range) (Fried, Rutishauser, Cerf, & Kreiman, 2014; Suthana & Fried, 2012). By directly recording the brain's electrical activity—be it summation of input signals (potentials in the dendrites and soma), or action potentials carrying a neuron's output signals ("spikes")—many of the pitfalls and uncertainties of the indirect measures used in functional neuroimaging, such as blood-oxygen-level-dependent (BOLD) signal, can be avoided (Logothetis, 2008). An additional advantage is that current can also be "injected" (passed through electrodes on the cortical surface or at depth in the brain), allowing direct electrical stimulation of tissue throughout the central nervous system. Instead of aiming to evoke brain activity (and then record it) using particular tasks, sensory stimuli, or behaviors, the brain can be directly stimulated and the resulting sensory, cognitive, motor, or emotional effects can be observed and correlated with the precise site of stimulation (Penfield & Boldrey, 1937; Selimbeyoglu & Parvizi, 2010). Additionally, with multiple simultaneous electrode sites, responses evoked in response to stimulation at a given site can also be investigated (Fransson, 2005; Golland, Golland, Bentin, & Malach, 2008).

Because of the invasiveness of implanted electrodes, such research cannot be conducted in healthy human participants. In some cases of serious neurological conditions, however, including medication-resistant epilepsy and Parkinson's disease (Bechtereva & Abdullaev, 2000; Lachaux, Rudrauf, & Kahane, 2003), electrical stimulation of the cortical surface or implantation of depth electrodes into deeper cortical and subcortical structures may be indicated in human patients by clinical criteria and protocols (Engel, Moll, Fried, & Ojemann, 2005; Suthana & Fried, 2012). In addition to providing ever-improving clinical benefits for these various conditions (Birn, Murphy, & Bandettini, 2008; Dixon et al., 2017; Foster & Parvizi, 2017), intracranial electrodes provide an unparalleled opportunity to investigate human brain function at very high spatiotemporal resolution.

In many ways, human cognitive electrophysiology remains in its infancy. Nonetheless, the collective results of such investigations in humans have provided unprecedented insights into the understanding of somatosensory and motor systems (Penfield & Boldrey, 1937; Penfield & Welch, 1951), visual perception (Fried, MacDonald, & Wilson, 1997; Kreiman, Koch, & Fried, 2000a; Quiroga, Reddy, Kreiman, Koch, & Fried, 2005), memory (Burke et al., 2014; Gelbard-Sagiv, Mukamel, Harel, Malach, & Fried, 2008; Lega, Jacobs, & Kahana, 2012), spatial mapping and navigation (Ekstrom et al., 2003; Jacobs, Kahana, Ekstrom, Mollison, & Fried, 2010), mathematical cognition (Daitch et al., 2016), visual imagery (Kreiman, Koch, & Fried, 2000b), and even consciousness (Quiroga, Mukamel, Isham, Malach, & Fried, 2008).

This seminal work has only touched on what is possible, however—particularly with respect to higher-order cognitive-affective processes that are difficult, if not impossible, to study in animal models. One such process is the self-generation of mental content by the human brain, the central concern of this *Handbook*. Although no known human electrophysiology has *directly* explored mental states such as mind-wandering, nonetheless many investigations have explored related phenomena, for instance spontaneous memory recall (Gelbard-Sagiv et al., 2008) and immersive, dream-like experiences (Vignal, Maillard, McGonigal, & Chauvel, 2007). Moreover, an increasing number of such studies have investigated default network hubs; given this network's acknowledged importance for self-generated thought (Fox et al., 2015), electrophysiological studies of these areas in humans are of great interest. As we shall see, stimulation and recording experiments in default network hubs can also be very informative, even when null results are obtained.

In attempting to discern origin sites responsible for creating self-generated mental content, both "positive" and "negative" evidence is valuable. By "positive" evidence we mean that which directly links activity in a given brain area to the subjective experience of self-generated mental content: for instance, electrical stimulation of the medial temporal lobe, as well as spontaneous electrical discharges therein, are both frequently associated with dream-like, hallucinated experiences (Fox et al., 2016; Selimbeyoglu & Parvizi, 2010; Vignal et al., 2007), and spontaneous recall of episodic memories is directly preceded by elevated firing rates in medial temporal lobe neurons (Gelbard-Sagiv et al., 2008). Conversely, "negative" evidence accrues when stimulation and/or spontaneous discharges fail to result in such subjective experiences, or sometimes any experiences whatsoever (null results): for instance, hundreds of stimulations to the posteromedial cortex in humans have failed to reliably elicit *any* noticeable subjective effects, including self-generated thought (Foster & Parvizi, 2017), despite the importance of this area to the default network (Greicius, Krasnow, Reiss, & Menon, 2003; Raichle et al., 2001; Yeo et al., 2011) and self-generated thought (Fox et al., 2015; Stawarczyk & D'Argembeau, 2015). In the following sections, we summarize what has been learned from human electrical brain stimulation studies about which regions appear to be likely thought-generation or -initiation sites, and which regions do not.

Positive Evidence: The Importance of the Medial Temporal Lobe and Temporopolar Cortex in Initiating Self-Generated Thought

Medial Temporal Lobe

The most substantial evidence to date points to the medial temporal lobe as a primary (if not the only) origin site for self-generating mental content of various kinds. Electrical brain stimulation to both the hippocampus (Bancaud, Brunet-Bourgin, Chauvel, & Halgren, 1994; Fish, Gloor, Quesney, & Oliver, 1993; Halgren, Walter, Cherlow, & Crandall, 1978; Kahane, Hoffmann, Minotti, & Berthoz, 2003; Mulak, Kahane, Hoffmann, Minotti, & Bonaz, 2008; Vignal et al., 2007) and the parahippocampal region (Feindel & Penfield, 1954; Penfield & Perot, 1963; Vignal et al., 2007) elicit subjective experiences akin to self-generated thought more than half of the time (according to reports in the existing literature) (Table 14.1; Figure 14.4)—considerably more often than any other area studied to date, with the possible exception of the temporopolar cortex (discussed in the next section). These experiences include memory recall (Penfield & Perot, 1963), visual hallucinations (Halgren et al., 1978; Kahane et al., 2003; Penfield & Perot, 1963; Vignal et al., 2007), and dreaming (Halgren et al., 1978; Vignal et al., 2007).

Stimulation of the amygdala also elicits such subjective experiences in about one-third of cases (Table 14.1; Figure 14.4). This fact is intriguing because the amygdala is the only subcortical structure reported to regularly elicit self-generated thought (Figure 14.4). Stimulation of other subcortical structures, such as the thalamus, globus pallidus, and subthalamic nucleus, results in a variety of interesting effects, but none of them bears much resemblance to self-generated thought the way we have defined it (Selimbeyoglu & Parvizi, 2010). Similar to the cortical medial temporal lobe structures, stimulation of amygdala can elicit long-term memory recall (Fish et al., 1993; Vignal et al., 2007), out-of-body experiences (Vignal et al., 2007), visual hallucinations (Fish et al., 1993), and dreams (Vignal et al., 2007).

Temporopolar Cortex

Although reports of stimulation to the temporopolar cortex are relatively rare, about half of these stimulations have resulted in subjective experiences resembling self-generated thought (Bancaud et al., 1994; Halgren et al., 1978; Mulak et al., 2008; Ostrowsky et al., 2002; Penfield & Perot, 1963). As with the medial temporal lobe, stimulation can elicit visual hallucinations (Bancaud et al., 1994; Halgren et al., 1978; Penfield & Perot, 1963), memories (Bancaud et al., 1994), and other thoughts (Ostrowsky, Desestret, Ryvlin, Coste, & Mauguière, 2002). Although this high rate of elicitation of self-generated mental content is suggestive, far too few stimulations have been conducted for any firm conclusions to be drawn. Further stimulations of temporopolar cortex alongside reports of subjective experiences would be highly valuable to a deeper understanding of its role in self-generated thought (see also "Discussion," later in this chapter).

Other Regions

There is also limited evidence for the importance of other regions, most notably the middle temporal gyrus (Kahane et al., 2003; Mullan & Penfield, 1959; Penfield, 1958; Penfield & Perot, 1963), superior temporal gyrus (Morris, Luders, Lesser, Dinner, & Hahn, 1984; Mullan & Penfield, 1959; Penfield & Perot, 1963), and temporo-occipital junction (Lee, Hong, Seo, Tae, & Hong, 2000; Morris et al., 1984; Penfield & Perot, 1963). Isolated reports of experiences such as complex visual hallucinations elicited by stimulation of the frontal lobe are also interesting (Blanke, Landis, & Seeck, 2000; Blanke, Perrig, Thut, Landis, & Seeck, 2000). Because the evidence in these cases is much more marginal, we do not discuss them further here, but suffice to say that the book is hardly closed on the involvement of other brain areas in self-generating mental content. Further details of these isolated reports can be found in Table 14.1 and Figure 14.4.

Also important is the general dearth of stimulation to subcortical areas reported in the literature; more information about subjective effects of stimulation to the brainstem, cerebellum, and other subcortical regions would be a welcome addition to the literature. For a comprehensive overview of subjective effects elicited by stimulation of subcortical structures, see the review by Selimbeyoglu and Parvizi (2010).

Negative Evidence: Marginal Roles for the Posteromedial Cortex and Inferior Parietal Lobule in Initiating Self-Generated Thought

Posteromedial Cortex

The broad area designated as the posteromedial cortex (Parvizi, Van Hoesen, Buckwalter, &

Table 14.1. Summary of Human Electrophysiology Studies Demonstrating Elicitation of Memories, Thoughts, or Hallucinatory, Dream-Like Experiences

Brain Region	Stimulations/ Discharges Eliciting	Total Stimulations/ Discharges	Percentage Eliciting	References
Temporal Lobe				
Hippocampus	25	46	54%	Bancaud, Brunet-Bourgin, Chauvel, & Halgren, 1994; Fish, Gloor, Quesney, & Oliver, 1993; Halgren, Walter, Cherlow, & Crandall, 1978; Kahane, Hoffmann, Minotti, & Berthoz, 2003; Mulak, Kahane, Hoffmann, Minotti, & Bonaz, 2008; Vignal et al., 2007
Amygdala	13	36	36%	Ferguson et al., 1969; Fish et al., 1993; Halgren et al., 1978; Vignal et al., 2007
Parahippocampal region	9	16	56%	Feindel & Penfield, 1954; Penfield & Perot, 1963; Vignal et al., 2007
Temporopolar cortex	5	11	45%	Bancaud et al., 1994; Halgren et al., 1978; Mulak et al., 2008; Ostrowsky, Desestret, Ryvlin, Coste, & Mauguière, 2002; Penfield & Perot, 1963
Inferior temporal gyrus	1	21	5%	Penfield & Perot, 1963
Middle temporal gyrus	7	42	17%	Kahane et al., 2003; Mullan & Penfield, 1959; Penfield, 1958; Penfield & Perot, 1963
Superior temporal gyrus	24	99	24%	Morris, Luders, Lesser, Dinner, & Hahn, 1984; Mullan & Penfield, 1959; Penfield & Perot, 1963
Temporo-occipital junction	4	17	24%	Lee, Hong, Seo, Tae, & Hong, 2000; Morris et al., 1984; Penfield & Perot, 1963
Frontal Lobe				
Inferior frontal gyrus	1	7	14%	Blanke, Landis, & Seeck, 2000
Middle frontal gyrus	2	8	25%	Blanke, Landis, et al., 2000
Orbitofrontal cortex	1	4	25%	Mahl, Rothenberg, Delgado, & Hamlin, 1964
Supplementary motor area	1	6	17%	Beauvais, Biraben, Seigneuret, Saïkali, & Scarabin, 2005
Parietal Lobe				
Inferior parietal lobule	2	42	5%	Blanke, Perrig, Thut, Landis, & Seeck, 2000; Schulz, Woermann, & Ebner, 2007
Posteromedial cortex (including posterior cingulate cortex)	0	248	0%	Foster & Parvizi, 2017

Based on data in Supplementary Table 1 in the comprehensive review conducted by Selimbeyoglu & Parvizi (2010). Updated from a previously published table (Fox et al., 2016). Data for brain areas with ≥ 10 stimulations/discharges reported in the literature are visualized in Figure 14.4. The null effects in the posteromedial cortex are included because of its inherent interest as a major default network hub.

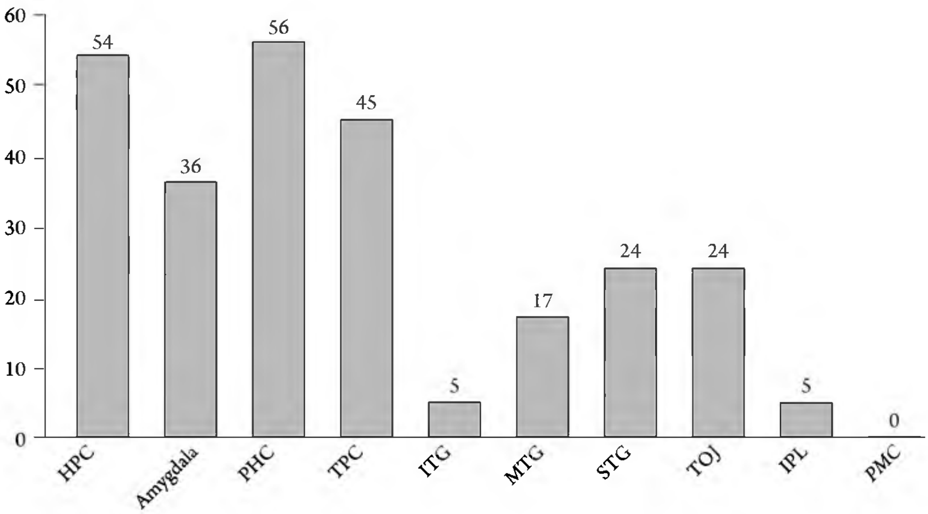

Figure 14.4. Preferential involvement of medial temporal lobe structures and the temporopolar cortex in electrophysiological stimulations (or spontaneous discharges) eliciting memories, thoughts, mental imagery, or hallucinatory, dream-like experiences.

Percentage of stimulations or spontaneous discharges that elicited a first-person experience of memories, thoughts, or hallucinatory, dream-like experiences, based on more than 100 independent investigations. Not shown are data for hundreds of other stimulations throughout the brain, for which no such thought- or dream-like experiences have ever been reported. Only brain areas with ≥10 stimulations or discharges reported in the literature are visualized. HPC: hippocampus; IPL: inferior parietal lobule; ITG: inferior temporal gyrus; MTG: middle temporal gyrus; PHC: parahippocampal cortex; PMC: posteromedial cortex; STG: superior temporal gyrus; TOJ: temporo-occipital junction; TPC: temporopolar cortex. Drawn from data in our Table 14.1, based on data in Supplementary Table 1 of the comprehensive review of Selimbeyoglu & Parvizi (2010); updated and modified based on my previously published figure (Fox et al., 2016). (See Color Insert)

Damasio, 2006), including the posterior cingulate cortex (BA 23/31), precuneus (BA 7), and retrosplenial cortex (BA 29/30), is another likely candidate area for initial generation of thought content. The posteromedial cortex is hypothesized to play a key role in initiating or facilitating memory recall (Shannon & Buckner, 2004), and memory recall and recombination represent a considerable proportion of self-generated thought (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Fox et al., 2013; Stawarczyk, Chapter 16 in this volume). The posterior cingulate cortex is consistently recruited during various forms of self-generated thought (Fox et al., 2015; Stawarczyk & D'Argembeau, 2015), and there is evidence from fMRI that activity there peaks in the 2-second time window during which spontaneous thoughts appear to be arising (Ellamil et al., 2016; Figure 14.3). Moreover, intracranial electrophysiological studies in humans have shown that distinct neuronal populations in the posterior cingulate show elevated high-gamma-band activity both at rest and during self-referential thinking (Dastjerdi et al., 2011).

Despite these promising features, however, the evidence to date from intracranial electrophysiological investigations in humans argues against any causal role for the posterior cingulate cortex, as well as adjacent retrosplenial cortex, in generating or initiating mental content. The most comprehensive study of this region to date was published only recently (Foster & Parvizi, 2017). Exhaustively cataloguing more than 800 electrical stimulations throughout medial posterior brain regions across 25 epilepsy patients, Foster and Parvizi (2017) found that stimulation to centrally located posteromedial brain regions *never* yielded subjective experiences or disturbances of any kind, unless stimulations were executed on dorsal or ventral border regions (Figure 14.5).

A possible exception to these results should be mentioned: a single-patient case study recently reported that electrical stimulation of the posterior cingulate cortex disconnects consciousness from the external environment and results in subjective experiences of "dreaming" (Herbet et al., 2014). If correct, these findings could suggest that posterior cingulate cortex, too, could be considered a powerful initiatory/generative site for self-generated thought (the authors' interpretation of their findings, conversely, is that electrical stimulation "disrupts" posterior cingulate cortex connectivity, which underlies conscious attention to the external world, thus making room for internally generated, dream-like experiences). There are important limitations to

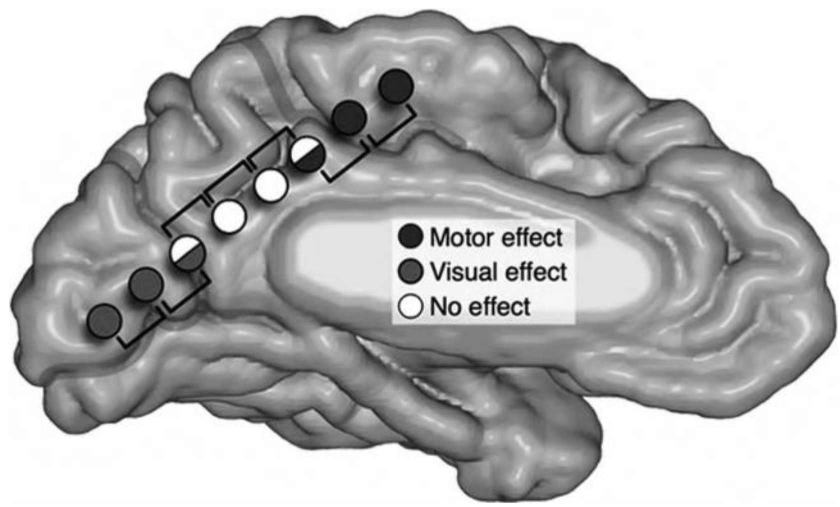

Figure 14.5. Null effects of electrical brain stimulation in the posteromedial cortex default network hub. Summary figure showing subjective effects produced by electrical brain stimulation of various regions of the medial posterior portions of cerebral cortex. More dorsal stimulations preferentially evoke motor effects (black circles), and more ventral stimulations largely evoke visual effects (gray circles). Some 248 stimulations of more central regions, however (white circles), corresponding closely to a major hub of the default network and overlapping with numerous regions known to be recruited by self-generated thought (see Figure 14.1), resulted in no discernible subjective effects of any kind. Reproduced with permission from Foster & Parvizi (2017). (See Color Insert)

this study, however, that render either interpretation unlikely. The central concern is that electrical brain stimulation was delivered not to the gray matter of the posterior cingulate cortex, but instead to the underlying white matter (in the posterior part of the cingulum; see Fig.1 in Herbet et al., 2014). The authors' interpretations of their findings, which focus on discussion of the posterior cingulate cortex, are problematic given that stimulation was in fact delivered to a white matter pathway known to project widely throughout the brain (Schmahmann et al., 2007; Wakana, Jiang, Nagae-Poetscher, Van Zijl, & Mori, 2004). Indeed, the cingulum is especially problematic in this respect because two of its main projections are to the medial prefrontal cortex and medial temporal lobe, both of which are strongly recruited during waking mind-wandering or "daydreaming" (Ellamil et al., 2016; Fox et al., 2015) and REM sleep, where dreaming usually occurs (Domhoff & Fox, 2015; Fox et al., 2013). Although the authors argue that the partial excision of the cingulum in their patient makes downstream stimulation an unlikely explanation (Herbet et al., 2014), nonetheless their results are very reminiscent of studies that delivered current directly to the medial temporal lobe and elicited dream-like experiences and dreamy states (Bancaud et al., 1994; Halgren et al., 1978; Penfield & Perot, 1963; Vignal et al., 2007). To summarize, the authors interpret their findings as related to posterior cingulate cortex function, whereas their paradigm involved the stimulation of a major fiber pathway also connected to the medial prefrontal cortex and medial temporal lobe, both of which appear to be directly involved in the creation of dreamy states and other forms of self-generated thought (Domhoff & Fox, 2015; Ellamil et al., 2016; Fox et al., 2013, 2015). Moreover, their localization of the stimulation electrodes appears to have been based on visual assessment during surgery, as opposed to a more reliable localization based on CT or MRI scans in patients. Given these limitations, this single-subject case study is insufficient to outweigh the results of some 25 patients where hundreds of stimulations to the posteromedial cortex yielded no such effects (Foster & Parvizi, 2017).

Inferior Parietal Lobule

Despite its consistent recruitment during various forms of self-generated thought (Andrews-Hanna et al., 2014; Fox et al., 2015; Figure 14.1) and its undisputed role in the default network (Buckner et al., 2008; Yeo et al., 2011), the inferior parietal lobule does not appear to be a critical origin site for self-generated thought. Two studies have undertaken fairly extensive stimulations to the inferior parietal lobule (Blanke, Perrig, et al., 2000; Schulz Woermann, & Ebner, 2007); of more than 40 stimulations to this region, only two (5%) elicited some subjective experience reminiscent of self-generated thought: whereas most stimulations elicited simple sensorimotor phenomena, one elicited visual hallucinations (Schulz et al., 2007) and another a self-described "out-of-body" experience reminiscent of dreaming (Blanke, Perrig, et al., 2000). Although these exceptions are intriguing, given that some 95% of stimulations to inferior parietal lobule have yielded no such effects (Figure 14.4), the safest conclusion at present is that it should not be considered as a primary thought generation center. It is important to note, however, that "inferior parietal lobule" designates a large swath of cortex where several networks meet one another (Yeo et al., 2011), and clearly not all of the stimulations reported here would fall within the boundaries of the default network. A more fine-grained approach might find that stimulation specifically to the default network subsection of the inferior parietal lobule results in higher rates of elicitation of self-generated thought.

Discussion

Caveat: The Varieties of Electrical Brain Stimulation

An important caveat to all the aforementioned results and conclusions is that electrical brain stimulation is not uniform: voltage, frequency, duration, and other parameters can differ markedly across experiments, and sometimes even within the same patient. Despite this wide variety of stimulation parameters, there is also a fair degree of consistency in some respects—for instance, the majority of studies used 50–60 Hz stimulation—but other factors, such as the current and duration of stimulation, are more variable (Selimbeyoglu & Parvizi, 2010). These facts are most relevant to our discussion of the posteromedial cortex, where null results appear to be the rule (Foster & Parvizi, 2017). The apparent "silence" of the posteromedial cortex may not be definitive: varying stimulation parameters (e.g., increasing its duration and/or strength) in future studies could conceivably lead to different (and positive) results in both the posteromedial cortex (Foster & Parvizi, 2017) and other brain areas.

What Is the Role of the Medial Prefrontal Cortex?

A major lacuna in our knowledge is the role played by the medial prefrontal cortex, which has been relatively rarely investigated in terms of subjective effects in human intracranial patients (Selimbeyoglu & Parvizi, 2010). The medial prefrontal cortex is one of the major hubs of the default network (Buckner et al., 2008; Raichle et al., 2001; Yeo et al., 2011) and is strongly recruited by essentially every form of self-generated thought examined to date, including mind-wandering/daydreaming (Fox et al., 2015), creative thinking (Liu et al., 2015), and dreaming (Domhoff & Fox, 2015; Fox et al., 2013). Future studies elucidating the role of this region are therefore critical to a more complete understanding of the neural origins of self-generated thought.

The Enigmatic Temporopolar Cortex

The high rate of self-generated thought elicited by stimulation of the temporal pole (Figure 14.4) is an intriguing finding that should be followed up with further research. The temporopolar cortex remains a relatively little-studied and poorly understood region, as reflected in the title of a recent comprehensive review: "The Enigmatic Temporal Pole" (Olson, Plotzker, & Ezzyat, 2007). However, anatomists have noted that its pattern of connectivity with other brain regions is strikingly similar to that of the amygdala—another region that appears central to thought generation (Figure 14.4; Fox et al., 2016). This connectivity includes dense interconnections with the orbitofrontal cortex, amygdala, and insula (Gloor, 1997; Kondo, Saleem, & Price, 2003; Olson et al., 2007; Stefanacci, Suzuki, & Amaral, 1996), often leading to its grouping with the medial temporal lobe and orbitofrontal/medial prefrontal cortex as a limbic or paralimbic area (Mesulam, 2000; Olson et al., 2007). Large-scale investigations of intrinsic resting state functional connectivity substantially agree with this conclusion, grouping the temporopolar cortex with medial temporal areas and the orbitofrontal/medial prefrontal cortex in a putative "limbic" network (Yeo et al., 2011).

Anatomical, electrophysiological, and self-report data therefore all point toward the temporopolar cortex as functionally and anatomically related to deeper medial temporal lobe structures. It should therefore come as little surprise that stimulation of this region likewise elicits various kinds of self-generated thought. Task-based functional neuroimaging further supports these links: temporopolar cortex recruitment has been reported in numerous independent fMRI and positron emission tomography (PET) investigations of self-generated thought (Christoff et al., 2009; Christoff, Ream, & Gabrieli, 2004; Dumontheil et al., 2010; Ellamil et al., 2016; McGuire et al., 1996), as well as our recent meta-analysis of these forms of cognition (Fox et al., 2015; Figure 14.1).

More detailed explanations of the temporopolar cortex's function have also been proposed: for instance, a large number of fMRI studies investigating mentalizing and "theory of mind" tasks have observed recruitment of temporopolar cortex (Binder, Desai, Graves, & Conant, 2009; Olson et al., 2007), prompting the recent proposal that this area may flexibly couple with other default network components to facilitate these and other social cognitive processes (Spreng & Andrews-Hanna, 2015). One possibility, therefore, is a role in mediating the large amount of social cognition known to take place during self-generated thought (Diaz et al., 2013; Klinger, 2008). Given the poor contemporary understanding of the temporopolar cortex, however, and other proposed functional roles (for instance, binding visceral-affective assessments with highly processed perceptual information; Olson et al., 2007), the door should be kept open to any number of other possibilities.

What Is Special about the Medial Temporal Lobe?

The possibility that the medial temporal lobe (especially the hippocampus) plays a crucial role in the "ignition" or initiation of self-generated thought has been previously suggested by other researchers (Buckner, 2010; Smallwood, 2013). Although a detailed discussion is beyond the scope of this chapter, some features of medial temporal lobe circuitry may help in explaining the important role played by this region (Fox et al., 2016). Whereas typical neocortical circuitry involves a preponderance of local (short-distance) and a corresponding paucity of long-distance connections (Douglas & Martin, 2004; Markram et al., 2004; Thomson & Bannister, 2003), hippocampal neurons appear equally likely to contact near and distant neighbors (Buzsaki, 2006; Li, Somogyi, Tepper, & Buzsaki, 1992; Li, Somogyi, Ylinen, & Buzsaki, 1994). Given that single neurons in the medial temporal lobe can encode very high-level, invariant representations of the world (for instance, highly specific famous faces or landmarks; Quiroga et al., 2005), this specialized and densely interconnected microcircuitry might provide a flexible substrate for encoding novel and arbitrary associations between one percept or idea and another. In the hippocampus's role as a spatial map, this capacity is thought to be critical in that it allows the mapping of "anything" to "anywhere" (Eichenbaum, Dudchenko, Wood, Shapiro, & Tanila, 1999; Ekstrom et al., 2003)—in principle, any known object or person could be set in any known space in the world, and the medial temporal lobe needs to be able not only to represent these arbitrary associations of object and place in perception, but also to consolidate them to long-term memory.

If a specialized microcircuitry indeed evolved in the hippocampus allowing for the arbitrary combination of neural activity encoding high-level percepts (in principle, allowing the matching of any object or person to any spatiotemporal locus), this capacity could also be "hijacked" via a process of exaptation—that is, the recruitment or involvement of a given structure in some function other than that for which it originally evolved (Gould, 1991; Gould & Vrba, 1982)—and utilized for the self-generation of novel/arbitrary combinations of memory traces. From the subjective perspective, the result of this process would be experienced as the spontaneous arising of thoughts, sudden insights and creative ideas, visual imagery and simulations, and even entirely *sui generis* spatiotemporal landscapes during what we call "dreaming" (Domhoff & Fox, 2015; Fox et al., 2013; Windt, 2010).

On this view, specific patterns of activity initiated in the medial temporal lobe would then recruit (or spread to) regions throughout the brain, likely in a content-dependent manner. There is some preliminary evidence for this kind of association between medial temporal lobe activity and that of other brain regions during self-generated thought. For instance, in an fMRI study of mind-wandering, both overall functional connectivity, as well as fluctuations (variability) in functional connectivity, between the medial temporal lobe subsystem of the default network and the posterior cingulate cortex tracked self-reports of daydreaming frequency (Kucyi & Davis, 2014). On a finer timescale, a study using intracranial EEG investigating spontaneous memory recall found that medial temporal lobe structures showed the earliest peaks in high gamma-band activity, whereas gamma-band peaks were observed slightly later in other areas throughout the temporal, parietal, and frontal lobes (Burke et al., 2014). The medial temporal lobe was not the only area to show high-frequency activity peaking prior to spontaneous recall, but it was the only area where this high gamma-band activity successfully predicted subsequent memory recall, highlighting its importance both in initiating and predicting the success of spontaneous memory recall (Burke et al., 2014). These findings suggest that spontaneous memory recall might be primarily initiated or generated in the medial temporal lobe, followed by a slightly delayed but much more widespread recruitment of other regions throughout the brain—similar to our hypothesis for spontaneous self-generation of mental content other than memory.

Conclusions and Future Directions

Functional neuroimaging has highlighted the importance of several brain networks to self-generated thought, most notably the default, visual, and frontoparietal networks (Fox et al., 2015), and has narrowed down the most likely initiation/generation sites to somewhere within the default network (Ellamil et al., 2012; Ellamil et al., 2016). Ultimately, however, all existing noninvasive neuroimaging modalities lack the spatiotemporal resolution to answer subtle questions about *where* in the brain self-created content is actually generated, as well as how and where this initial self-generated activity subsequently spreads (Fox et al., 2016). Human intracranial electrophysiology, despite being confined to clinical contexts, has helped to again narrow our focus, pointing toward the medial temporal lobe and temporopolar cortex as especially relevant to thought generation, while simultaneously pointing to an only marginal role (if any) for other default network hubs, including the posterior cingulate cortex (Foster & Parvizi, 2017) and inferior parietal lobule (Fox et al., 2016). Future work will need to corroborate, contest, and further refine these coarse generalizations, and understudied but potentially important regions, such as medial prefrontal cortex, will need to be more heavily investigated.

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CHAPTER

15 Mind-Wandering and Self-Referential Thought

Arnaud D'Argembeau

Abstract

When one's mind wanders, one frequently experiences thoughts, images, and feelings about oneself and one's life. These self-referential thoughts involve diverse contents and take various forms, but most often focus on specific future events that are closely related to one's personal goals and concerns. Neuroimaging studies show that such spontaneous thoughts recruit many of the same brain regions—largely corresponding to the default network—as directed self-referential thought. The medial prefrontal cortex is most consistently involved and might contribute to assign value and to integrate processed contents with autobiographical knowledge. The tendency of the wandering mind to focus on self-related information might foster a sense of personal identity and lay the foundation for long-term goal pursuit.

Key Words: mind wandering, spontaneous thought, self, autobiographical memory, goals, future thinking, medial prefrontal cortex, default network

A fascinating feature of the human mind is its ability to temporarily disengage from current sensory input to mentally simulate alternatives to the here and now. During our daily activities, the mind indeed frequently drifts away from the task at hand and focuses on various thoughts and mental images that are only loosely (if at all) related to our immediate environment. These thoughts can be remarkably varied in their content and phenomenology, yet a bit of introspection readily indicates that many of them involve self-referential information—memories of personal experiences, anticipations of and plans about one's future, evaluations of one's personal characteristics and life situations, thoughts about one's social relationships, and so on. The purpose of this chapter is to discuss the nature, neural correlates, and possible functions of such self-referential thoughts.

The Centrality of Self-Referential Thought When the Mind Wanders

The occurrence of thoughts that are not tied to the immediate environment (here referred to as "task-unrelated thought")[1] is a frequent phenomenon: On average, people's minds wander between 25% and 50% of the time in daily life, although there is substantial individual and situational variability in this respect (Kane et al., 2007; Killingsworth & Gilbert, 2010; Song & Wang, 2012). Furthermore, many of the thoughts (around 30%) that people experience in their daily life are judged to be spontaneous (Klinger & Cox, 1987). It has long been proposed that the content of daydreaming and mind-wandering is not random, but is often focused on self-relevant information, such as personal goals and concerns (Klinger, 2013; J. L. Singer, 1998; Smallwood & Schooler, 2006), and recent research on the characteristics of task-unrelated and spontaneous thoughts largely supports this view.

A number of studies have investigated the properties of mind-wandering episodes occurring while performing various tasks in the laboratory. Using a retrospective questionnaire administered after task completion to assess subjective aspects of mind-wandering, Andrews-Hanna, Reidler, Huang, and Buckner (2010) found that task-unrelated thoughts were often judged to revolve around personally relevant concerns. Similarly, Stawarczyk, Majerus, Maj, Van der Linden, and D'Argembeau (2011) collected subjective ratings of mind-wandering episodes occurring in the context of a sustained attention task and found that, on average, participants rated their thoughts as personally important and related to their goals. In a study by Baird, Smallwood, and Schooler (2011), participants reported the content of their mental states at several occasions during a choice-reaction time task, and the subsequent coding of described thoughts revealed that the majority of task-unrelated thoughts (66%) included specific mentions of the individual's self. Relatedly, Cole and Berntsen (2016) observed that memories and future thoughts that were spontaneously activated during a vigilance task were frequently linked to the participants' current concerns.

Investigations of how different thought characteristics relate to each other also point to self-relevance as a central dimension of mind-wandering. For example, Stawarczyk, Cassol, and D'Argembeau (2013) had participants rate various characteristics of task-unrelated thoughts and applied a multilevel factor analysis to these data. The results showed that personal significance was an important factor in explaining variations in thought characteristics, with dimensions that loaded most strongly on this factor being the importance of thought content, relationship to personal goals, and frequency of occurrence in daily life. In the same vein, other studies have indicated that self-relatedness is a central dimension characterizing task-unrelated thought content (Ruby, Smallwood, Engen, & Singer, 2013; Ruby, Smallwood, Sackur, & Singer, 2013).

The self-relevance of mind-wandering has likewise been demonstrated in studies investigating the characteristics of thoughts in daily life. Using an experience-sampling method to assess task-unrelated thought content, Song and Wang (2012) found that most mind-wandering episodes were related to one's self and personal life. Andrews-Hanna et al. (2013) asked participants to report and assess a series of thoughts that had been recently in their minds in daily life. Although the characteristics of reported thoughts varied widely, on average, participants characterized their thoughts as highly self-relevant. Furthermore, when examining the relationships between the different characteristics of thoughts using hierarchical clustering analysis, it was found that personal significance was an important dimension characterizing thought content.

Other studies have focused more specifically on particular types of self-related thoughts. For example, in a series of studies by Berntsen and colleagues (e.g., Berntsen, 1996; Berntsen & Jacobsen, 2008; Finnbogadottir & Berntsen, 2013), participants monitored the occurrence of involuntary (spontaneous) autobiographical memories and future thoughts in their daily life and recorded their characteristics in a diary. Overall, these studies have shown that involuntary autobiographical memories and future thoughts are common in daily life, are often activated in response to situational cues, and typically arise in states of diffuse attention.

In summary, a number of studies using various methods to assess mind-wandering in the laboratory or in natural settings converge to show that task-unrelated and spontaneous thoughts are frequent and often involve personally significant contents. The next section considers more deeply the different forms that these self-related thoughts can take.

Varieties of Self-Referential Thought

Self-referential thoughts can vary widely in their content, specificity, and temporal orientation. Some thoughts rely on personal semantic information, such as abstract representations of one's personal characteristics (e.g., one's personality traits, abilities, goals, social roles, preferences, and values) and knowledge of facts about one's life (Klein & Gangi, 2010; Markus & Wurf, 1987; Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012). Other thoughts involve the mental simulation of specific life episodes, either events that occurred in one's personal past or situations that might happen in one's personal future (D'Argembeau & Van der Linden, 2004; Schacter, 2012; Szpunar, 2010). Although the extent to which the wandering mind involves these different types of self-referential thought remains to be investigated in detail, current evidence suggests that it tends preferentially toward particular forms.

One of the most consistent findings has been that the wandering mind focuses most frequently on future events; for example, Smallwood, Nind, and O'Connor (2009) observed that task-unrelated thoughts that occurred while performing an undemanding task were mostly future-oriented, a finding that has been replicated in several laboratory studies of mind-wandering (Baird et al., 2011; Ruby, Smallwood, Engen, & Singer, 2013; Ruby, Smallwood, Sackur, & Singer, 2013; Smallwood et al., 2011; Stawarczyk et al., 2013; Stawarczyk, Majerus, Maj, et al., 2011). Similarly, studies investigating the characteristics of task-unrelated thoughts in daily life have shown that most thoughts focus on the future (Andrews-Hanna et al., 2013; Song & Wang, 2012). Furthermore, there is evidence that future-oriented mind-wanderings are perceived as more personally significant than non-future-oriented mind-wanderings (Stawarczyk et al., 2013), and often involve the anticipation and planning of personally relevant future goals (Baird et al., 2011).

The future orientation of task-unrelated thoughts seems particularly pronounced when self-relevant information is salient in a person's mind. Indeed, research has shown that priming personally significant contents increases the prospective bias of mind-wandering. Stawarczyk, Majerus, Maj, et al. (2011) asked participants to write an essay about their personal goals or about a topic unrelated to personal goals (i.e., a familiar itinerary); then, the temporal focus of mind-wandering during an unrelated task was assessed. The results showed that participants who had previously thought about their personal goals subsequently experienced more future-oriented mind-wandering. In a related vein, Smallwood et al. (2011) found that making people think about their personality traits increased future-oriented mind-wandering in a subsequent task.

Other data suggest that, although task-unrelated thoughts can vary widely in their representational format and degree of abstraction, they most often focus on specific events. Andrews-Hanna et al. (2013) found that 77% of thoughts reported to happen in daily life pertained to a specific event and, of these, 60% were oriented toward the future. Similarly, Stawarczyk et al. (2013) found that the contents of mind-wandering episodes were mostly related to something concrete and well-defined (e.g., a particular situation or action). Some studies have further compared the characteristics of spontaneous versus voluntary autobiographical representations, showing that spontaneous memories and future thoughts are typically more specific than their voluntary counterparts (Berntsen & Jacobsen, 2008; Cole, Staugaard, & Berntsen, 2016).

Altogether, these findings indicate that the wandering mind can represent diverse contents and take various forms, but most often involves the representation of specific future events that are closely related to one's personal goals (for a more in-depth discussion, see Chapter 16 by Stawarczyk in this volume).

Neural Correlates of Directed and Spontaneous Self-Referential Thought

Neuroimaging research has shown that mind-wandering is associated with activations in a specific set of brain regions, which largely corresponds to the so-called default network (Buckner, Andrews-Hanna, & Schacter, 2008) and includes the medial prefrontal cortex, posterior cingulate/precuneus, inferior parietal lobules, and areas of the medial and lateral temporal lobes (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011) (for meta-analyses, see Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Stawarczyk & D'Argembeau, 2015). Many of these regions are also activated when people are explicitly instructed to process self-related information, which provides additional support to the view that self-referential thought is an important component of the mind-wandering state. This section first presents an overview of the neural correlates of different types of self-representation (as revealed by task-based studies), and then considers the few studies that have investigated the neural correlates of task-unrelated and spontaneous self-referential thought.

The neural correlates of different types of self-representation have been extensively investigated using functional neuroimaging. Some studies have focused on personal semantic knowledge, such as the representation of one's personality traits. In a typical study (e.g., Kelley et al., 2002), participants are asked to evaluate the self-descriptiveness of traits (e.g., polite, dependable, daring), and this task is compared to making other types of trait judgements (e.g., assessing their descriptiveness in reference to another person). Several meta-analyses have shown that both self- and other-referential judgments engage regions supporting semantic processing (such as the lateral temporal cortex), and the medial prefrontal cortex (mPFC) is typically more activated during self- versus other-referential judgments (Araujo, Kaplan, & Damasio, 2013; Murray, Schaer, & Debbane, 2012; van der Meer, Costafreda, Aleman, & David, 2010). Research further suggests that the mPFC is involved in processing different types of personal semantic information: not only one's personality traits, but also one's attitudes, values, and physical attributes (e.g., Brosch, Coppin, Schwartz, & Sander, 2012; Jenkins & Mitchell, 2011; Zysset, Huber, Ferstl, & von Cramon, 2002).

The neural basis of autobiographical memory—memories of one's past experiences and knowledge of facts about one's life—has also received extensive attention (for a review, see Cabeza & St. Jacques, 2007). In many studies, memories of specific personal experiences (i.e., events that happened at a particular place and time in an individual's life) are compared with the retrieval of non-personal information (e.g., non-personal semantic knowledge or stimuli that have been learned in the laboratory before the scanning session). Neuroimaging evidence indicates that such autobiographical memory retrieval is associated with activations in the mPFC, medial and lateral temporal areas, posterior cingulate/retrosplenial cortex, and inferior parietal lobes (for meta-analyses, see Kim, 2012; Martinelli, Sperduti, & Piolino, 2013; McDermott, Szpunar, & Christ, 2009; Spreng, Mar, & Kim, 2009; Svoboda, McKinnon, & Levine, 2006). Furthermore, lesion data have revealed that damage to these areas is associated with deficits in autobiographical memory retrieval (Philippi, Tranel, Duff, & Rudrauf, 2015).

A recent meta-analysis of neuroimaging studies (Martinelli et al., 2013) has compared the neural correlates of different types of self-referential thought: representations of personal characteristics (such as personality traits), knowledge of personal facts, and memories for specific events. The results show that each type of self-referential thought is associated with unique brain activations, with a shift from posterior to anterior regions with increasing abstraction of representations. Indeed, specific memories predominantly activate posterior structures, including the medial and lateral temporal lobes and posterior cingulate/precuneus, whereas abstract representations of personal characteristics recruit only medial prefrontal structures; finally, knowledge of personal facts is associated with anterior activations, as well as posterior structures (mainly the lateral temporal cortex). Interestingly, the mPFC is the only brain region that is consistently activated when thinking about one's traits, retrieving specific experiences from one's past, and accessing knowledge of facts about one's life, with both common and distinct activations across these three kinds of self-referential thought.

As mentioned in the previous section, the wandering mind often focuses on future events and involves the processing of personal goals. The neural correlates of future-oriented and goal-directed thought are thus of particular interest. Neuroimaging studies in which participants are explicitly instructed to reflect on their personal goals have shown that this process recruits areas of the default network. For example, Johnson et al. (2006) asked participants to think about their hopes and aspirations, about their duties and obligations, and about non-self-relevant topics (e.g., polar bears fishing). The results showed that the mPFC, posterior cingulate/precuneus, and lateral temporal cortex were more activated when thinking about personal goals than when thinking about non-self-relevant topics. There were also distinct activations as a function of the type of personal goals considered: a region of the mPFC showed greater activation when thinking about hopes and aspirations, whereas a posterior medial region showed greater activation when thinking about duties and obligations. Subsequent studies have detected similar activations in the mPFC, posterior cingulate, and lateral temporal cortex when reflecting on personal goals, especially promotion goals (i.e., things the individual would like to achieve) (for a meta-analysis, see Stawarczyk & D'Argembeau, 2015).

In recent years there has also been increasing interest in episodic future thinking—the ability to imagine or simulate specific events that might happen in one's personal future (D'Argembeau, 2012; Schacter, Addis, & Buckner, 2008; Szpunar, 2010). A number of neuroimaging studies have shown that such mental simulations of future events depend on largely the same brain regions as autobiographical remembering—the mPFC, posterior cingulate and restrosplenial cortices, medial and lateral temporal regions, inferior parietal lobules, and parts of the lateral prefrontal cortex (e.g., Addis, Wong, & Schacter, 2007; Szpunar, Watson, & McDermott, 2007; for a meta-analysis, see Benoit & Schacter, 2015). These different brain regions likely support different component processes involved in episodic future thought; for example, the medial temporal lobe may support the flexible retrieval and recombination of episodic details to construct representations of novel events (Addis & Schacter, 2012), whereas the lateral temporal cortex may represent semantic knowledge that is used for constructing coherent events (Irish, Addis, Hodges, & Piguet, 2012).

A few studies have investigated whether personal goal processing is associated with specific activations within this core network supporting episodic future thought. It has been found that medial prefrontal and posterior cingulate cortices are more activated when thinking about goal-related compared to goal-unrelated future events, suggesting that cortical midline structures may underpin the processing of personal goals during episodic future thinking (D'Argembeau et al., 2010). In line with this view, a recent meta-analysis has shown that studies of episodic future thinking and studies of personal goal processing are associated with overlapping activations in the mPFC and posterior cingulate cortex, as well as other regions of the core network (Stawarczyk & D'Argembeau, 2015). It has also been found that imagining taking various steps and actions to achieve personal goals depends on the functional coupling of the core network with the frontoparietal control network, a system supporting cognitive control (Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010). Thus, the frontoparietal control network may also contribute to personal goal processing, perhaps by monitoring and integrating future-oriented thoughts in coherent sequences to achieve imagined end-states. A recent study has further clarified the role of distinct brain areas in personal goal processing by showing that imagining what it would be like to achieve a given goal mainly involves the mPFC, whereas constructing a detailed plan of how to reach this goal engages regions from both the core network and the frontroparietal control network (Gerlach, Spreng, Madore, & Schacter, 2014).

While many studies have investigated the neural correlates of self-referential thought using directed self-processing tasks, only a few studies have examined the brain regions associated with task-unrelated and spontaneous self-referential thought. Some studies investigated thought processes spontaneously occurring when people were not required to perform a particular task (the so-called resting state). In a pioneering study, Andreasen et al. (1995) used positron emission tomography (PET) to investigate similarities and differences in neural activity between the explicit retrieval of autobiographical memories and a rest condition (i.e., lying quietly with no specific instructions about mental activity). They found that the mPFC and medial posterior areas (precuneus/retrosplenial cortex) showed greater activity during both autobiographical memory retrieval and rest compared to a semantic memory condition. Interviews with the participants indicated that they spontaneously thought about a variety of things during the rest condition, but especially about self-related contents such as past experiences and future activities. The authors concluded that the psychological commonality between the rest and autobiographical memory conditions is that "both involve something personal and highly individual" (p. 1583).

Another PET study examined the commonalities in brain activation between the resting state and the active reflection on one's personality traits (D'Argembeau et al., 2005). It was found that both conditions were associated with common activation in the mPFC compared with conditions requiring participants to reflect on non-self-related contents. Furthermore, an analysis of the content of mental activity (using verbal reports and rating scales obtained after each scan) showed that participants spontaneously experienced self-referential thought during the rest condition, and the amount of self-referential processing correlated specifically with the activity of the mPFC. Common activations in the mPFC and posterior cingulate cortex during the resting state and directed self-reference tasks have also been observed in a more recent functional magnetic resonance imaging (fMRI) study (Whitfield-Gabrieli et al., 2011), and have been confirmed by a meta-analysis comparing the location of activations in neuroimaging studies on the default network (i.e., brain regions showing stronger activation during the resting state compared to active tasks) with the location of activations associated with various self-related tasks (e.g., trait judgments, autobiographical memory, face recognition, and name perception) (Qin & Northoff, 2011).

There is also evidence that self-referential thoughts that occur while performing an unrelated task are associated with similar neural correlates as directed self-referential thoughts. Stawarczyk and D'Argembeau (2015) performed a meta-analysis of neuroimaging studies of episodic future thinking, on the one hand, and a meta-analysis of neuroimaging studies of mind-wandering, on the other hand. A conjunction analysis showed that these two types of studies were associated with common activations in several regions of the default network, including the mPFC, posterior cingulate cortex, left inferior parietal cortex, and left medial and lateral temporal regions. Considering that most mind-wandering episodes are future-oriented (see previous discussion), this finding suggests that task-based and task-unrelated future thoughts are supported by largely similar brain regions. Some differences between the two kinds of self-referential thoughts were also noted, however. In particular, the lateral prefrontal cortex showed greater activity during directed future thinking compared to mind-wandering. Similarly, it has been found that voluntary episodic memories involve the lateral prefrontal cortex to a greater extent than involuntary episodic memories, with otherwise extensive overlaps in default network activity between the two kinds of memories (Hall et al., 2014). Together, these results suggest that directed and spontaneous self-referential thoughts share many commonalities, but may differ in the extent to which they rely on effortful cognitive processes (see also Dixon, Fox, & Christoff, 2014).

In summary, neuroimaging studies have shown that directed self-referential thoughts are associated with activations in a set of brain regions that largely corresponds to the default network. The specific areas that are recruited depend on the type of self-representation under consideration, with abstract thoughts relying mainly on the mPFC and lateral temporal cortex, while more specific (past or future) thoughts recruit additional regions supporting the representation of episodic details (e.g., the medial temporal lobe and posterior cingulate/restroplenial cortex). A number of studies and meta-analyses have further demonstrated that many of the same areas are activated during the resting state or in association with mind-wandering, suggesting that these brain regions are also involved in spontaneous or unconstrained self-referential thought processes. Across all these studies, the mPFC is the brain region that has been most consistently associated with different types of self-representation, indicating that this region might play a particularly important role in both intentional and spontaneous self-referential cognition.

What Is the Role of the Medial Prefrontal Cortex in Self-Referential Thought?

While it has become clear that the mPFC plays a key role in self-referential thought, the exact processing operations mediated by this region are not fully understood. One possibility is that the mPFC contributes to the appraisal or representation of the subjective value or significance of self-related information. Indeed, the mPFC is thought to play a broad role in affective and value-based processing (Roy, Shohamy, & Wager, 2012). Most notably, research has shown that medial prefrontal activity encodes the subjective values of various types of rewards, which has led to the view that the mPFC integrates information from multiple sources to represent the significance or value of stimuli (for review, see Levy & Glimcher, 2012; Peters & Buchel, 2010b; Rangel & Hare, 2010; Sescousse, Caldu, Segura, & Dreher, 2013). Although these studies focused on the subjective valuation of stimuli from the external environment, the medial prefrontal activations that are observed in relation to self-referential thought could reflect a similar valuation mechanism (D'Argembeau, 2013). Stimuli and mental representations that refer or relate to the self tend to be assigned a unique value, and the function of the mPFC may precisely be to evaluate or represent such significance. This account is, for example, supported by the finding that activity in the mPFC increases linearly with the personal importance of the mental representations under consideration (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010; D'Argembeau et al., 2012). By flexibly assigning degrees of value to self-related contents, the mPFC might play an important role in the construction, stabilization, and modification of self-representations.

Another (not necessarily mutually exclusive, but somewhat broader) view is that the mPFC supports the integration of multiple representations during self-referential thought. It has been proposed that self-reference acts as an integrative hub for perception, decision-making, and memory, helping to bind together different types of information and even different stages of processing (Sui & Humphreys, 2015). In support of this view, there is, for example, evidence that people recall more episodic details about items judged in reference to the self, suggesting that self-reference enhances the binding of different forms of information in memory (e.g., items and associated contextual details) (Conway, Dewhurst, Pearson, & Sapute, 2001). A potential role of the mPFC in this integrative process is suggested by evidence showing that the self-reference effect in memory is predicted by medial prefrontal activity in healthy individuals (Macrae, Moran, Heatherton, Banfield, & Kelley, 2004) and is abolished in patients with focal brain damage to the mPFC (Philippi, Duff, Denburg, Tranel, & Rudrauf, 2012). More generally, there is substantial evidence that the mPFC is involved in relating and integrating incoming information to preexisting knowledge structures (Brod, Werkle-Bergner, & Shing, 2013; Kroes & Fernández, 2012; Preston & Eichenbaum, 2013; van Kesteren, Ruiter, Fernández, & Henson, 2012).

The integration of multiple representations may be particularly important for autobiographical remembering and future thinking, which inherently involve different types or levels of self-related information (Conway, 2005; D'Argembeau & Mathy, 2011). For example, there is evidence that specific memories and future thoughts are often part of higher-order autobiographical knowledge structures that organize specific events in broader themes and causal sequences—referred to as event clusters (Brown & Schopflocher, 1998; D'Argembeau & Demblon, 2012). In a recent fMRI study, we found that the processing of such event clusters is associated with increased activation in the mPFC and with greater functional coupling between the mPFC and posterior regions supporting semantic and episodic representations (Demblon, Bahri, & D'Argembeau, 2016). These findings suggest that the function of the mPFC during autobiographical remembering and future thinking might be to integrate specific event representations with higher-order autobiographical knowledge (e.g., personal goals and general knowledge about one's life). Through this integrative process, the mPFC might contribute to contextualize specific event representations within an individual's life story, thus rendering memories and future thoughts truly autobiographical.

On the Possible Functions of Spontaneous Self-Referential Thought

The fact that mind-wandering is such a pervasive experience makes it unlikely that it merely consists in a lapse of attention with no intrinsic value. On the contrary, there is growing evidence suggesting that mind-wandering may serve adaptive functions, such as planning (Baird et al., 2011) and problem-solving (Ruby, Smallwood, Sackur, et al., 2013).

The main function of mind-wandering might be to allow the mental simulation of alternatives to the here and now, and in particular to envision possible futures. As mentioned earlier, most mind-wandering episodes indeed involve future-oriented and goal-related contents. The wandering mind may anticipate a variety of future events, conceive possible ways to attain or avoid envisioned situations, and predict the probable outcomes of different courses of action. In turn, these mental simulations may be used to inform decisions and behaviors. Many mind-wandering episodes are subjectively perceived as fulfilling such future-oriented functions—evaluating and planning for possible situations, making decisions, and solving problems (Stawarczyk et al., 2013; Stawarczyk, Majerus, Maj, et al., 2011). Although the extent to which such future-oriented thoughts are beneficial in guiding decisions and behavior remains to be investigated in detail, recent evidence suggests that this might be the case. For example, a recent study suggests that mind-wandering can help people to better specify their goals and plans, which might lead to more effective goal achievement (Medea et al., 2016). Furthermore, it has also been found that mind-wandering (Smallwood, Ruby, & Singer, 2013) and future thinking (Lin & Epstein, 2014) are associated with reduced delay discounting (i.e., with a greater capacity to resist the temptation of an immediate reward in favor of receiving a larger reward later in the future). Interestingly, neuroimaging studies suggest that the mPFC might mediate this effect of future-oriented thoughts on farsighted decisions (Benoit, Gilbert, & Burgess, 2011; Bernhardt et al., 2014; Peters & Buchel, 2010a).

Another potentially important function of mind-wandering may be to contribute to our sense of personal identity. People in modern societies construct their personal identity by creating an evolving life story that integrates past, present, and possible future experiences in such a way as to provide their lives with some degree of unity, purpose, and meaning (McAdams, 2001; J. A. Singer, Blagov, Berry, & Oost, 2013). The construction of such narratives critically depends on autobiographical reasoning, a process of reflective thinking through which we form links between disparate elements of our life and the self (Habermas & Bluck, 2000). Autobiographical reasoning helps in establishing personal identity and continuity across change, and research has shown the importance of this process for identity development, maturity, and well-being (King, Scollon, Ramsey, & Williams, 2000; Lilgendahl & McAdams, 2011; McLean & Pratt, 2006; Raffard et al., 2010; J. A. Singer, Rexhaj, & Baddeley, 2007). Intriguingly, a recent study (D'Argembeau et al., 2014) has shown that the neural correlates of autobiographical reasoning closely correspond to a dorsomedial prefrontal subsystem of the default network, which might play a broad role in introspective processes (Andrews-Hanna, 2012). Although this issue remains to be investigated in detail, this might suggest that spontaneous self-referential thought plays a role in reflecting on the broader meaning and implications of personal experiences, thereby contributing to the construction, maintenance, and update of an individual's life story. In addition, frequent mental trips to the past and future during the mind-wandering state might also provide a more direct, experiential sense of continuity of the self through time (Prebble, Addis, & Tippett, 2013). Through these processes, the wandering mind might thus contribute to the creation and functional maintenance of self-models, which then lay the foundation for long-term motivation and future planning (Metzinger, 2013).

Conclusion

When our attention is not entirely focused on the external environment, various thoughts and mental images tend to spontaneously populate our minds. These spontaneous mentations frequently involve personally significant contents and often focus on future, goal-related events. Neuroimaging research suggests that the activity of a specific set of brain regions, largely corresponding to the default network, correlates with the formation of self-referential thoughts during the mind-wandering or resting state. The specific areas that are recruited depend on the content and specificity of the mental representation under consideration, but the mPFC appears to play a broad role in processing various types of self-related contents. While the specific function of this brain region remains to be investigated in detail, current evidence suggests that it might process the subjective value of self-related information and/or integrate multiple representations in the service of self-referential thought. Overall, the tendency of the wandering mind to focus on self-related contents may foster one's sense of personal identity and may serve adaptive functions, such as planning and long-term goal pursuit.

Acknowledgments

Arnaud D'Argembeau is supported by the Fonds de la Recherche Scientifique-FNRS, Belgium.

Note

1. Mind-wandering involves "a shift in the contents of thought away from an ongoing task and/or from events in the external environment to self-generated thoughts and feelings" (Smallwood & Schooler, 2015). Importantly, however, mind-wandering is a type of thought that is characterized not only by its content, but also by its spontaneous and dynamic nature; it involves thoughts that arise freely due to an absence of strong constraints on thought contents and on the transitions from one thought to another (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). In empirical research on mind-wandering, terms referring to the content (such as "task-unrelated" and "stimulus-independent" thought) or the spontaneous nature of mind-wandering are sometimes used interchangeably, which is problematic because these terms designate separable dimensions of thought (Christoff et al., 2016). Whenever possible, in this chapter I use the term "task-unrelated thought" when describing empirical research that investigated mind-wandering from a content-based perspective (i.e., by assessing the contents of thoughts in terms of their relationship to an ongoing task or activity), and the term "spontaneous thought" when describing research that assessed the unconstrained nature of thoughts.

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CHAPTER

16

Phenomenological Properties of Mind-Wandering and Daydreaming: A Historical Overview and Functional Correlates

David Stawarczyk

Abstract

Mind-wandering and daydreams (i.e., spontaneous thoughts that are both task-unrelated and decoupled from current sensory perceptions) have recently become the object of increased interest in cognitive psychology and neuroscience. To date, however, there have been relatively few attempts at investigating the form and content of these thoughts, and what individuals are exactly thinking about when they daydream or their minds wander from the here and now. This chapter provides a historical overview of the studies that have investigated the phenomenological properties of mind-wandering and daydreams. It reviews the current state of research, examining how specific phenomenological features of these thoughts are related to beneficial and deleterious aspects of cognitive and affective functioning. It concludes by discussing possible avenues for future investigations, such as how the content and context of occurrence of mind-wandering and daydreams might interact to determine their functional outcomes.

Key Words: mind-wandering, daydreams, phenomenology, cognitive psychology, affect

Although the beginning of experimental research on mind-wandering and daydreaming can be traced back to the spreading of cognitive psychology during the early 1960s (for seminal works on this topic, see Antrobus, Singer, & Greenberg, 1966; Singer, 1966; Singer & McCraven, 1961), there has been a surprisingly low number of studies investigating the phenomenological features and content of these particular kinds of spontaneous cognition. One of the first things that one may indeed reasonably wonder when hearing for the first time of mind-wandering or daydreaming is, "What are people thinking about when their minds drift away from the here and now and engage in spontaneous cognitions?" Are people thinking of dreamlike and chimeric contents, as illustrated by the idiomatic expression "building castles in Spain," or are their thoughts more closely related to their everyday activities and to the achievement of short-term personal goals? From there, one may also wonder whether there is some kind of regularity between individuals in the content of mind-wandering and daydreams. For instance, do people tend to think of similar topics when their minds wander, or has each individual his own pattern of thoughts during this type of spontaneous cognition? Finally, a last important question might be how the phenomenological features of mind-wandering and daydreaming are related to other variables outside the domain of spontaneous thought. In other words, can the form and content of daydreams and mind-wandering episodes predict the degree to which these thoughts are associated with functional or deleterious aspects of individuals' daily cognitive functioning?

The aim of the present chapter will be to discuss and answer the preceding questions in two different sections. In the first section, I will focus on the phenomenological structure of mind-wandering and daydreams. I will do so by providing a historical perspective of the studies that have investigated the form and content of these two kinds of spontaneous cognition. I will begin by reviewing the early questionnaire studies that assessed the features of daydreams, and then the more recent experience-sampling research on mind-wandering. In the second section, I will center my attention on the few studies that have examined how some phenomenological features of mind-wandering and daydreams are related to beneficial and deleterious aspects of cognitive and affective functioning outside their direct impact on task performance. Finally, I will conclude this chapter with a brief summary of the current state of research on the phenomenology of mind-wandering and daydreams and the possible avenues that could be interesting to investigate for future research.

Phenomenological Structure of Mind-Wandering and Daydreaming

In the general population, there is a common lay-belief that daydreams and mind-wandering episodes are mostly fleeting thoughts about random topics with no particular personal meaning. For instance, many influential thinkers throughout history, such as Plato, Blaise Pascal, and Sigmund Freud, have argued that daydreams and other kinds of spontaneous thoughts are mostly fanciful and are distinct from reality, and therefore should be disregarded in favor of more deliberate and controlled forms of cognition (Klinger, 1990). Can mind-wandering and daydreams truly be considered as pointless or futile thoughts, however? On the one hand, if these two forms of spontaneous cognition represent nothing more than "psychological noise" that disturbs individuals from their current task at hand, then no consistent phenomenological structure should emerge from the investigation of the content and form of these thoughts. On the other hand, if mind-wandering and daydreams are the product of a well-defined cognitive and neural system, and if this particular kind of thoughts plays a role in several important aspects of our daily cognitive functioning, such as planning (e.g., Baird, Smallwood, & Schooler, 2011; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011), the generation of creative ideas (e.g., Baird et al., 2012), prospective memory (e.g., Mason & Reinholtz, 2015), or the regulation of mood and emotions (e.g., Engert, Smallwood, & Singer, 2014; Mar, Mason, & Litvack, 2012; Ruby, Smallwood, Engen, & Singer, 2013), then it is likely that these two types of spontaneous cognition might represent a more phenomenologically structured phenomenon than what might be initially assumed.

Questionnaire Studies on the Features of Daydreams

One of the first published studies that examined the regularities that exist across individuals in the content of spontaneous thoughts was conducted by Singer and McCraven (1961). In this study, the authors asked a large sample of 240 college students to rate the frequency with which they experience in their everyday life a list of 93 specific examples of potential daydreams. Their main finding was that the most frequently endorsed instances of daydreams were those related to future practical concerns during social situations (e.g., thinking about work that needed to be done in the following weeks), rather than those related to fanciful or wish-fulfilling ideation (e.g., thinking about inheriting an important sum of money). Although a limitation of this study is that the authors solely computed frequency estimates and did not use more advanced statistical techniques such as factor analyses to obtain their results, this research can still be considered as a pivotal study in the domain of spontaneous thought because it was one of the first to suggest that daydreams may possess common phenomenological features across individuals, including a future temporal orientation and a relationship with short-term personal concerns in interpersonal situations.

Capitalizing on these results, the authors then created a more exhaustive questionnaire, the Imaginal Process Inventory (IPI; Singer & Antrobus, 1970), designed to assess the general dimensions of private mental experiences in daily life, rather than specifically the features of daydreams and spontaneous thoughts. This 344-item questionnaire comprises 28 subscales that investigate various factors related to the individual's inner mental life, such as night dreaming, distractibility, need for external stimulations, or boredom tendency, in addition to daydreaming-related dimensions, such as the frequency of these thoughts, their temporal orientation, their visual and auditory nature, or the positive and negative emotional reactions that individuals experience with their occurrence. Across different studies, the authors computed several factor analyses on the scale scores of the IPI and consistently found three second-order factors (e.g., Huba, Segal, & Singer, 1977; Singer & Antrobus, 1972; Starker, 1973, 1974), leading them to develop a short 45-item version of the IPI, the Short Imaginal Process Inventory, specifically designed to assess these three general dimensions of inner mental life (SIPI; Huba, Aneshensel, & Singer, 1981; Huba, Singer, Aneshensel, & Antrobus, 1982). Interestingly, the first of these factors was named *positive-constructive daydreaming* and is characterized by vivid daydreams oriented toward the future and problem-solving, and more generally with attitudes consisting of acceptance and positive reactions to daydreams. The second factor was *guilty-dysphoric daydreams* and mainly consists of hostile, fearful, and guilty daydreams associated with stressful and negative emotional reactions. Finally, the last factor was termed *poor attentional control* and reflects a general tendency toward boredom and distractibility associated with fleeting thoughts. Although the IPI and SIPI departed from the specific investigation of the content and features of spontaneous thoughts, their factorial structure nonetheless replicated the initial finding by Singer and McCraven (1961) that an important qualitative feature of daydreaming might be a future temporal orientation associated with problem-solving processes.

One of the most extensive investigations of the phenomenological features of daydreams with the IPI was conducted by Leonard Giambra with the aim of clarifying the changes that occur in daydreaming and inner mental life across the life span (Giambra, 1999a, 1999b, 2000). For approximately 25 years, starting in the early 1970s, Giambra administered the full IPI to a large sample of more than 3,000 participants before examining and contrasting how scores on various groups of subscales vary with age. A first set of investigations focused on daydreaming frequency and the three different subscales assessing the present, past, and future temporal orientation of daydreams (Giambra, 1999b). Results of these analyses first revealed the now well-accepted finding that the tendency to experience daydreams generally decreases with increasing age (for a recent review on this topic, see Maillet & Schacter, 2015). Giambra further showed that future-oriented daydreams were generally more prominent across age groups than past and present daydreams, but that this effect decreased with aging. More precisely, the future orientation was significantly greater than the past and present orientations from the youngest age group (17–24 years); but by 45–54 years and 65–74 years, the differences for present and past, respectively, had become non-significant. It is only in the oldest age group (75–84 years) that scores for past and present daydreams became higher than those for future daydreams. This first set of results suggests that daydreaming is mostly future-oriented and that the predominance of this temporal orientation remains relatively stable with increasing age, except for the oldest groups of individuals.

Giambra also examined whether daydreams tend to occur more consistently in the form of visual than auditory imagery (i.e., imagining sounds other than one's own voice, such as tunes or voices of acquaintances). He found that scores on the visual imagery subscale were consistently higher than those for auditory imagery across all age groups and that both forms of imagery generally declined with increasing age. In accordance with the finding that the vividness of daydreams might be lower in older adults, he also found in a second set of results that scores on the absorption in daydreams and hallucinatory vividness of daydreams subscales strongly decreased with age (Giambra, 1999a). Finally, in a third set of analyses (Giambra, 2000), he showed that scores on the problem-solving subscale of daydreams were generally much higher than on other subscales assessing the content of daydreams, including hostile, fear of failure, heroic, sexual, guilt, bizarre-improbable, and achievement-oriented daydreams. Furthermore, scores on the problem-solving subscale remained relatively stable across age groups, whereas scores for most of the other content subscales showed moderate to high decline with aging. Overall, these results confirm those of Singer and McCraven (1961) and the studies that investigated the factorial structure of the IPI/SIPI by showing the importance of future-oriented and problem-solving daydreams.

Unfortunately, following the creation of the IPI and SIPI, no clear and elaborated attempts were made to further develop retrospective tools designed to assess the occurrence and characteristics of spontaneous thoughts in daily life and, at present, these two questionnaires are still the only self-rating scales available to assess the general features of daydreams, mind-wandering, and inner mental life of healthy individuals. Several questionnaires have recently been created to retrospectively assess the features of inner thoughts occurring during functional magnetic resonance imaging (fMRI), and more particularly following resting state periods (e.g., Delamillieure et al., 2010; Diaz et al., 2013; Diaz et al., 2014; Gorgolewski et al., 2014); however, the use of these scales is still in its infancy, and further studies are still required to clearly assess their validity and factorial structure. Be that as it may, the initial attempts to determine the phenomenological structure of daydreaming with the use of retrospective self-rating scales, such as the IPI and SIPI, still remain significant today because they revealed the important findings that (1) daydreams and more generally spontaneous thoughts might be reducible to a limited number of important dimensions that are common across individuals, and (2) the fancifulness/wish-fulfilling aspects of spontaneous thoughts might not be as preponderant as argued by early influential thinkers.

Early Experience Sampling Studies of Mind-Wandering and Thought Content

Surprisingly, following the preliminary investigations with retrospective questionnaires of everyday life experiences, very few studies attempted to further examine in detail the content and phenomenological features of mind-wandering and daydreams for several decades. Although the IPI and SIPI provided some important findings, their main limitation is that they completely rely on long-term memory processes from daily life experiences, and it has been questioned whether individuals are truly able to give an accurate evaluation of their spontaneous thought patterns over such extended time periods (Singer, 1993, 2003). To address this concern, researchers gradually started to rely more and more on online experience sampling of mind-wandering during laboratory tasks with methods such as thought-probes to minimize dependency on memory processes. This methodological switch in the study of spontaneous thoughts was, however, also accompanied by an impoverishment of the phenomenological dimensions of mind-wandering that were investigated. Until recently, most of the studies that used online experience sampling indeed solely focused on the mere presence of spontaneous thoughts, with thought-probes consisting of dichotomous questions simply asking whether individuals were mind-wandering or not during the task just prior to their appearance. The aims of these studies also departed from the idea of describing the general phenomenological structure of spontaneous thoughts; their main focus was rather to investigate how contextual factors, such as task demands and complexity, can influence either the frequency of mind-wandering episodes or the extent to which these episodes negatively impact task performance (for reviews on this topic, see Randall, Oswald, & Beier, 2014; Smallwood, Fishman, & Schooler, 2007; Smallwood & Schooler, 2006).

Some early studies using thought-probes nonetheless attempted to investigate spontaneous thoughts beyond their mere presence or absence, but in these cases the authors did not examine in depth the content and form of mind-wandering episodes; rather, they mostly focused on a single phenomenological dimension of these thoughts, such as their representational format (e.g., inner speech versus visual imagery; Antrobus, Singer, Goldstein, & Fortgang, 1970; Antrobus et al., 1966), the intentionality of their occurrence (Forster & Lavie, 2009; Giambra, 1995), or their structuration in complex sequences of thoughts (Stuyven & Van der Goten, 1995; Teasdale, Proctor, Lloyd, & Baddeley, 1993). Although these studies greatly advanced the understanding of some important aspects of mind-wandering, such as how these thoughts might depend on the same cognitive resources as those required for task performance (e.g., Smallwood, 2013; Thomson, Besner, & Smilek, 2015), for most of this time no clear advances were made to answer the important question of what individuals are actually thinking about when their minds wander from the here and now.

A notable exception to the general decrease of interest of early experience-sampling studies in thought content is the research conducted by Klinger and Cox (1987), who examined the dimensions of thought flow in everyday like. These authors asked their participants to report the content of their latest thoughts (i.e., not only spontaneous but all kinds of thoughts) when randomly probed with a beeper in their daily life and to rate them on a wide variety of phenomenological dimensions including, among others, vividness, fancifulness, improbability, controllability, or deliberateness. During a mean of four and a half days, 29 participants reported and rated a total of 1,425 thoughts. These thoughts were then submitted to a within-individuals factor analysis to assess how their phenomenological features related to each other when mean inter-individual differences on each dimension were controlled for. The detailed results of this study are reported elsewhere (e.g., Klinger, 1990, 2009), but one of the most interesting findings was that the dimensions related to (1) the fancifulness of the thoughts and (2) directedness/deliberateness loaded on orthogonal factors. These results indicate that the spontaneous nature of the thoughts is unrelated to the degree to which their content departs from reality. These findings thus argue against the proposal that daydreams and mind-wandering are mostly chimerical wish-fulfilling ideations by demonstrating that the approximately 10% of thoughts rated as mostly fanciful in this study are evenly distributed between spontaneous and directed thoughts.

The Prospective Bias of Mind-Wandering

Although the study by Klinger and Cox (1987) reported some interesting findings on the relationship between the phenomenological dimensions of thought flow, it did not offer detailed answers to the question of what people are exactly thinking about when they experience spontaneous cognitions. It is only in recent years that researchers have started to investigate more exhaustively the form and content of mind-wandering with online experience-sampling procedures. A first important step in this direction was made by Smallwood, Nind, and O'Connor (2009), who asked their participants about the precise temporal orientation of their mind-wandering episodes during attentional and reading tasks. Their main finding was that mind-wandering sampled during task performance is characterized by a prospective bias (i.e., that in most circumstances mind-wandering is temporally oriented toward the future more often than the past; see Table 16.1) and that this bias can be reduced by increasing task demands during attentional tasks, or by greater interest and more prior experience with the topic of the text during reading tasks. These findings can be directly related to the previously mentioned questionnaire studies, which showed that future orientation is an important dimension of daydreams and are consistent with the idea that the content of mind-wandering episodes and daydreams might possess common properties across individuals.

A direct follow-up of the study by Smallwood et al. (2009) was made in our lab, with the aim of gaining a more complete view of what characterizes the prospective bias of mind-wandering (Stawarczyk et al., 2011). More specifically, we asked participants to write a short description of each mind-wandering episode that they reported to thought-probes during a laboratory attentional task, the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). At the end of this task, our participants were further requested to rate each of their reported thoughts on a variant of the Memory Characteristics Questionnaire adapted for mind-wandering studies (a questionnaire the original purpose of which is to investigate the phenomenological properties of episodic memories; Johnson, Foley, Suengas, & Raye, 1988). Importantly, besides temporal orientation, we also asked our participants to determine the possible functions of their mind-wandering episodes and how distant from the here and now were the events referred to in their thoughts. Our findings replicated the prospective bias of mind-wandering by showing that approximately half of reported episodes were directed toward the future, with the other half being evenly distributed between past, present, and atemporal episodes (see Table 16.1). Furthermore, our findings also revealed that most mind-wandering episodes were given personal goal-oriented functions, such as planning (35%), decision-making (8%), and the appraisal of events (10%), in comparison to having no function (29%) or non-personal goal-oriented functions, such as self-entertainment (7%) or trying to maintain arousal (8%). Finally, we also found that most future-oriented episodes were about upcoming events within a short temporal distance from the present moment, with 79% of these thoughts being about events happening later in the same day or in the next seven days. Together, these results confirm the prospective bias of mind-wandering and further indicate that these thoughts are mostly directed toward planning and preparing for upcoming events in the near future.

Following the studies by Smallwood et al. (2009) and Stawarczyk et al. (2011), there has been an exponential number of studies further assessing the prospective bias of mind-wandering (see Table 16.1 for a detailed list of the recent studies that have investigated the temporal orientations of mind-wandering episodes). For instance, Baird et al. (2011), also demonstrated that most mind-wandering episodes are future-oriented, and further showed that these future episodes are specifically characterized by a combination of goal- and self-directed contents compared to past, present, and atemporal episodes, suggesting that the content of future-oriented mind-wandering mainly consists in autobiographical planning. Smallwood et al. (2011) also demonstrated the importance of self-related processes during future-oriented mind-wandering by showing that the prospective bias of these thoughts could be increased by asking participants to reflect on their own personality traits before the experience-sampling period. Jackson, Weinstein, and Balota (2013) showed that the prospective bias of mind-wandering sampled during task performance is still present in older adults, although it is reduced when allowing participants to report atemporal episodes. Ye, Song, Zhang, and Wang (2014) demonstrated that future-oriented episodes are already the most prevalent kind of mind-wandering in 10-year-old Chinese children. Iijima and Tanno (2012) showed that the prospective bias of mind-wandering is also present in Japanese participants and replicated the finding that this bias is reduced with increasing task difficulty. Finally, several studies demonstrated that the prospective bias of

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	Prospective Bias	Future	Past	Present	Atemporal	Task	Assessment Method	Parti
2006)	NO	31 (28)	32 (28)	/	/	Rest during fMRI	Retrospective rating on an analog scale	12 (w desig
	NO	5 (15)	1 (3)	/	/	WM during fMRI		
l., 7b)	NO	26%	23%	/	10%	Rest during fMRI	Retrospective interview	19
l et al., y 1	YES	.33 (.02)	.23 (.02)	/	/	Rest, CRT, and WM	Thought-probes	76 (w desig
l et al., y 2	YES	.27 (.03)	.20 (.03)	/	/	WM	Thought-probes	77 (w desig
	NO	.10 (01)	.09 (02)	/	/	Reading		
, 2010)	YES	63.4%	36.6%	/	/	Vigilance (forward vection)	Retrospective rating on an analog scale	25 (b desig
	NO	40.03%	59.07%	/	/	Vigilance (backward vection)		
Hanna)	YES	28.7%	19.2%	/	15%	Rest during fMRI	Retrospective questionnaire	139
k et al.,	YES	59%	14%	17%	11%	SART preceded by personal goal priming	Thought-probes and retrospective questionnaire	46 (b desig
	YES	41%	25%	19%	15%	SART preceded by mental navigation		
, 2011)	YES	48%	12%	28%	11%	CRT	Thought-probes	47
l et al.,	YES	.32 (03)	.20 (.02)	/	/	CRT and WM preceded by self-reflection tasks	Thought-probes	68 (n
l or, y 2	YES	1.7 (.15)	.92 (.23)	/	1.58	CRT preceded by mood induction procedures	Thought-probes	82 (b desig

anno,	YES	.33 (.03)	.23 (.03)	/	/	Zero-back WM	Thought-probes	31 (w desig
	NO	.20 (.03)	.30 (.05)	/	/	One-back WM		
	NO	.09 (.03)	.11 (.03)	/	/	Two-back WM		
y 2	YES	41.3%	28.8%	/	/	Daily life	Retrospective evaluation (proportion of participants responding "always" or "frequently" when asked if their daydreams are about the past of the future)	17,55
Kane,	YES	.26 (.27)	.10 (.18)	/	/	Reading	Thought-probes	242
	YES	.33 (.36)	.17 (.29)	/	/	Reading		
	YES	.22 (.23)	.11 (.17)	/	/	Stroop		
	NO	.18 (.25)	.17 (.26)	/	/	SART		
ang,	YES	40.53%	21.53%	15.92%	22.02%	Daily life	Thought-probes	165
Hanna)	YES	59.8 % (25.4)	40.2% (25.4)	/	/	Daily life	Retrospective rating of self-generated thoughts about specific events	76
t al.,	NO	5.04 (2.24)		/	/	Daily life	Retrospective ratings on a continuous scale ranging from 1 (always past) to 10 (always future)	200 p Weste
	YES	5.85 (2.57)		/	/			200 p East A
2013)	NO	2.72	2.14	3.43	/	Rest	Retrospective rating on three continuous scales ranging from 1 (completely disagree) to 5 (completely agree)	1,355
al., 2013)	YES	3.33 (1.34)	2.82 (1.32)	/	/	SART	Self-caught reports	89 (b desig
	NO	1.36 (2.13)	2 (1.23)	/	3 (1.23)			

ued

	Prospective Bias	Future	Past	Present	Atemporal	Task	Assessment Method	Part
	YES	1.72 (1.08)	.83 (.53)	/	/	SART	Self-caught reports	57 ol (betw desig
	NO	1.03 (1.34)	.93 (1.32)	/	1.03 (.07)			
al., 2013)	YES	2.72 (.78)	1.38 (.22)	/	/	SART	Thought-probes	82 (b desig
	NO	2.59 (.92)	1.07 (.56)	/	1.9 (.55)			
	YES	1.83 (.39)	.67 (.82)	/	/	SART	Thought-probes	74 ol (betw desig
	NO	1.68 (.78)	.34 (.22)	/	2.66 (84)			
., 2013)	YES	3.7 (2.7)	3.2 (2.9)	/	/	Rest during fMRI	Retrospective evaluation of the number of past and future thoughts	24 yo
	YES	2.8 (2.2)	2.1 (3)	/	/			22 m
	NO	2.6 (2.6)	2.8 (2.2)	/	/			17 ag
., 2013)	YES	3.40 (.24)		/	/	Daily life	Thought-probes and continuous scale ranging from 1 (distant past) to 5 (distant future)	24
llwood, inger,	YES	4.45 (.19)	2.72 (.14)	/	/	CRT	Thought probes and two independent scales ranging from 1 to 9 to assess past and future orientation	84 (w desig
	YES	4 (.23)	2.74 (.13)	/	/	WM		
llwood, inger,	YES	3.38 (.12)	2.26 (.08)	/	/	CRT	Thought probes and two independent scales ranging from 1 to 9 to assess past and future orientation	
, au, 2013)	YES	59%	10%	20%	9%	SART preceded by stressful concern priming	Thought-probes and retrospective questionnaire	32 (b desig

	YES	52%	32%	10%	6%	SART preceded by neutral concern priming		
, Cassol, beau,	YES	43%	26%	15%	16%	SART	Thought-probes and retrospective questionnaire	67
2014)	NO	2.62	2.44	3.74	/	Rest	Retrospective rating on three continuous scales ranging from 1 (completely disagree) to 5 (completely agree)	562
l., 2014)	YES	4.2 (2.7)	3.5 (2.5)	/	/	CRT and WM preceded by a stress induction procedure	Thought probes and two independent scales ranging from 1 to 9 to assess past and future orientation	99 (w desig
	YES	4.4 (2.8)	3 (2.3)	/	/	CRT and WM preceded by rest		
& 2014)	NO	.22 (.30)	.22 (.32)	/	/	Reading	Thought-probes	150
y 2	YES	.25 (.02)	.14 (.02)	/	/	CRT	Thought-probes	71 ch subje
	YES	26 (.03)	11. (02)	/	/	WM		
al., 2015)	YES	50%	10.5%	39.5%	/	Daily life (driving)	Retrospective questionnaire about the participants' most recent driving trip	109
et al.,	NO	25%	46%	29%		Vigilance with cue words	Thought-probes	17 dy indiv
	NO	28%	41%	31%				19 nc indiv
-Clavertz)	YES	4.05 (2.91)	2.23 (2.32)	2.31 (2.10)		SART	Thought-probes	111

ses studies that investigated the temporal orientation of mind-wandering and daydreams with tools other than the Imaginal Process Inventory (IPI) or Short Imaginal Process I
e was performed on healthy young adult participants except when stated otherwise in the Participants column.

time; fMRI = functional magnetic resonance imaging; SART = sustained attention to response task; WM = working memory.

mind-wandering is not limited to laboratory tasks, and that most mind-wandering episodes sampled in daily life are also future and goal-oriented (e.g., Berthie et al., 2015; Poerio, Totterdell, & Miles, 2013; Song & Wang, 2012).

Not all studies consistently showed the prospective bias of mind-wandering, however. For instance, and in contrast to a later study (Andrews-Hanna, Reidler, Huang, & Buckner, 2010), two early studies that retrospectively assessed the content of thoughts directly after fMRI did not find a clear prevalence of future-oriented mind-wandering episodes compared to past episodes (Fransson, 2006; Mason et al., 2007a, 2007b). Miles, Karpinska, Lumsden, and Macrae (2010) found that a retrospective rather than a prospective bias of mind-wandering could be induced when performing a vigilance task involving backward rather than forward illusions of self-motion. Contrary to most other studies, McVay and colleagues (McVay & Kane, 2012; McVay, Unsworth, McMillan, & Kane, 2013) found the presence of a prospective bias of mind-wandering during reading tasks, but not during a less demanding attentional go/no-go task. On the basis of a retrospective evaluation of daily life thoughts, Christian, Miles, Parkinson, and Macrae (2013) found that the prospective bias of mind-wandering is more prominent in participants from Eastern Asian than Western cultures. Finally, Plimpton, Patel, and Kvavilashvili (2015) included irrelevant cue words during a vigilance task and found a retrospective rather than prospective bias to mind-wandering. Although these studies indicate that further investigations remain to be done to clearly determine the circumstances that influence our mind's tendency to wander toward the future, they nonetheless represent a minority of the literature. To date, the vast majority of experience-sampling research converges on the finding that, whenever individuals experience mind-wandering, there is a higher probability that the focus of their thoughts will be directed at planning and preparing for upcoming events rather than remembering past memories.

Mind-Wandering and Personal Goals

In parallel to the studies on temporal orientation, a more indirect yet complementary way in which the prospective bias of mind-wandering has been investigated is by examining the relationship between these thoughts and personal-goals/future-related concerns. In an initial study involving US college students, Antrobus et al. (1966) played a fake alarming radio broadcast about the entry of the Chinese Communists into the war in Vietnam going on at the time. They found that participants who heard the broadcast reported more mind-wandering during a subsequent vigilance task in comparison to a control group who solely heard tape-recorded music before the task. A qualitative analysis of the content of thoughts reported by the participants in the experimental group showed that many mind-wandering episodes were directed at dealing with the induced concerns, consisting, for instance, in reflections about how a possible draft in the US army would affect their personal future. The authors interpreted these findings in the sense that an important function of spontaneous thoughts might be to help individuals to adjust their conceptual model of the future when presented with contradicting information that forces them to revise their system of relationship with the environment.

A few years later, Klinger (1978) used a different approach, asking his participants to describe their personal goals in a first experimental session. In a second session, he asked the same participants to perform a dichotic listening task in which two different sections of the same narrative were played in each ear for 15 minutes. Crucially, at different time intervals, the two narrations were modified to include either words belonging to the participants' own personal goals or to the personal goals of another participant. A few seconds following these modified sections, the narrations were interrupted by thought-probes, and the author found that participants (1) spent more time listening to the narration modified to include segments related to their personal goals, and (2) had thoughts related to their own personal goals more frequently than to the other participants' goals. Klinger interpreted these findings in favor of his *current concerns theory*, which proposes that individuals are constantly involved in a myriad of personal goals (or current concerns) throughout their daily life. Cues related to these goals either in the external world or coming from the individuals' own thoughts would be particularly effective in capturing attention and, in a situation where no behavioral actions can be performed to advance toward the achievement of the cued personal goals (for instance, because of being already engaged in another task), the typical response of most individuals would be to engage in thoughts related to the management of these goals (for more detailed discussions of the current concern theory, see Klinger, 1971, 1996, 1999, 2009; 2013, and also Klinger, Marchetti, & Koster, Chapter 17 in this volume). Klinger later extended these findings by showing (with retrospective self-rating questionnaires) that the current concerns rated as being most important or as requiring actions in the impending future were the most likely to influence the content of thoughts in daily life (Klinger, Barta, & Maxeiner, 1980). Similarly, Gold and Reilly (1985) asked their participants to describe in a diary the content of daydreams experienced in their daily life and found that approximately 65% of the reported thoughts were about the five most important current concerns that the participants listed in an earlier session.

Following these initial studies, several research teams have attempted to prime personal goals or future-related concerns to influence the content and/or frequency of mind-wandering. For instance, in our previously mentioned study (Stawarczyk et al., 2011), we further asked half of our participants to write a one-page essay on their most important personal goal or to perform a control spatial navigation task before performing the SART with thought-probes. We found that participants who previously reflected on their personal goal subsequently reported more temporally and functionally future-oriented mind-wandering episodes than participants in the control condition. These findings were recently replicated by Kopp, D'Mello, and Mills (2015), who showed that participants asked to make a "to do list" of their current personal goals subsequently reported more mind-wandering during a reading task than control participants asked to make a list of the features that define a car. In the same vein, Masicampo and Baumeister (2011) found that writing about two unfulfilled personal goals resulted in more mind-wandering directed toward these goals in a subsequent reading task, but that this effect could be reduced by asking participants to detail precise ways to reach these goals, rather than simply describing them as well as their personal importance. Using a procedure slightly similar to the one used by Klinger (1978), McVay and Kane (2013) inserted words related to participants' personal goals in a modified version of the SART with thought-probes and showed that responses to the probes preceded by words cuing the participants' personal goals were more likely to consist in mind-wandering reports than responses to the probes preceded by words related to the goals of other participants. Finally, in another study performed in our lab (Stawarczyk, Majerus, & D'Argembeau, 2013), we told our participants a cover story falsely informing them that they would perform either a stressful task (to do a videotaped speech about one's physical appearance) or a neutral task (to do a simple visual planning task) following the SART with thought-probes. We found that more than 25% of reported mind-wandering episodes in the experimental group were described as attempts to prepare for the supposedly subsequent task, versus only 2% in the control group. Furthermore, participants who reported a higher increase in negative affect after being told about the stressful speech also reported a higher frequency of mind-wandering during the SART, suggesting that emotions might play an important role in the association between personal goals/current concerns and spontaneous thoughts.

Although the preceding studies suggest that personal goals and mind-wandering episodes are strongly coupled, results of the studies that simply asked individuals to rate on Likert scales the extent to which their mind-wandering episodes are related to personal goals without using any form of goal-priming procedures found only moderate associations between these two variables. For instance, in another study where we asked our participants to rate the content of each of their mind-wandering episodes during the SART with thought-probes (Stawarczyk, Cassol, & D'Argembeau, 2013), we found that the mean score for the item asking about the strength of the relationship between mind-wandering and personal goals was slightly below the midpoint of the scale (i.e., mildly related to personal goals). Similar findings were reported for the retrospective evaluation of daily life thoughts (Andrews-Hanna et al., 2013) and for the online experience sampling of mind-wandering in everyday life (McVay, Kane, & Kwapil, 2009; Poerio et al., 2013), which also found mean self-rating scores reflecting only moderate relationships with personal goals.

A potential explanation for the lower than expected association between mind-wandering episodes and personal goals outside goal-priming and cuing procedures can be related to the results of Klinger et al. (1980), who found that highly valuable personal goals and those for which actions have to be carried out in the close future are the most likely to influence thought content. It could therefore be that, in experience-sampling studies, most mind-wandering episodes relate to personal goals that are of moderate importance but for which individuals will need to take actions in the near future. Although this proposal remains to be specifically investigated, it is supported by two preliminary lines of evidence: first, by the findings that most future-oriented mind-wandering episodes are related to events supposed to happen in the next few days rather than the far future (e.g., Andrews-Hanna et al., 2013; Andrews-Hanna et al., 2010; Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011); second, by the results that mind-wandering episodes related to the future not only have higher ratings regarding their relationships with personal goals than those being attributed other temporal orientations but, additionally, that episodes about events happening in the far future (i.e., in more than one week) are also more strongly associated with personal goals than those happening in the near future (Stawarczyk, Cassol, & D'Argembeau, 2013). Together, these results suggest that there could be a valuation trade-off between importance and imminence to determine the topic of future-related spontaneous thoughts, potentially explaining why most self-ratings of mind-wandering episodes reflect that these thoughts are about short-term and mildly important concerns, rather than more meaningful (but often long-term) personal goals.

In summary, investigations on the relationships between personal goals and mind-wandering nicely complement the research on temporal orientation by showing that induced future-related concerns are likely to influence the frequency and content of spontaneous thoughts. Notably, several studies have shown that a significant part of mind-wandering episodes reported during tasks following goal-priming procedures are directly aimed at dealing with the cued personal goals. Research that investigated the degree to which "naturally" occurring mind-wandering episodes (i.e., without prior cuing of future-related concerns) are related to personal goals in laboratory and daily life settings revealed slightly less convincing findings, however. Self-ratings of such episodes showed only a moderate association with personal goals. The precise reasons why some spontaneous thoughts are more likely to be related to low-relevance rather than high-relevance personal goals and concerns still remains to be investigated, and I have proposed that the imminent requirement of behavioral actions might moderate the influence of importance on the probability of personal goals to influence thought content.

Other Phenomenological Features of Mind-Wandering

Temporal orientation and relationships with personal goals are currently the two most investigated phenomenological properties of mind-wandering and daydreams. To date, the other features that characterize the form and content of these two kinds of spontaneous thought have received much less attention from the scientific community and are also generally associated with more mixed findings. In the following subsections I will summarize the findings related to the most widely investigated phenomenological properties of mind-wandering outside temporal orientation and goal-relatedness: (1) representational format, (2) emotional valence, (3) realism and specificity, (4) unintentionality, (5) sequential versus fragmented form, (6) repetitiveness, (7) visual perspective, and (8) self and social aspects.

First, regarding representational format, there is evidence that mind-wandering is generally as likely to be in the form of visual images as inner speech (e.g., Diaz et al., 2014; Song & Wang, 2012; Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011), with other modalities (e.g., auditory, tactile, gustatory, etc.) representing a much smaller proportion of this kind of spontaneous thought (Christian et al., 2013; Klinger & Cox, 1987). Regarding the relationships between inner speech and visual imagery, we found in one of our studies that these two representational formats are strongly negatively correlated at the within-individual level (coefficient of –.55; Stawarczyk, Cassol, & D'Argembeau, 2013), suggesting that a particular mind-wandering episode is less likely to involve inner speech if it strongly consists of visual imagery. Not all results are consistent with this finding, however. Klinger and Cox (1987), for instance, found in their within-individuals factorial analyses that inner speech was unrelated to visual imagery and that the auditory modality (i.e., mentally imagining sounds other than one's own voice) loaded on a factor independent from visual modality. It could be that differences in the kinds of thoughts sampled in these studies—exclusively mind-wandering for Stawarczyk, Cassol, & D'Argembeau (2013) versus all kinds of thoughts for Klinger and Cox (1987)—are the cause of these discrepant findings. On the other hand, at the between-individuals level, results of our study revealed that these two representational formats were much less negatively correlated (coefficient of –.22), suggesting that individuals are generally not characterized by a style of mind-wandering consistently occurring mostly in either visual or verbal forms (Stawarczyk, Cassol, & D'Argembeau, 2013). Intriguingly, in an early paper, Antrobus et al. (1970) reported that performing a visual task strongly interfered with visual imagery during mind-wandering, whereas auditory tasks rather interfered with auditory imagery. These results have not yet been replicated, however, and future studies should investigate more precisely (1) the factors that influence verbal versus visual imagery during spontaneous thoughts, as well as (2) the precise relationships that exist between these two kinds of representational formats.

A second important dimension regards the emotionality of mind-wandering episodes. Findings here are generally consistent within the literature; most studies have shown that when people engage in spontaneous cognition, it is mostly to think about slightly pleasant topics. For instance, we found in our studies that approximately 42% of reported mind-wandering episodes were associated with positive affect, whereas only 19% were related to negative affect (Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011). Similar ratings were found for the daily life sampling of mind-wandering, with proportions of 42.5% of pleasant versus 26.5% of unpleasant mind-wandering episodes (Killingsworth & Gilbert, 2010). Other studies that rated on Likert scales the affective valence of spontaneous thoughts from daily life (e.g., Andrews-Hanna et al., 2013; Song & Wang, 2012) or occurring during laboratory sessions (Ruby, Smallwood, Engen, et al., 2013; Tusche, Smallwood, Bernhardt, & Singer, 2014) also consistently found that, on average, these thoughts are mildly positive (for a recent discussion on this topic, see Fox, Thompson, Andrews-Hanna, & Christoff, 2014).

Third, in line with the findings that most mind-wandering episodes are about autobiographical planning for events in the near future, we found in our studies that most reported episodes are rated as (1) having highly realistic content (85%–90% of episodes), (2) being related to specific events or actions (approximately 75% of reported thoughts), and (3) that these two dimensions are strongly positively correlated at the within-individuals level (coefficient of .52), suggesting that the specific events imagined by our participants are nearly always very realistic (Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011). In the same vein, Andrews-Hanna et al. (2013) found that 77% of daily life thoughts retrospectively assessed by their participants were related to specific events. Klinger and Cox (1987) found in their study that approximately 90% of reported thoughts involved none to low level of either physical impossibly, inappropriate actions, or reality distortions. Less consistent with these previous findings, two other studies that sampled mind-wandering in daily life found that these thoughts involve on average a moderate amount of fantasy (Kane et al., 2007; McVay et al., 2009). These later results should be considered carefully, however, because the wording of the item used in these two studies to assess fancifulness (i.e., "I was daydreaming or fantasizing about something") makes it somewhat difficult to clearly determine whether the thoughts that scored high on this dimension truly departed from real-world events. Nevertheless, we can conclude overall from the current state of research that mind-wandering is generally about precise, concrete, and highly realistic events.

A fourth important phenomenological dimension is the unintentionality of mind-wandering. Most studies generally consider that, when people mind-wander, it is mostly in an unintended manner. However, it is also possible that some individuals could deliberately engage in thoughts unrelated to the task at hand (for a recent discussion on this topic, see Seli, Wammes, Risko, & Smilek, 2016). In our studies, we found that deliberate mind-wandering episodes occur much less frequently than unintentional episodes during the SART, with approximately 10% of mind-wandering being rated as intentional (Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011). Forster and Lavie (2009) found similar results, reporting that 13.9% of responses to thought-probes in their experiment involved deliberate mind-wandering versus 38.3% for unintentional mind-wandering during a visual search task. More recently, Seli et al. (2016) found that 9% of probe responses were deliberate mind-wandering episodes versus 24% of unintentional episodes while memorizing a videotaped lecture. Not all studies are consistent with these results, however. Giambra (1995), for instance, reported in several experiments using low-demand vigilance tasks that deliberate mind-wandering episodes outnumbered unintentional episodes. Seli and colleagues also recently created a four-item self-rating scale designed to assess the frequency of deliberate and unintentional mind-wandering in daily life (e.g., Carriere, Seli, & Smilek, 2013; Seli, Carriere, & Smilek, 2015; Seli, Smallwood, Cheyne, & Smilek, 2015) and found roughly similar ratings for these two kinds of thoughts across studies. Finally, studies that used experience-sampling methods in everyday life revealed that, when asked whether they allowed their minds to wander on purpose, individuals generally report that their mind-wandering episodes consisted of a mixture of unintentional and deliberate thoughts (Kane et al., 2007; McVay et al., 2009). In sum, although research generally considers mind-wandering episodes as reflecting unintentional thoughts, several studies suggest that a non-negligible proportion of these episodes nonetheless consist of deliberate disengagements from the current task at hand.

A fifth phenomenological feature of mind-wandering is the degree to which this kind of spontaneous cognition consists of structured sequences of thoughts (e.g., as in reasoning, argumentation, etc.) versus disjointed segments of thoughts with no particular continuity. In their investigation of thought flow in daily life, Klinger and Cox (1987) found that thoughts were mostly coherent, although approximately 20% of them involved a moderate to high level of disconnected segments. Teasdale et al. (1993) found in a laboratory session that sequential mind-wandering was nearly four times more prevalent than fragmented thoughts during periods of rest. However, this difference became non-significant when their participants performed more demanding working memory tasks, with the frequency of sequential mind-wandering episodes decreasing to the same level as fragmented episodes (the rate of which did not change across conditions). The authors interpreted these results in the sense that sequential thoughts might be more resource consuming than fragmented ones. Two years later, Stuyven and Van der Goten (1995) replicated these findings and additionally found that, in comparison to rest, the frequency of sequential mind-wandering was less affected by a finger tapping than a random letter-generation task. In the studies performed in our lab, we found that approximately 25% of reported mind-wandering episodes during the SART were rated as highly structured sequences of thoughts (Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011). Although requiring further investigations, these results suggest (1) that mind-wandering involves both sequential and fragmented segments of thoughts, and (2) that the respective proportions of these two kinds of spontaneous cognition might depend on task difficulty.

Another important dimension of mind-wandering is whether this phenomenon is mainly composed of repetitive thoughts that chronically reappear throughout daily life or rather consists of more varied topics that continuously change over time (Watkins, 2008, 2010). When asked to rate whether the content of each of their reported mind-wandering episodes reoccurs repetitively in daily life, we found in our studies that participants gave average scores close to the anchor point "sometimes" of the scale, suggesting that some but not all spontaneous thoughts possess repetitive content (Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk et al., 2011). More interestingly, we also found that scores regarding the repetitiveness of reported thoughts correlated highly with both the personal importance and goal-relatedness of these thoughts (coefficients higher than .50 at the within-individuals level and higher than .70 at the between-individuals level), suggesting that the more a mind-wandering episode is related to important personal goals, the more it is likely to occur repetitively in daily life. Andrews-Hanna et al. (2013) later confirmed these findings by showing that repetitiveness is part of a general "personal relevance" dimension of thoughts, along with other variables related to the importance of thought content (e.g., goal-directedness, centrality to self-identity, self-relevance, etc.). Together, these findings are consistent with the *current concerns theory* (Klinger, 1971, 1996, 1999, 2009, 2013) and its proposal that the most important personal goals are more likely to influence the content of thoughts occurring in everyday life.

A much less examined dimension is the visual perspective adopted while mind-wandering (i.e., first- versus third-person perspective). Andrews-Hanna et al. (2013) found that 64.3% of thoughts in their study were rated as having a first-person point of view, 18.7% as having a different perspective, and 17% did not have any particular visual perspective. In another study, Christian et al. (2013) replicated the finding of a prevalence of the first-person perspective in participants form Western cultures (60.4%), whereas participants from Eastern Asian cultures reported a bias toward the third-person perspective in their mind-wandering episodes (59.5%). Female participants also showed a preference for first- (59.9%) over third-person imagery, whereas no preference was found in male participants. Interestingly, East Asian participants and males also reported less vivid mental imagery during mind-wandering than Westerners and females. The authors did not assess whether this difference was attributable to visual perspective, however. Generally, more studies should be conducted to determine whether differences in visual perspective during mind-wandering are associated with other phenomenological variables such as emotional intensity, self-relatedness, temporal distance, or coherence, similar to findings on episodic memories (e.g., Sutin & Robins, 2008, 2010).

Finally, a last important dimension concerns the social aspects of mind-wandering content. As discussed earlier, Singer and McCraven (1961) found in their seminal study that the most frequently endorsed instances of daydreams were related to interpersonal situations. In an online questionnaire study involving a vast number of participants (*N* = 17,556), Mar et al. (2012) found that 73.2% of respondents reported always or at least frequently daydreaming about other people, whereas only .8% reported that their daydreams never had social contents. Using online experience sampling of mind-wandering in daily life, Song and Wang (2012) found that the proportion of mind-wandering episodes focusing on people (70.95%) was significantly higher than the proportion of episodes focusing on objects (29.05%). In their study about daily life thinking, Andrews-Hanna et al. (2013) found that the thoughts reported by their participants were highly self-relevant (see also Baird et al., 2011; Smallwood et al., 2011) but only moderately involved other people. Similar findings were reported by Ruby, Smallwood, Engen, et al. (2013) who showed that mind-wandering episodes are generally more self- than other-related. Interestingly, these authors computed several principal component analyses on the dimensions of mind-wandering and consistently found that self-related episodes tend to be more future-oriented, whereas past episodes tend to more consistently involve thoughts about other people (Engert et al., 2014; Ruby, Smallwood, Engen, & Singer, 2013; Ruby, Smallwood, Sackur, & Singer, 2013). Although these findings remain to be replicated by other research teams, studies on the social aspects of mind-wandering generally converge toward the finding that, if most mind-wandering episodes are about oneself, they also quite frequently involve other people.

In summary, we have shown in this subsection that, apart from temporal orientation and goal-relatedness, mind-wandering episodes (1) occur most generally under the form of visual imagery or inner speech; (2) are mostly about pleasant rather than unpleasant topics, resulting in a slightly positive emotional bias; (3) are in most cases about highly realistic and specific events; (4) can either occur unintentionally or in a more deliberate way; (5) can take the form of both sequential or fragmented segments of thoughts (and that increasing task demands may particularly reduce the frequency of sequential mind-wandering); (6) do not necessarily consist of repetitive thoughts, although episodes focusing on more important and self-relevant topics tend to reappear more consistently in daily life; (7) mainly involve a first- rather than third-person visual perspective (although culture and gender may influence this effect); and finally (8) nearly always involve self-related contents but also frequently focus on other people and social situations.

How the Phenomenology of Mind-Wandering and Daydreaming Is Related to Daily Life Functioning

In the previous section, I have shown that, far from being wish-fulfilling ideations or random representations of fanciful topics, daydreams and mind-wandering episodes generally show consistent phenomenological properties across individuals. Studies that have examined the content of these two kinds of thought have more specifically revealed that their main features are a future temporal orientation associated with autobiographical planning processes related to specific events. A question that naturally follows from these findings is: "Do future- and goal-oriented mind-wandering episodes have concrete beneficial impacts on daily life functioning in comparison to other kinds of episodes?" One may indeed wonder whether using mind-wandering and daydreams in a constructive way to plan and prepare for future events may effectively be associated with a better daily cognitive and affective functioning. To date, however, studies assessing this particular question are relatively scarce, and their results often show mixed findings. In the present section, I will first review questionnaire studies that retrospectively assessed the general features of daydreams, and then the results of research that focused on more specific instances of mind-wandering during laboratory tasks and daily life.

Regarding the retrospective evaluations of daydreams in daily life, questionnaire studies using the IPI (Singer & Antrobus, 1970) or SIPI (Huba et al., 1982) have generally shown that high scores on the *positive-constructive daydreams* dimension are associated with beneficial correlates (or at least the absence of negative correlates), whereas the opposite is commonly found for the *guilty-dysphoric daydreams* and *poor attentional control* dimensions (e.g., Finnbogadottir & Berntsen, 2013; Giambra & Traynor, 1978; Klinger, Henning, & Janssen, 2009; Wilson et al., 2014). For instance, Zhiyan and Singer (1997) administered the SIPI to their participants, as well as two other questionnaires assessing (1) the tendency to experience positive and negative affect in daily life and (2) the Big Five personality traits. On the one hand, they found that *positive-constructive daydreams* correlated positively with openness to experience, conscientiousness, and positive affect. On the other hand, *guilty-dysphoric daydreams* and *poor attentional control* were both related to higher neuroticism and negative affect in daily life. In addition, *poor attentional control* was also negatively correlated with conscientiousness and experience of positive affect in daily life. These results suggest that the tendency to experience and enjoy vivid future-oriented daydreams associated with problem-solving processes is related to positive emotional outcomes in everyday life and personality traits reflecting higher intellectual curiosity and self-discipline.

In a more recent study, Marcusson-Clavertz, Cardena, and Terhune (2016) used experience sampling of mind-wandering in daily life and further asked their participants to complete the SIPI, a working memory task, and the Stroop task in a laboratory session. The aim of these authors was to examine how individual differences on the SIPI dimensions modulate the relationships between daily life mind-wandering and cognitive task performance. They found that, for participants with high levels of *guilty-dysphoric daydreams*, mind-wandering frequency was negatively correlated with working memory capacity, whereas the opposite was found for participants scoring low on this dimension. Next, as concerns *positive-constructive daydreams*, results showed that mind-wandering frequency is related to poor inhibition abilities during the Stroop task, but only for participants with below average scores on this particular dimension. Together, these results suggest that the relationship between cognitive abilities and mind-wandering is moderated by thought content: the more an individual has a tendency to experience high *positive-constructive* or low *guilty-dysphoric daydreams*, the less his or her mind-wandering episodes are likely to be related to poor inhibition abilities and low working memory capacity, respectively.

An issue with the IPI/SIPI dimensions is that they represent a combination of different facets, some of which are not directly representative of spontaneous thought features per se (e.g., positive and negative attitudes toward daydreams) and it may be questionable whether similar positive correlates would emerge for experience sampled mind-wandering episodes, and more specifically those whose content reflects autobiographical planning processes. Preliminary results in this regard came from the study of Baird et al. (2011), who found that the tendency of their participants to report future-oriented mind-wandering during low-demand task performance was associated with higher working memory capacity. In accordance with the SIPI findings, these results suggest that the tendency to experience constructive spontaneous thoughts is associated with better cognitive functioning. Other findings regarding the specificity of prospective mind-wandering came from a study of ours where we examined how future-/goal-oriented mind-wandering (1) differs from other kinds of episodes along several phenomenological dimensions, and (2) whether these differences are consistent with the supposed role of these episodes in planning and preparing for future events (Stawarczyk, Cassol, & D'Argembeau, 2013). Our main findings were that future-/goal-oriented episodes generally focused on more personally important, concrete, and specific events, and that these episodes were also more deliberate and structured in sequential thoughts than other episodes (i.e., past, present, and atemporal mind-wandering). In accordance with our hypotheses, these results indicated that prospective mind-wandering possesses features making it more likely than other forms of mind-wandering to beneficially influence future behaviors.

More concrete evidence in favor of the beneficial outcomes of prospective mind-wandering were recently found by Mason and Reinholtz (2015). In this study the authors asked their participants to perform specific actions in their daily life (i.e., to send an email or text message to the experimenter at a specific time and date without using external memory aids). The two authors then examined whether self-reported mind-wandering episodes specifically related to these future tasks (and occurring outside the enactment window) would predict the probability of the participants subsequently remembering to perform the requested actions. Across five experiments, the results generally showed that participants who reported more intention-related mind-wandering episodes were indeed more likely to send the email or text message at the right moment. These findings are particularly important because they are currently the only firm evidence indicating that future-oriented mind-wandering about a planned action can increase the probability of carrying out this action and, more generally, that spontaneous thoughts can effectively reinforce goal pursuit by fulfilling a self-reminding function.

In addition to its goal-reminding utility, there is also some recent evidence from experience-sampling studies on the possible emotion-regulation function of future-oriented mind-wandering. For instance, Ruby, Smallwood, Engen, et al. (2013) investigated whether the socio-temporal content of mind-wandering episodes can predict changes in mood states during a laboratory attentional task. Using time lag analyses, they found that (1) reports of mind-wandering episodes related to the past and other people when interrupted by a thought-probe predicted lower mood at the next thought-probe, and (2) this finding remained significant even if the emotional valence of the initially reported thought was positive. In contrast, mind-wandering episodes focusing on the future and the self were associated with better mood state at the next probe, even if the content of these initial episodes was negatively emotionally toned. Consistent with these findings, Engert et al. (2014) exposed their participants to a stress-induction procedure before assessing their levels of stress hormones and asking them to perform an attentional task with thought-probes. These authors found that the content of mind-wandering episodes reported by their participants generally moderated the levels of alpha-amylase and cortisol in saliva samples following the stressor. More specifically, (1) thinking about future- and self-related topics was associated with lower levels of cortisol and alpha-amylase, whereas (2) thinking about the past and other people was associated with a higher alpha amylase peak following the stress induction, and (3) negatively toned thoughts were associated with higher levels of cortisol. Together, the results of these studies suggest that future-oriented mind-wandering has beneficial effects on mood, independently of its emotional valence, and also is associated with reduced biological marker responses to stressors.

Not all findings are consistent with beneficial correlates of future-oriented mind-wandering, however. For instance, McVay et al. (2013) assessed mind-wandering during more demanding tasks than Baird et al. (2011) and did not replicate the finding that future-oriented mind-wandering is associated with a better working memory capacity. In another study, Ruby, Smallwood, Sackur, and Singer (2013) found no association between the future/self and past/other content of mind-wandering episodes and performance in a social problem-solving task. In their daily-life investigation on the affective consequences of mind-wandering, Poerio et al. (2013) found that future-oriented episodes had no effect on feelings of sadness and anxiety 15 minutes after the initial thought report. In addition, their findings revealed that it was the affective valence of the thoughts that was congruently predictive of subsequent mood states, rather than their temporal orientation. Similarly, Andrews-Hanna et al. (2013) found for their retrospective assessment of daily life thoughts that temporal orientation was unrelated to the experience of depression and negative affect in their participants. Again, it was instead the affective valence of the thoughts (and, to a lower extent, the tendency to rate the content of thoughts as more personally significant) that was predictive of lower emotional well-being. Finally, in the study where we induced a stressful concern in our participants before the SART with thought-probes (Stawarczyk, Majerus, & D'Argembeau, 2013), we found that the number of future-oriented mind-wandering episodes aiming at dealing with the induced concern was associated with a maintenance, rather than a decrease, of negative affect during the SART. It could be that, in this particular study, the experience of repetitive future thoughts about the induced concern was indicative of unsuccessful rather than successful attempts to deal with this particular concern. Nevertheless, these results indicate that further studies should be conducted to clearly determine the affective and cognitive correlates of prospective mind-wandering.

Finally, aside from autobiographical planning processes, some studies have found that other features related to the content of mind-wandering and daydreams can also influence the affective correlates of these thoughts. For instance, Franklin et al. (2013) used experience sampling in daily life and found that the presence of mind-wandering was generally associated with lower mood than moments where individuals reported being focused on their current task (see also Killingsworth & Gilbert, 2010). Importantly, however, a more detailed examination of mind-wandering content showed that episodes rated as high for either interest or usefulness were associated with better mood than moments where individuals were focused on task. In another study, Mar et al. (2012) found with retrospective reports that, whereas the frequency of daydreaming about people in daily life was positively correlated with loneliness, it was only daydreams about people for whom the participants could not be close (i.e., strangers, fictional characters, or past/potential romantic partners) that explained this relationship. Daydreaming about family members and close friends was not associated with loneliness and was instead related to an increased perception of social support and greater life satisfaction. These results suggest that phenomenological dimensions other than temporal orientation and emotional valence are important to take into account when examining the affective correlates of mind-wandering, daydreams, and, more generally, spontaneous thought.

In summary, we have shown in this section that evidence suggesting that some forms of mind-wandering may have more beneficial outcomes than others is currently very scarce. Evidence from questionnaire studies suggests that either a high score on the positive-constructive or low score on the guilty-dysphoric dimensions of daydreams are associated with better emotional and cognitive functioning. However, the extent to which these effects are due to daydreams per se and not to other variables associated with these two general dimensions of inner mental life (e.g., acceptance and emotional reactions to spontaneous thoughts) remains unknown. With regard to experience sampled mind-wandering, apart from a single recent study by Mason and Reinholtz (2015), there is no really direct evidence that future- and goal-oriented mind-wandering can concretely facilitate the achievement of personal goals. There are some indications that future-oriented mind-wandering is associated with beneficial effects on mood states and biological reaction to stressors, but these findings need to be replicated. Some other studies have found, for instance, that it is the affective valence of thought content, rather than its temporal orientation, that is predictive of mood states and emotional well-being. Finally, it seems that other variables, such as the social proximity of imagined individuals and the subjective interest and usefulness of thought content, also influence the affective correlates of spontaneous thoughts.

Conclusions and Future Directions

In this chapter I have attempted to answer two important questions: (1) What are people thinking about when they daydream and their minds wander from the here and now? (2) Can the form and content of these two kinds of thoughts influence their correlates outside the domain of spontaneous cognition? First, regarding the form and content of mind-wandering and daydreams, early questionnaire studies are generally consistent in finding that, rather than being fanciful ideations, important phenomenological dimensions of daydreams are a future temporal orientation associated with problem-solving processes. These findings were later confirmed by experience-sampling research during daily life and laboratory tasks that demonstrated a prospective bias of mind-wandering associated with autobiographical planning processes. Several studies have also shown that cuing and inducing future-related concerns can strongly influence the content and frequency of mind-wandering, suggesting that these thoughts are closely related to the processing of personal goals. Finally, other phenomenological features of mind-wandering have been much less investigated and the most consistent findings are that these thoughts (1) are mostly about oneself and events happening in the near rather than distant future, (2) generally occur under the form of a visual image or inner speech, (3) focus on specific and highly realistic events, and (4) show a slight positive emotional bias. Second, regarding the question of whether the content of mind-wandering and daydreams can moderate the beneficial or deleterious correlates of these thoughts, there is currently little direct evidence that future-oriented mind-wandering can concretely facilitate the achievement of personal goals or intended actions. Some questionnaire and experience-sampling studies have found that future-oriented/constructive daydreams and mind-wandering are associated with beneficial affective and cognitive correlates, but these findings have not been consistently replicated across research groups.

One possible way to explain the contrast between research that consistently showed the importance of prospective thoughts to daydreaming and mind-wandering and, on the other hand, the inconclusive results of the studies that assessed how this kind of thought may beneficially impact daily life could be related to the lack of investigation of the context in which these spontaneous thoughts occurs. Based on the findings that mind-wandering is generally more frequent and also has a lower negative impact on performance during low-demand and easy tasks, Smallwood and Andrews-Hanna (2013) recently proposed that it is crucially important to take into account the context of mind-wandering episodes, in addition to their content, to clearly determine their beneficial outcomes. To date, however, very few studies have assessed whether and how the phenomenological properties of mind-wandering are influenced by the context in which it occurs, and even fewer have attempted to determine how this modulating effect of context on content may moderate the relationships between mind-wandering and its possible outcomes (but see Ruby, Smallwood, Sackur, & Singer, 2013). Interestingly, some evidence suggests that the association between mind-wandering and higher ability to delay future gratification (Smallwood, Ruby, & Singer, 2013) and to generate creative ideas (Baird et al., 2012) is stronger for mind-wandering occurring during low- rather than high-demand tasks. Furthermore, we have seen in this chapter that mind-wandering seems to be more consistently future-oriented and structured in complex sequences of thoughts during low- than high-resource-consuming tasks. An interesting avenue for future studies in the growing field focusing on the phenomenological properties of spontaneous thoughts might therefore be to examine whether the beneficial correlates previously found for mind-wandering episodes during low-demand tasks can be explained by the higher occurrence of future-oriented and complex episodes in this particular context.

To conclude, it is important to remember that the study of the phenomenological properties of spontaneous thoughts is still in its infancy, being less than one decade old for the precise investigation of daydreaming and mind-wandering content with thought-probes. I nonetheless believe that a major next step in the study of this particular kind of cognition, and for which we hope that this *Handbook* will represent a strong anchor point, will be to develop an integrative theoretical model of spontaneous thoughts. I think that it will be crucial for this model to include the various dimensions reflecting the phenomenological features of thoughts, and a key component of this theoretical framework will require more precisely investigating how different kinds of daydreams and mind-wandering episodes can concretely influence our daily cognitive and affective functioning, be it deleteriously or beneficially.

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CHAPTER

17

Spontaneous Thought and Goal Pursuit: From Functions Such as Planning to Dysfunctions Such as Rumination

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Abstract

Spontaneous thoughts occur by default in the interstices between directed, task-oriented thoughts or moments of perceptual scrutiny. Their contents are overwhelmingly related to thinkers' current goals, either directly or indirectly via associative networks, including past and future goals. Their evocation is accompanied by emotional responses that vary widely in type, valence, and intensity. Given these properties of thought flow, spontaneous thoughts are highly adaptive as (1) reminders of the individual's larger agenda of goals while occupied with pursuing any one of them, (2) promotion of planning for future goal pursuits, (3) deeper understanding of past goal-related experiences, and (4) development of creative solutions to problems in goal pursuit. The same mechanisms may occasion repetitive but unproductive thoughts about the pursuit, the consequences of the failure, or the self, and strong negative emotions steering the train of thought may lead to narrowing of its focus, thus producing rumination.

Key Words: spontaneous thought, adaptive, goal, rumination, emotion

Under normal conditions, the brain never just rests. As circumstances change from, for example, focusing on tasks to seemingly aimless musing, or from waking to the various phases of sleep (or the reverse of these), the parts of the brain that are most active change from one set to another. Studies of the contents of consciousness have long recognized this apparently unceasing activity, and the technology of brain imaging has permitted researchers to gradually reveal the neural reality that underlies it. Two important generalizations have emerged from these studies, which are also central components of the *goal theory of current concerns* (Klinger, 1971, 1975, 1977, 2013; Klinger & Cox, 2011a): (a) spontaneous thought represents the mental baseline; (b) the content of spontaneous thought is mainly related to personal goals.

Basic Properties of Spontaneous Thought

Spontaneous Mentation as Baseline or Default Mental State

First, as early observations suggested, spontaneous thought (in the sense of "unintended, nonworking, non-instrumental mental content that comes to mind unbidden and effortlessly"; Christoff, 2012, p. 52; Klinger, 2009) constitutes a baseline state of mental activity that occurs irresistibly in the absence of instrumental, task-oriented mental activity (Klinger, 1971). Spontaneous thought in this sense includes mostly such states as mind-wandering and other forms of daydreaming. In parallel, early brain imagers discovered that when their research participants turned from task mentation to mind-wandering, certain brain structures, such as the posterior cingulate cortex, medial prefrontal cortex, and possibly medial temporal lobe, predictably became particularly active; they dubbed these the default mode network (e.g., Andrews-Hanna, Reidler, Huang, & Buckner., 2010; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007; Raichle et al., 2001; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011b)—"default" here carrying the same meaning as the earlier term "baseline."

To be clear, mind-wandering is not the only kind of conscious content that can be observed while the default mode network is active. That is, other self-referential and perceptually decoupled content may also occur (e.g., Spreng, Mar, & Kim, 2009). Moreover, mind-wandering is often interwoven with executive systems (Christoff, 2012; Christoff et al., 2009), with the default mode network being positively correlated with the frontoparietal control network during internally focused tasks (e.g., Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010). Still, mind-wandering is clearly a prominent part of the default mix (for a more extended discussion of the relationship between the default mode network and mind-wandering, see Klinger, 2013).

Mind-wandering accounts on average for between about a third and a half of conscious thoughts (Killingsworth & Gilbert, 2010; Klinger & Cox, 1987–1988). It would therefore be surprising if it could have evolved in the absence of important contributions to human functioning.

Content of Spontaneous Mentation as Principally Goal-Related

A second important generalization is that the content of spontaneous waking thought and dreaming is prominently related to the individual's goal pursuits, directly or indirectly, including metaphorically. For animal species, pursuit and adequate attainment of goals is, of course, a categorical imperative for survival. Furthermore, progress toward one's goals is an important determinant of an individual's positive affect (Klug & Maier, 2015). It is therefore not surprising that a chief focus of thought, spontaneous and otherwise, is the pursuit of an individual's goals, great and small. The goal pursuits in mind-wandering are mostly those in the individual's current life, but may also, by association in spontaneous mentation, be those of the past or contemplated future, as revealed through thought- or dream-sampling using probes (Hoelscher, Klinger, & Barta, 1981; Klinger, 1978, 2009; Nikles, Brecht, Klinger, & Bursell, 1998). This view is also supported by indications of spontaneous planning during mind-wandering (Baird, Smallwood, & Schooler, 2011; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011a)—presumably planning for action toward one of the participant's goals. Studies of thoughts retrospectively recalled as thoughts about "today and yesterday" were also characterized, in comparison with things less thought about, as being about goals marked by stronger commitment or by obstacles to their attainment (Klinger, Barta, & Maxeiner, 1980).

Spontaneous thoughts are probably triggered by cues (meaningful stimuli) that may be external in the environment or internal in the person's own mental activity and that are associated with one or another of the individual's goals. Such cues may take many forms, such as the name of a loved one or something associated in the person's mind with a loved one (or with an enemy, etc.), or a word, image, or smell associated with an ongoing goal pursuit, including cues related to failure to achieve a goal (Chatard & Selimbegović, 2011, Study 6).

A growing literature indicates that becoming committed to pursuing a goal boosts the cognitive-processing priority for cues related to that goal. Thus, knowing a person's goals is a good predictor of which cues (such as spoken words) the person will attend to, recall, and have thoughts or dreams about—namely, those that are associated with the person's own goals, as compared with someone else's goals (Hoelscher, Klinger, & Barta, 1981; Klinger, 1978, 2009, 2013; Nikles et al., 1998). (The parallels in findings with thoughts and dreams become less surprising in light of the argument that dreams are partly akin to mind-wandering in regard to both content and neural substrates; Domhoff & Fox, 2015.)

The processing priority may also be found in interference effects. For example, in the classic Stroop procedure, in which participants are under instructions to name as quickly as possible the color of the font of words displayed one at a time, participants typically respond more slowly when the meaning of the word conflicts with the color, such as green font for the word *red*. Presumably, word meaning takes precedence in cognitive processing over font color. Similarly, reaction times (RTs) in reporting the font color of goal-related words are typically on average longer than they are to non-goal-related words (Johnsen Laberg, Cox, Vaksdal, & Hugdahl, 1994; Riemann & McNally, 1995; Gilboa-Schechtman, Revelle, & Gotlib, 2000; Fadardi & Cox, 2008) or images. Presumably, the own-goal-relatedness of the word's meaning grabs processing priority over identification of font color, thereby slowing reporting of font color. This processing priority could readily account for the tendency of conscious mental content in mind-wandering to gravitate toward material related to the individual's own goals. The stimuli for shifts in the content of mind-wandering segments are presumably internal ones in the individual's own ongoing stream of thought.

Interestingly, a recent study provided evidence for the notion that attention allocation is strongly influenced at early stages by the goal-relatedness of information (Vogt, Lozo, Koster, & De Houwer, 2011). In this study, individuals either received a disgust or a neutral induction. As expected, it was shown that a disgust induction elicited attention toward disgust-related pictures that were briefly presented. More important, individuals in the disgust induction condition also showed heightened attention for pictures representing cleanliness, which is due to disgust triggering the goal to be clean and attention thus being allocated to the means (e.g., cleaning products) of becoming clean.

It is, of course, hard to control particular segments of participants' thought stream experimentally so as to examine their role as internal cues to further thoughts. The evidence described in the preceding showed that subtle own-goal-related external stimuli strongly affected the content of thoughts and dreams, but those cues were external. However, in a different kind of interference method, Kopp, D'Mello, and Mills (2015) instructed some participants to list the features of an automobile and other participants to list their to-do plans for the next five days. Subsequently, all read a scientific text and indicated whenever they became aware of their mind wandering to task-unrelated thoughts (TUTs) or to task-related interference (TRIs). As predicted, the participants who had just reminded themselves of their short-term goals reported more TUTs and displayed less comprehension of the text than did the control group, whereas the groups did not differ in TRIs. The difference in TUTs mediated the difference in comprehension. Presumably, recounting one's own goals triggered more subsequent distracting thoughts, probably also about one's own goals. Other research (McVay & Kane, 2013) has also shown with thought probes that displaying word triplets that contain words alluding to participants' personal concerns, as compared with other word triplets, increased subsequent mind-wandering.

Mind-wandering is, of course, by definition thought that wanders off-task. However, Dijksterhuis and his colleagues (e.g., Dijksterhuis & Meurs, 2006; Dijksterhuis & Nordgren, 2006) have proposed that "unconscious thought," defined as "thought or deliberation in the absence of conscious attention directed at the problem" at hand (Dijksterhuis, Bos, Nordgren, & van Baaren, 2006, p. 1005), provides important contributions to goal attainment, such as superior decision-making. Their investigations have provided evidence in support of this position (but see Nieuwenstein et al., 2015). However, this evidence is based on a procedure that, typically and tacitly, operationalizes unconscious thought as whatever mental processing occurs during a task designed to distract the participant from a previous assignment that is to be resumed after an intervening distractor task. This seems very similar to the operational definition commonly used for opportunities for mind-wandering, except that the distracting tasks assigned by Dijksterhuis's group, such as the *n*-back task (i.e., pressing a space bar when the character on a screen is the same as one *n* trials ago), are intended to block all conscious thought. What we now know about mind-wandering makes it likely that this procedure reduces but does not completely block it. It remains an open question as to the extent or way that "unconscious thought" and mind-wandering are in fact different processes. Perhaps future brain-imaging research can address this question.

The reason for raising this point here is that one investigation (Bos, Dijksterhuis, & van Baaren, 2008) finds clearly that, in the absence of an experimentally induced goal to complete a task later, the contribution of unconscious thought to that task disappears. This supports the view that continuing the processing of task-relevant information depends on having established the current concern that underlies a goal pursuit. Relatedly, a review of other evidence indicates that "goal completion dissolves the cognitive, affective, and behavioural effects of goal striving" (Oettingen, 2012, p. 34), indicating that successful goal pursuit ends the cognitive effects of the respective current concern.

Duration and Frequency of Spontaneous Thought Segments

Thought segments are on average very brief. A group of 20 participants, who had received practice with feedback at estimating brief time lapses, rated the durations of their latest thought segments prior to probes, and of the segments just preceding those, in both laboratory settings and, for 12 of them, while living their otherwise normal daily lives. A segment here was defined as a thought that is thematically homogeneous and ends when the topic shifts. These participants' median estimates of segment duration were 5 seconds in both laboratory and daily-life settings, with a mean of 9 seconds in the laboratory setting and 14 seconds (with a standard deviation of 22 seconds) outside the laboratory (Klinger, 1978). These participants rated their confidence in their own estimates as "very confident" 64% of the time and as "moderately confident" 35% of the time. Pope (1977) asked participants in a laboratory to signal with a key press every time their mind shifted to a new topic, which happened on average about 5 to 6 seconds apart. This agrees very approximately with the findings described in the preceding (Klinger, 1978).

These estimated durations applied to all of a participant's sampled thoughts, not just the spontaneous ones, but participants in Klinger's (1978) sample also rated each thought on a variety of variables, including Directedness and Undirectedness, the latter being equivalent to spontaneity. The correlations of Undirectedness ratings with Duration for daily-life samples were –.18 for the latest thought segment and –.08 for the just-previous thought segment; the corresponding correlations for Directedness were .17 and .11. The corresponding correlations for Undirectedness in laboratory samples were –.05 and .00; for Directedness, they were .06 and .02. Clearly, these are all very small correlations. It therefore seems safe to consider spontaneous thoughts, which make up between about a third and a half of people's thought segments, to be of approximately the same duration as directed thoughts.

The implication is that mental content continually jumps from one goal-related topic to another in brief segments that may or may not reflect the same goal. A very rough estimate provides the generalization that waking mental activity over a 16-hour day contains about 4,000 such thought segments (Klinger, 1990), of which perhaps between about 1,300 to 2,000 are spontaneous.

Emotional Responses in Relation to Spontaneous Thoughts

There are a number of reasons to believe that thoughts carry emotional charge and may, in fact, be triggered by at least low-amplitude, fragmentary emotional responses (*proto-emotional* responses; Klinger, 1996). First, there are substantial intra-individual correlations, across words, between the strength of participants' self-rated emotional response to each word and the extent to which they rated each word as related to their "important concerns, problems, worries, or goals that currently preoccupy" them. These correlations range from .45 (Bock & Klinger, 1986) to a set of correlations that ranged from 0.57 to 0.65 in four unpublished data sets.

Second, goal-relatedness of thoughts is associated with emotional arousal. For example, another investigation (Nikula, Klinger, & Larson-Gutman, 1993) prompted participants for their thought content when experimenters observed unsolicited skin-conductance responses, which are often taken to indicate emotional response. Ratings for the goal-relatedness of thoughts were at those times significantly higher than when participants' thoughts were sampled during electodermally quiescent periods. Using a different approach, inducing an affectively negative concern experimentally led to increased mind-wandering and, subsequent to the mind-wandering episodes, continuing negative affect, suggesting that the mental content of the mind-wandering contributed to maintaining the negative affect (Stawarczyk, Majerus, & D'Argembeau, 2013; see also Watkins, Grafton, Weinstein, & MacLeod, 2015, in regard to "emotional extrapolation").

Also, in a lexical-decision task (pressing a button as quickly as possible to indicate whether a letter on a screen was an X or a Y; Schneider, 1987), one side of the screen contained words intended to be peripheral distracting stimuli and probably not consciously perceived. The emotional-arousal effect of the distractor words (as subsequently rated by the participants) was inversely correlated with reaction time to the letters being judged as X or Y; that is, words that participants rated as emotionally arousing slowed their task response—gained higher cognitive processing priority over the assigned lexical decision-making—in a way similar to that found with goal-related words in the Stroop. That this really was an effect of emotion is supported by the finding that the interference with task responses was associated with participants' scores on the Affective Intensity Measure (Larsen & Diener, 1987). Given the preceding evidence that goal-related thoughts accompany emotional arousal and that mind-wandering mostly features goal-related thoughts, it is of interest that mind-wandering is itself associated with pupillary dilation, often viewed as indicative of emotional arousal (Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013).

This similarity between emotional arousal and goal-relatedness in the effects of distractor words on cognitive processing is consistent with the view that "being goal-related" means "being emotionally arousing." It presumably follows that the emotional tenor of mind-wandering is to some extent determined by the affective quality of the emotional response to cues, which accompanies or perhaps evokes the next segments of thought flow. Glowing recollections of a good time at a party, of recognition for an accomplishment, or of a loving social interaction would expectedly carry a strongly positive emotional charge. Recollections of personal rejection or failure—threats to or loss of important goal attainments—would expectedly carry a strongly negative emotional charge. Furthermore, mood at one time point is associated with the affective tone of subsequent thoughts (Poerio, Totterdell, & Miles, 2013). Correspondingly, emotionally charged thought segments are likely to lead to further segments of similar affective quality, whether anticipation of future positive consequences in the case of a foregoing positive segment, or, in the case of foregoing negative segments, subsequent segments of self-examination, self-criticism, anger at others with anticipation of future avoidance of them or revenge, and imagined future episodes of rejection, failure, or loss. With strong emotional charge, as when important goals are involved, the resulting thought stream may be funneled into loops of thematically and emotionally related or event-repetitive content, as in rumination (rumination is discussed at greater length in a later section).

Adaptiveness of Spontaneous Thoughts

The preceding view on spontaneous thoughts suggests both adaptive and maladaptive consequences. That spontaneous thoughts must have significant adaptive benefits is a clear logical inference from the apparent fact that humans have evolved to spend up to half of their mental activity engaging in them.

The notion that such an ubiquitous process must have significant adaptive advantages for the human species has received recognition (Baars, 2010; Klinger, 1990; Smallwood & Andrews-Hanna, 2013), but so far only limited research attention, although that is gradually changing, including integration with advancing neuroscientific findings (Andrews-Hanna, 2012; Andrews-Hanna, Smallwood, & Spreng, 2014; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Gruberger Ben-Simon, Levkovitz, Zangen, & Hendler, 2011). From a purely inductive standpoint, based on informal observation of the contents of spontaneous thoughts, a number of possible benefits are already apparent.

Keeping Track of Goals

First, given the brevity of most mind-wandering segments and the large number of them during a particular day, and given the tendency for these segments to cycle through thematic material relevant to an individual's numerous current goals, it is apparent that mind-wandering serves the function of reviewing an individual's agenda of goals other than the goal being currently pursued. This must surely refresh memory of these other goals and, most likely, serve as a reminder mechanism for taking timely action.

Promoting Planning

Second, given that a substantial portion of mind-wandering or daydream segments are future-oriented (Andrews-Hanna et al., 2010; Baird et al., 2011; Buckner, Andrews-Hanna, & Schacter, 2008; Klinger & Cox, 1987–1988; Smallwood, Nind, & O'Connor, 2009; Smallwood, Schooler, et al., 2011), they provide an arena for spontaneous planning or contributions to planning. Indeed, there is now evidence for such a planning function. On the one hand, these spontaneous contributions are in most instances imaginary fragments that bear on goals and plans without providing a linear planning process (Schacter, 2012). On the other hand, there is no reason to believe that mind-wandering cannot wander onto and perhaps be interrupted by brief operant (i.e., instrumental) segments. Researchers discovered that mind-wandering often includes an interweaving of default-network activity with executive brain systems (Christoff, 2012; Christoff, Ream, & Gabrieli, 2004; Christoff et al., 2009; Mason et al., 2007; Spreng et al., 2010). One would expect such a process to contribute to the formulation of concrete plans for future behavior, as found by Baird et al. (2011) and Stawarczyk et al. (2011a). For example, spontaneous imagery of an upcoming party might portray an awkward interaction with an individual who is expected to be present, which might stimulate some operant thoughts of how to handle that situation. Spreng et al. (2010), based on fMRI observations, proposed a three-network model of how this switching process happens. The three networks are the default-mode network, the dorsal attention network, and a frontoparietal control network. The first two have "an intrinsic competitive relationship" (Spreng et al., 2010, p. 303), whereas the third plays a key role in the switch back and forth.

Creative Problem-Solving

It has long been recognized in popular culture that difficult problems requiring non-routine and hence creative solutions can benefit from merely allowing time to pass before trying to finalize them, as in the advice to "sleep on" the problem. It is likely that not only sleep, but also periods of spontaneous mentation, such as mind-wandering, facilitate this kind of incubation. There are numerous anecdotal accounts of people having important insights into difficult problems during carriage rides, bathing, taking a walk or a nap, and so on—that is, activities conducive to spontaneous mentation (e.g., Klinger, 1990; Singer, 2009). Now there are also relevant controlled experiments.

Dijksterhuis and Meurs (2009), investigating the efficacy of "unconscious thought" (Dijksterhuis & Nordgren, 2006), assigned participants to tasks such as finding creative names for pastas or unusual uses for a brick and placed them in one of three conditions: immediate responses, or responses following three-minute periods of either focused thought about the problem or a distractor task. In three experiments, the participants responded with more creative or divergent responses after the distractor task than after the other activities. The investigators hoped to design distractor tasks that would suppress conscious thought, but from what we know about mind-wandering—very brief segments, focused on unmet goals—it seems unlikely that the suppression could have been complete (Singer, 1966). It is therefore likely but uncertain that spontaneous thoughts could have been responsible for the results.

However, Baird et al. (2012) provided participants with two opportunities to think of unusual uses for common objects. Between these opportunities, some participants engaged in a very undemanding task that would provide plenty of time for spontaneous thoughts, and others received a very demanding task that would limit spontaneous mentation. The group who had the undemanding interim task performed significantly better than the other group on the second opportunity to come up with creative solutions. Evidently the chance to engage in spontaneous thought, as in mind-wandering, fostered the necessary incubation of creative solutions in a way that improved performance.

Reviewing Past Experiences

Of course, coming up with new ideas often involves drawing on one's past experiences. Also, there is pleasure to be savored when reliving one's past good times and successes, perhaps in relation to hopes for more of them. Furthermore, when faced with one's own limitations and failures, transcending these often thrusts one into scrutinizing what one might have done differently, sometimes leading to useful insights that improve performance later on. Indeed, the contents of spontaneous thoughts and dreams include a substantial portion of memories and reflections on past events (Andrews-Hanna et al., 2010; Klinger & Cox, 1987–1988), especially during negative moods (Smallwood et al., 2011; Smallwood & O'Connor, 2011). Reviewing past experiences for benefits to future endeavors is presumably advantageous in reaching one's goals.

Reduced Delay Discounting

Delay discounting is the phenomenon in which people, given the choice, prefer to receive smaller rewards soon rather than larger rewards later; that is, they presumably discount the value to them of the reward the more remote it will be in time. This preference may keep a person from maximizing well-being by settling for less than is available, be it money, career satisfaction, or a solid personal relationship. There is evidence that people whose minds wander more than others display less delay discounting (Smallwood, Ruby, & Singer, 2013), presumably therefore displaying more patience and arriving at more prudent choices. Unfortunately, because this evidence is correlational rather than experimental, one cannot be sure regarding the direction of causality.

Consolidation of Memories

There is ample evidence that sleep helps to consolidate long-term memories (e.g., Pace-Schott, Germain, & Milad, 2015), especially during rapid-eye-movement (REM) sleep (McDevitt, Duggan, & Mednick, 2014) and especially with regard to goal-relevant features (Bennion, Payne, & Kensinger, 2015). It now appears that periods of spontaneous thinking confer a similar, albeit weaker, consolidation benefit. In an extensive review of relevant literature, Christoff, Gordon, and Smith (2011) concluded that "recent findings suggest that the off-line processing that occurs during periods of rest is associated with the kind of memory consolidation processes that occur during sleep" (p. 264).

Superiority in Shifting Between Internal Thought Flow and External Stimuli

There are individual differences in control over the direction of attention between internal and external processes. The ability to shift back and forth appears positively related to the individual's working memory capacity (Rummel & Boywitt, 2014). Additionally, trait measures of mind-wandering appear inversely related to the size of attentional blinks (Thomson, Ralph, Besner, & Smilek, 2015); that is, when individuals are presented with a pair of stimuli in rapid enough succession, they do not register the second of those stimuli. The maximum inter-stimulus interval for this to happen is the size of an individual's attentional blink. In the study by Thomson et al. (2015), high scores on trait mind-wandering predicted shorter blinks, meaning that people whose minds wander more can on average shift more rapidly than others to the second stimulus in such a pair. Thomson et al. suggest that this is an indication of adaptively finer control over the focus of attention.

Facilitating Action Toward Goal-Attainment

Setting goals and moving on them generally begin with mental processes, often spontaneous, that recognize the desirability of an outcome, its attainability, and the means necessary for attaining it. It is, of course, difficult in observational research to disentangle these processes for purposes of establishing what leads to what. The closest that investigators have come so far is by instructing human participants to initiate daydream-like experiences and to vary something about the nature of these experiences, such as what the person might look forward to enjoying as a result of goal attainment or the obstacles that the person might imagine having to overcome (e.g., Oettingen, Pak, & Schnetter, 2001). These imaginal segments are clearly not completely spontaneous in regard to their initiation and certain features of content, but once initiated and broadly determined by the investigator, they then unfold in perhaps partly spontaneous fashion. Experimental evidence indicates that induced daydreaming of this kind can influence subsequent real-life goal attainment. Oettingen et al. (2001) have in a number of studies established that optimal goal-attainment "requires explicit, simultaneous mental elaborations of both the desired future and present reality as instigated in the mental contrasting procedure" (p. 748), as for example reaching health-promoting goals (Johannessen, Oettingen, & Mayer, 2012), exercise goals (Sheeran et al., 2013), and a variety of goals in a depressed sample (Fritzsche et al., 2016). Dwelling only on the pleasures of attainment or only on the obstacles in its way tended to be counterproductive in leading participants to reach their goals (e.g., Oettingen, 1996), as, for instance, in their teachers' ratings of actual achievement (Oettingen et al., 2001). Other studies of thoughts initiated by experimental instructions but allowed to unfold spontaneously have also found effects on intentions or actions likely to advance particular goal pursuits (e.g., Gollwitzer, 1990; Gollwitzer, Heckhausen, & Ratajczak, 1990; Nenkov & Gollwitzer, 2012). Whether these findings with only partially spontaneous thoughts will transfer to the effects of fully spontaneous thoughts remains to be demonstrated. (For a summary of research related to mental contrasting and prospective thinking, see Oettingen, 2012).

Costs of Spontaneous Thoughts

Research on the consequences of mind-wandering has focused heavily on its costs in the form of attentional lapses and degraded performance. However, it is important to keep in mind that neuroscientists became interested in mind-wandering and the default mode network as their participants switched from working on tasks to more relaxed intervals between tasks (Raichle et al., 2001). Mind-wandering occurs most often when the brain is less than fully occupied with tasks (such as during rest or undemanding tasks) or the external environment (e.g., Andrews-Hanna et al., 2010), when it is often safe to *decouple* brain activity (Smallwood, Tipper, et al., 2013) briefly from the external environment and ongoing tasks.

Because of this timing, there may be only modest impacts of mind-wandering on performance, but in other cases the impact can be substantial. Mooneyham and Schooler (2013) have presented an extensive review of empirical work on these costs, which include impaired comprehension when reading, impaired sustained attention to tasks, poorer performance on measures of working memory and general aptitude, and, on average, lowered mood. Since the publication of this review, Mrazek, Phillips, Franklin, Broadway, and Schooler (2013) have similarly reported impaired reading comprehension associated with prompt-assessed mind-wandering. A number of further studies have found additional costs: attentional lapses associated with impaired performance on the Stroop task (Unsworth & McMillan, 2014), a significant relationship between mind-wandering proclivity and frequency of falls in older adults, presumably at least partly because of inattention to external stimuli (Nagamatsu, Kam, Liu-Ambrose, Chan, & Handy, 2013), particularly in the left visual field (Kam, Nagamatsu, & Handy, 2014), and reduced empathic responses to others' physical discomfort, as assessed by participants' ratings and electrophysiologically with event-related potentials (Kam, Xu, & Handy, 2014). By contrast, when leaving aside its perseverative, ruminative forms, mind-wandering appears unrelated to most measures of health (Ottaviani & Couyoumdjian, 2013; Ottaviani, Shapiro, & Couyoumdjian, 2013).

Nevertheless, the cognitive impairment found in these studies must be qualified by other findings that even during mind-wandering, people retain some sensitivity to external cues when these relate to potentially important matters or when a stimulus is unexpected (Kam et al., 2013). This conclusion is consistent with sleeping or otherwise occupied participants' disproportionate response to and incorporation of unexpected cues related to their goal pursuits (Hoelscher, Klinger, & Barta, 1981; Klinger, 1978). Furthermore, the interference of mind-wandering with task activity appears to affect especially response inhibition and working memory, but not set-shifting (assessed in this case by delays caused after shifts in task rules within a series of trials; Kam & Handy, 2014). The costs of mind-wandering to task performance are therefore apparently different for different aspects of performance and different kinds of external cues, the brain seemingly weighing the relative importance of external information versus maintaining the ongoing stream of thought (Handy & Kam, 2015).

Spontaneous Thoughts and Mood

The findings for the cognitive costs of mind-wandering are easily understandable. Perceptual decoupling is bound to interfere to some extent with absorbing one's reading material and to distract from other ongoing tasks, including, of course, those that are measures of a person's cognitive capacity. Mooneyham and Schooler's (2013) generalization regarding lowered mood, however, must be treated with caution.

The generalization that mind-wandering lowers mood was misleadingly emphasized in the title and summary statements of an otherwise important article by Killingsworth and Gilbert (2010), an experience-sampling study with a huge sample. Close inspection of their data fails to support the generalization that mind-wandering *as such* lowers mood, only that the thematic *content* of mind-wandering segments influences mood. Inasmuch as minds wander to concerns about one's own goal pursuits, especially those that are still incomplete and those that may be in trouble (Klinger, Barta, & Maxeiner, 1980), one might expect lower, more serious moods on average. However, in Killingsworth and Gilbert's own data, participants rated 42.5% of their mind-wandering episodes as about something "pleasant," with mood then averaging slightly above the overall mood average, roughly equaling mood when not mind-wandering. They rated 31% of the remaining mind-wandering episodes as about something "neutral," with average mood slightly below overall average but above the mood scale's midpoint. Participants rated mood as sharply below overall average and below the scale midpoint only during the 26.5% of mind-wandering samples that they characterized as about something "unpleasant." Thus, only particular thought content, not mind-wandering *as such*, was associated with substantially lowered mood (cf. also Smallwood & Andrews-Hanna, 2013; Stawarczyk, Majerus, Van der Linden, & D'Argembeau, 2012). This was also the conclusion reached in subsequent experience-sampling studies (Marchetti, Koster, & de Raedt, 2013; Poerio, Totterdell, & Miles, 2013; see also, Fox, Thompson, Andrews-Hanna, & Christoff, 2014).

Maladaptive and Excessive Daydreaming

There has recently been an upsurge of interest in a condition in which people spend large amounts of time in imaginative daydreaming, usually involving imaginary companions or casts of characters that recur over time, sometimes as long as years, which gains a kind of quasi-reality (Bigelsen & Schupak, 2011; Schupak & Rosenthal, 2009). Interestingly, an early case report was documented by Féré in his *La Pathologie des émotions* (1892/1899). M. M. was a 37-year-old commercial man, married and with children, who suffered from long periods of absent-mindedness. During these zone-outs, he was somewhat insulated from the surrounding environment or carried on his daily duties in a rather unconscious and mechanical way. Nevertheless, his daydreams were very structured and coherent, given that in his imaginary life "M. M. had constructed at Chaville on the borders of the wood, a pavilion surrounded by a garden. By successive additions the pavilion became a chateau, the garden a park; stables horses and pieces of water were introduced to ornament the domain. [. . .] A woman arrived to animate this scene: two children were born, it only remained to make this ideal ménage legitimate. This was the only drawback to the happiness of our dreamer" (Féré, 1892/1899, p. 316). Although this is an anecdotal report and does not represent the virtually unlimited variety of people's daydreams, the generation of vivid and emotionally salient, imaginary second lives recurs in recent reports of excessive daydreaming as well (Bigelsen & Schupak, 2011).

Importantly, recent accounts show that excessive daydreamers are fully aware that the persons depicted in their daydreams are fictional—there is no question here of delusion or other psychotic phenomena—and the range of the daydreamers' ability to function in real life may range from excellent to seriously impaired. These daydreamers appear to develop an attachment to their daydream sequences that makes it hard to abandon them. Attempts to suppress them may lead to a yearning, even grief over their loss. These daydreamers are variably accepting or distressed by their habitual daydreaming, especially if they perceive that the daydreams interfere with fully actualizing their potential in real-life goal attainment.

It is unclear to what extent unusual amounts of habitual fanciful daydreaming can be considered a particular psychological disorder. Certainly if it distresses or significantly handicaps the daydreamer and the daydreamer feels incapable of controlling it, it can at least be considered a condition that merits clinical intervention. However, its manifestations vary enough across daydreamers that there is no clear single psychopathology with which it can be classified. In some ways it qualifies as obsessive thought, but it seems distinct from that diagnosis in that, whereas its existence in this quantity distresses the daydreamer, the experience of it while it happens feels positively satisfying, and suppressing it leads to grief—a sense of loss of the daydreamed pseudo-reality—rather than to anxiety. It has addictive properties, but at this point there appears to be no research that establishes these. Addiction is a matter of warped decision-making, warped choices. In the case of addiction to substances such as alcohol, there are physical changes that skew decisions by overweighting the subjective value of the substance. It is unclear that daydreaming can instill the same changes. However, it is known that imagining perceptions or actions engages much of the brain's systems that would be engaged by actual perceptions and actions (Kosslyn, Thompson, & Alpert, 1997). Perhaps longer-term imagining of fictional individuals can foster emotional attachments in the same way that extended personal contacts can foster emotional attachments to actual others. Terminating the fictional relationship may then yield a goal-disengagement process (Klinger, 1975, 1977; Klinger & Cox, 2011a) somewhat similar to that produced by the loss of a valued real other person.

Rumination

Rumination is a form of repetitive self-focus that leads to and exacerbates depressive symptoms (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Spasojevic & Alloy, 2001). Rumination has been conceptualized in various ways, emphasizing either the trait or the context-dependent nature of rumination (Smith & Alloy, 2009). Moreover, various theories have provided different proposals on the main triggering events of rumination, which include negative mood as well as goal non-attainment (Smith & Alloy, 2009).

THE CURRENT CONCERNS APPROACH TO RUMINATION

The *goal theory of current concerns* described earlier (e.g., Klinger, 1977, 2013; Klinger & Cox, 2011a) is helpful in explaining many of the key features of rumination; that is, goal-related cues, presumably including those in one's own thought stream, carry varying degrees and kinds of emotional charge and receive processing priority. Thoughts with strongly emotional content would have a high likelihood of evoking associated subsequent thoughts. These are also likely to carry a similar valence of emotional charge (positive or negative). This process is apparent in, for example, people happily in love, where affect is predominantly positive, but also in people grieving over a rejection, loss, or significant failure, especially while they are disengaging from their seemingly doomed goal (Klinger, 1975, 1977; Klinger & Cox, 2011a), when affect is predominantly negative. The focused nature of the resulting streams of thought is precisely what we observe in rumination. Given the role of emotional response in this process, one would predict that individuals high in trait affectivity would be especially prone to fall into ruminative states. The frequently demonstrated high correlation between trait rumination and measures of negative affect supports this prediction (e.g., Watkins et al., 2015).

In support of the idea of narrowed cognitive processing of goal- and emotion-related cues, Grol, Hertel, Koster, and De Raedt (2015) instructed participants to imagine an emotionally wrenching scenario (having just run over people with one's car) and then either dwell on their negative feelings about it, or engage in problem-solving thinking. In a visuo-spatial task where participants needed to process self- versus non-self-related stimuli and detect targets in the periphery, participants high in trait rumination showed attentional narrowing toward personally relevant stimuli, with reduced retention of personally irrelevant peripheral stimuli. Given the close relationship between trait rumination and negative affectivity, it would appear that the strong negative emotions provoked by the ruminative instructions to focus on an emotionally devastating scenario led to thoughts responding repeatedly to ongoing emotionally charged stimuli, both internal (ideation) and external (self-referential experimental stimuli), thereby maintaining the narrow focus of rumination. This notion of difficulties in controlling attentional-processing priorities can be related to a large body of research on information processing and rumination, to which we now turn.

INDIVIDUAL DIFFERENCES AND IMPAIRED ATTENTIONAL DISENGAGEMENT THAT MODERATE COGNITIVE AND EMOTIONAL MECHANISMS IN RUMINATION

Nothing in the *current concerns* approach excludes other factors from operating in rumination, such as individual differences in attentional focus, inhibitory ability, or properties of working memory and executive control functions (e.g., Whitmer & Gotlib, 2013). On the one hand, *current concerns theory* describes mechanisms that govern the flow of spontaneous thoughts in general and indicates how these can operate to produce ruminative thought. Individual differences enter only insofar as different individuals are committed to different sets of goals and vary in the properties and strength of their emotional reactions. However, this formulation can be mapped onto theories that emphasize the cognitive processes related to rumination and that focus on the way in which certain emotionally salient thoughts receive cognitive processing priority. These theories are interesting to explain the persistence of rumination, despite efforts to control this process.

Key mechanisms for the cycling in rumination within a narrow content field have been proposed in a number of theories. Many of these theories emphasize individual differences in cognitive processing styles. For instance, *attentional focus theory* (Whitmer & Gotlib, 2013) provides a variable of individual differences in the degree to which individuals constrict their attention and thought content to particular cognitive themes after they are started. This constriction is enhanced in negative mood states and is weakened during positive moods. An individual's typical degree of constriction would moderate the likelihood that a negatively toned ruminative stream, once started, will continue.

Individual differences in emotional extrapolation, posited by Watkins, Grafton, Weinstein, and MacLeod (2015), refers to the likelihood that an initial mood state associated with some event, presumably including a thought segment, will persist to color expectancies for subsequent events. *Current concerns theory* also posits some degree of such emotional continuity, in that the thematic content of an emotionally potent, goal-related thought segment is predicted to lead by association to thematically and emotionally related (but not identical) subsequent thought segments. This hypothesized continuity is confirmed by findings of negative affect being maintained across mind-wandering segments (Stawarczyk, Majerus, & D'Argembeau, 2013). Watkins et al. (2015), moreover, theorize that the extent of such continuity constitutes a kind of individual trait. People high in emotional extrapolation would experience amplified emotional continuity. When the emotion is predominantly negative, as in trait negative affectivity (Tellegen et al., 1988), the trait would dispose toward greater likelihood of rumination.

The impaired disengagement factor posited by Koster, De Lissnyder, Derakshan, and De Raedt (2011) as a prominent route toward depression refers to impaired control of attention that weakens the individual's ability to switch from a stream of negative repetitive thoughts to something more constructive that might help to dispel the negative mood. Importantly for this formulation, Koster et al. (2011) propose that, with sufficient repetition and progressive impairment of attentional control, the resulting rumination becomes habitual, further hindering its interruption and redirection. This approach is, then, not primarily an individual-differences approach, but suggests a pathogenic extension of the thought-flow processes described earlier.

Thus, these important approaches identify different possible mechanisms responsible for individual differences in susceptibility to rumination by moderating the processes posited by *current concerns theory*, whose model assumes that, with a powerful enough emotional tone, any goal pursuit (or failed pursuit) can become the subject of repetitive thought by any individual. Such repetitive thought is tantamount to rumination, or may be so in the presence of certain additional qualities, depending on the definition of rumination.

Interesting empirical support for information-processing theories of rumination comes from studies that attempt to experimentally improve attentional or cognitive control where rumination and depressive symptoms are studied as outcome variables. For instance, in a recent study where individuals with heightened levels of rumination were allocated to either a cognitive control training versus an active control condition, it was observed that individuals undergoing cognitive control training for two weeks showed lower emotional reactivity to a lab stressor as well as lowered levels of depressogenic rumination during a subsequent exam period (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015).

RESPONSE STYLES AND CONTROL THEORIES OF RUMINATION

The most influential theory of rumination is currently still the *response styles theory* (RST), which defines rumination as "behaviors and thoughts that focus one's attention on one's depressive symptoms and on the implications of those symptoms" (Nolen-Hoeksema 1991, p. 569). According to this theory, individuals react to negative mood by initiating ruminative processing with the aim of enhancing their self-understanding, which unfortunately leads to a paradoxical increase in negative mood (Lyubomirsky & Nolen-Hoeksema, 1995). Within the RST, two specific ruminative subtypes have been defined and are worth mentioning: reflective pondering and depressive brooding (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Reflective pondering is considered the less maladaptive form of rumination, as it reflects the extent to which individuals try to improve their mood by engaging in problem-focused thinking. Brooding is considered the more detrimental form of rumination, as it represents "a passive comparison of one's current situation with some unachieved standard" (Treynor et al., 2003, p. 256).

Importantly, Martin and Tesser, consistent with earlier current-concerns theory and evidence regarding depression (Klinger, 1975, 1977; Klinger, Barta, & Maxeiner, 1980), proposed a *control theory* account of rumination. This theory proposes that, as in the earlier current-concerns account of depression, state rumination is initiated by, and focuses on, a perceived discrepancy between one's goals and one's current state and continues until the goal is either attained or abandoned (Martin & Tesser, 1989, 1996). Compared with RST, this account is focused less on depressed mood but can be applied more broadly to a wide range of circumstances. Interestingly, it has been found that cuing unresolved personal goals indeed was associated with an increased number of negative ruminative thought intrusions during a sustained attention-to-response task, compared with cuing a resolved personal goal (Roberts, Watkins, & Wills, 2013).

In an attempt to link the RST and the control theory of rumination, Watkins and Nolen-Hoeksema (2014) proposed that rumination can be conceptualized as a mental habit (Hertel, 2004) that starts with episodes of self-focused repetitive thought, triggered by goal discrepancies, which become habitual through an automatic associative process between repetitive thinking and its context (e.g., physical location, mood). When, over time, these contexts trigger a passive focus on negative content combined with low levels of concrete thinking (see Watkins, 2008), the habit of depressive rumination is acquired. The latter type of habitual rumination is thought to be context-independent of goals and resistant to change.

RUMINATION AND SPONTANEOUS THOUGHTS

Given the relevance of goals and mental habits in spontaneous thoughts, one might suspect a rather large overlap between ruminative thinking and daydreaming. However, correlational studies clearly report only moderate correlations (Epel et al., 2013; Marchetti, Van de Putte, & Koster, 2014). One explanation for this is that the term *daydreaming* is often used to refer specifically to fanciful mental streams, whereas *rumination* is generally serious and uncreative. In these senses, daydreaming and rumination are by no means the same phenomenon, even though both can usually be construed as instances of mind-wandering, and both are generally instances of spontaneous thought. In a new integrative framework aiming to understand the link between spontaneous thought and cognitive risk factors, Marchetti, Koster, Klinger, and Alloy (2016) propose that spontaneous thought, defined most broadly, can act as a context in which cognitive risk factors for depression such as rumination (but also thoughts of hopelessness, negative self-esteem, and cognitive reactivity) can be readily expressed, which is especially the case in conditions of heightened negative affectivity. In that sense, rumination is a specific subtype of spontaneous thought characterized by dominant negative thought content that is processed in an abstract and repetitive way so as to lock the train of thoughts into a thematically narrow content channel (Klinger, 2013; Watkins, 2008). Here it is important to note that this differs from many other instances in which spontaneous thought unfolds in an open, expansive, and divergent way (Marchetti et al., 2014; Watkins, 2010).

An interesting finding in this regard is empirical evidence showing that the affective consequences of spontaneous thought are multifactorially determined, based on the presence of individual-difference variables that heighten the susceptibility to engaging in state rumination (Marchetti, Koster, & De Raedt, 2013). More specifically, rest-related spontaneous thoughts seem capable of shaping transitory ruminative thoughts in individuals showing, primarily, medium to high levels of trait cognitive reactivity and, secondarily, significant trait levels of ruminative brooding.

Clinical Implications

Traditionally, clinical interventions have targeted only selective kinds of spontaneous thought, such as maladaptive aspects of daydreaming and rumination, which show partial overlap with spontaneous thought (Marchetti et al., 2016; Watkins, 2010). However, examining the content and, perhaps, frequency of spontaneous thought in general could have some interesting clinical implications that are worthy of further examination.

Spontaneous Thought as Ancillary Information About Motivational Structure

Broadly speaking and in keeping with a transdiagnostic approach, psychopathology is often characterized and maintained by problematic goals architecture. This can take a number of different forms. First, psychopathology, such as anxiety and depression, is frequently characterized by strong avoidance-related goals (see Hayes, Wilson, Gifford, Follette, & Strosahl, 1996), often based on negative experiences and avoiding danger, rejection, or hurt. This has important consequences for the cognitive processing of situations. For instance, for someone with social anxiety and the goal to avoid rejection by others, a social situation may cue attention to social threat and the context-specific means to reach safety (e.g., excuses to leave a gathering early), which can impair new learning and maintain threat-related beliefs. Frequently, such avoidance-related goals outweigh other more positively oriented goals so as to render individuals less likely to process positive information and/or actively pursue desired outcomes.

Given the dependence of spontaneous thought content on an individual's goals, these processes can be predicted to determine the content of the individual's thought flow. Although cognitive therapies try to change clients' beliefs and mental habits as a way to change behavior, it is ultimately the client's behavior and affect that the therapy tries to influence. Insofar as spontaneous thought content is itself troublesome, these procedures have some merit, but altering a client's pattern of goal pursuits—the client's *motivational structure*—can also predictably contribute to changed cognitive processing and spontaneous thought flow. Thus, one strategy for changing troublesome spontaneous thought flow is to change the motivational structure—the individual's set of goals—that largely determines its content and frequency.

Psychopathology can also be rooted in negative life events where individuals see important goals blocked (Klinger, 1975, 1977; Klinger et al., 1980). Here it is crucial for individuals to be capable of disengaging from unattainable goals and to reorient and engage with goals that are more attainable. For various reasons (e.g., perfectionism, high standards, high valuation of the goal, lack of promising alternative goals, etc.) individuals can experience problems with disengaging from desired but unattainable goals or engaging with new goals. These states powerfully impact spontaneous thought content and affect.

Based on our theoretical position that the content of spontaneous thought has important links to each individual's goals, this content (such as mind-wandering, which is pervasive and often adaptive, but may sometimes be viewed as interfering and disruptive) can in the therapeutic context be used in multiple ways, for instance as diagnostic information to aid in obtaining a clear view of the client's goal structure. The content of spontaneous thought and, probably, night dreams can signify or help to clarify individuals' motivational and cognitive structure (Beck, 1971/2004; Klinger, 1971). There are validated measures of goal structure in questionnaire form, such as the Motivational Structure Questionnaire and Personal Concerns Inventory (Cox & Klinger, 2011a; Klinger, 1987; Klinger & Cox, 2011b), but these rely on clients' memories and self-insights. Inferences from examination of clients' spontaneous thought content may add important information.

Modifying Spontaneous Thought Content by Modifying Motivational Structure

Assessing motivational structure is important for treatment of a wide variety of conditions, perhaps especially, but not exclusively, depression, addiction, alienation, aimlessness, and goal conflicts. These may require interventions aiming to replace maladaptive motivational structures with more adaptive ones. For instance, within the Systematic Motivational Counseling framework, validated techniques have been developed to identify maladaptive goals and then help clients disengage from them in favor of more realistic and attainable goals (Cox & Klinger, 2011b). The efficacy of this type of intervention that focuses on clients' motivational structure, rather than solely on cognitive and/or behavioral aspects, has recently been documented in alcoholic patients (Cox, Fadardi, Hosier, & Pothos, 2015), miscellaneous substance abusers with traumatic brain injuries (Cox et al., 2003), and group treatment in a general clinical population (Fuhrmann, Schroer, & de Jong-Meyer, 2011).

The general plan of these interventions is first to assess motivational structure (the types of goals chosen, the degree of commitment to and valuation of each, and expectancies of success) and then to discuss the findings with regard to such matters as the interrelationships among the goals, the degree to which the valuation is the client's own versus someone else's whom the client is trying to satisfy, the reasonableness of the expectancies, conflicts among the goals and possible resolution of them, shifting from aversive to appetitive goal pursuits, disengagement from inappropriate or fruitless goals, possible additional or alternative goals that fit the client's own true values and might provide greater satisfaction, and realistic steps that might render discouragingly difficult goals attainable. The goal of these interventions is, of course, a more adaptive motivational structure, which should brighten mood and help clients abandon destructive behaviors such as substance abuse. In addition to the already cited studies supporting this hypothesis, higher adaptive motivational structure has been found related to lower alcohol consumption in people whose consumption has led to objective life difficulties, such as in the workplace, family and other social relationships, the legal system, health, and so on (Cox et al., 2002). In clients with low scores on adaptive motivational structure, there was no correlation between difficulties incurred from drinking and amount consumed. Although this result was correlational and hence does not permit a firm conclusion about causality, it seems a reasonable inference that highly adaptive motivational structure facilitates reducing injurious alcohol consumption. Although these investigations did not assess spontaneous thought content, their interventions can be predicted to have changed it as well.

As indicated earlier, goal commitments establish cognitive processing priorities that direct attention to goal-related cues. This can become problematic for a variety of conditions and has been investigated with substance abusers. In much of the world, for example, grocery stores sell alcoholic beverages and often place these in locations that are hard to overlook. Heavy imbibers report that these displays rivet their attention and, even if they are trying to reduce alcohol use, nevertheless make it harder not to buy. Similarly, when faced with a series of words, the attention of heavy drinkers is drawn to words associated with alcohol use (as to other important goals). One clinical intervention has been designed to reduce this problem by retraining attention. Using Stroop-like interventions, participants adopt the goal of attending to the font color instead of to the semantic meaning of alcohol-related words, or to the color outlines around various depicted bottles. The administrator provides feedback and encouragement. Results show that a series of such training sessions reduces the processing priority of alcohol cues and reduces the amount of alcohol subsequently consumed for up to a three-month follow-up assessment (Cox et al., 2015; Fadardi & Cox, 2009). Although these investigations are still in their early stages (Koster & Bernstein, 2015) and so far have not assessed spontaneous thought, the effect on attentiveness—as one kind of cognitive processing—can be predicted to have also affected thought content, among other clinical outcomes.

Training for Concrete Versus Abstract Thought for Facing Difficulties and Mental Contrasting for Goal Attainment

Another topic, which has been raised in the context of rumination by Watkins, is that the specificity of thought can be important in determining whether thinking has beneficial or detrimental consequences. The work by Watkins (e.g., 2008, 2010) has shown that abstract versus more concrete thought can be problematic in maintaining negative affect. Often, sufficiently concrete cognitive processing is necessary to facilitate adaptive thought and behavior (e.g., planning, problem-solving). Excessive levels of abstract negative (and probably also positive) spontaneous thinking can undermine concrete steps toward a goal. Similarly, although expectancy of ultimate success is important for well-motivated behavior, fantasizing only about positive outcomes and trouble-free goal-pursuit, rather than thinking about the concrete realities necessary for success, reduces chances of energetic pursuit and of success (Oettingen, 2012). To address these aspects, promising training interventions have been developed to rebalance the proportion and occurrence of abstract versus concrete thought (Watkins et al., 2012) and to tie aspirations to concrete processing of steps necessary to achieve them (Oettingen, 2012), processes that at first almost certainly enlist mental activity beyond that of purely spontaneous thought and the default mode network (Achtziger, Fehr, Oettingen, Gollwitzer, & Rockstroh, 2009). Whether the habits of thought developed in these trainings eventually become spontaneous remains to be established.

Conclusions

Spontaneous thought is a phenomenon that is of long-standing interest to researchers. We have reviewed some of the research showing the clear adaptive as well as maladaptive consequences of this phenomenon. Based on a goal perspective, it becomes clear why spontaneous thought is so pervasively present in mental life. Moreover, this perspective also casts light on how spontaneous thought can become maladaptive. The progress with regard to methodologies available to study this phenomenon, as well as the strong interest in spontaneous thought from philosophical, psychological, and biological traditions, renders this field an exciting area for integrated research and theory.

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CHAPTER

18

Unraveling What's on Our Minds: How Different Types of Mind-Wandering Affect Cognition and Behavior

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Abstract

Mind-wandering encompasses a variety of different types of thought, involving various different experiential qualities, emotions, and cognitive processes. Much is lost by simply lumping them together, as is typically done in the literature. The goal of this chapter is to explore the nuances that distinguish different types of mind-wandering. The chapter draws on research on mind-wandering as well as other literatures to gain a better understanding of how these different types of mind-wandering affect cognition and behavior. It specifically discusses the distinct effects of different types of mind-wandering on task performance, working memory, mood, and creativity. Finally, the chapter discusses the idea of deliberate engagement in particular types of mind-wandering as a way to achieve desirable outcomes, such as maintaining a positive mood, enhancing creativity, or aiding decision-making.

Key Words: mind-wandering, cognition, behavior, creativity, working memory, decision-making

The stream of consciousness is a stream with many twists and turns. Even though our sense organs continuously process information about the outside world, much of the time our minds ignore this input and focus instead on spontaneous thoughts unrelated to our current task or environment. When mental activity becomes decoupled from the environment in this way, the processing of external information is reduced, sometimes to the point where our eyes mindlessly scan what's in front of us without making much sense of the information (Schooler et al., 2011; Smallwood, Beach, Schooler, & Handy, 2008; Smallwood, Brown, et al., 2011).

This phenomenon has been studied under a variety of terms, the most prominent ones being *mind-wandering* and *daydreaming* (e.g., Singer & Schonbar, 1961; Smallwood & Schooler, 2006). In the literature, these terms have typically been used interchangeably. Mind-wandering has sometimes been defined as task-unrelated thought (e.g., Smallwood & Schooler, 2006), stimulus-unrelated thought (e.g., Teasdale et al., 1995), or spontaneous thought (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). Moreover, in colloquial language, the terms *mind-wandering* and *daydreaming* are sometimes applied to situations in which one is thinking about something other than one's primary task (e.g., reading or listening to a lecture), but also to describe periods when one is engaged in no extrinsic task whatsoever and is simply staring out into space. Admittedly there is a fine line between engaging in a non-demanding task (e.g., walking) and doing "nothing," so the distinction between task-unrelated thought and stimulus-unrelated thought is somewhat blurry. In the present chapter, we will therefore use the term *mind-wandering* to encompass a heterogeneous phenomenon (see Seli et al., in preparation), in line with colloquial usage, and the term *task-unrelated thought* when referring specifically to situations in which mind-wandering occurs during another primary task or activity.

Over the last decades, researchers have made considerable progress at uncovering when and how much people mind-wander (Giambra, 1989; Kane et al., 2007; Killingsworth & Gilbert, 2010; McVay, Kane, & Kwapil, 2009; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2011), why they do so (McVay & Kane, 2009; McVay & Kane, 2010; Smallwood, 2010), what parts of the brain are involved in it (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Mason et al., 2007; Smith et al., 2006; Smallwood et al., 2008), and how mind-wandering affects cognition and behavior (see Mooneyham & Schooler, 2013, for a review). However, the question of "where" our spontaneous thoughts go when they wander off task has received considerably less attention. Mind-wandering is usually defined in the broadest sense, encompassing all types of spontaneous, task-unrelated thought: the banal, fleeting thoughts, complex problem-oriented reflections, fantasies, or intrusive thoughts and worries. But these various types of thought have such different experiential qualities, and involve such different emotions and cognitive processes, that we may lose much by simply lumping them together, as is typically done in the literature. Accordingly, we suggest that systematic analysis of the nature and impact of different types of mind-wandering may help to clarify the nuanced role that different types of mind-wandering play in our daily lives. The goal of this chapter is to explore these distinctions and nuances.

The chapter will draw on research on mind-wandering as well as other literatures that examine different aspects of "thinking" (be it task-related or unrelated, spontaneous, or instructed) more generally. We aim to illustrate how combining these literatures helps us gain a better understanding of how different types of spontaneous thought affect cognition and behavior. Finally, we discuss the idea of deliberate engagement in particular types of mind-wandering as a way to achieve desirable outcomes, such as maintaining a positive mood, enhancing creativity, or aiding decision-making.

Measuring Spontaneous Thought and Discerning Types of Mind-Wandering

Mind-wandering poses a dual challenge to scientific investigation. It is spontaneous, and thus cannot be experimentally induced (although experimental manipulations can decrease or increase the *likelihood* of spontaneous stimulus-unrelated thoughts), and it is subjective, meaning that it cannot be directly observed from the outside. Because we cannot directly observe people's private thoughts, mind-wandering is typically measured through indirect measures, such as errors made on tasks, or through self-report measures.

A frequently used technique to gather self-reports other than through traditional questionnaires is to intermittently probe people about the current content of their thoughts, or simply whether they are mind-wandering or not at a particular moment during a task. By sampling enough of such moments, a technique called "thought sampling" or "experience sampling" (e.g., Antrobus, 1968; Giambra, 1995; Kane et al., 2007; Killingsworth & Gilbert, 2010; Schooler, Reichle, & Halpern, 2004; Parks, Klinger, & Perlmutter, 1998), researchers can get an idea of how often and when people mind-wander and how it affects their cognition and behavior. Another way to assess instances of mind-wandering is by asking participants to "self-catch" their task-unrelated thoughts. This, naturally, requires that they be aware of their task-unrelated thoughts, and is often used as an additional measure in combination with probe-initiated self-reports. These types of measures are used to test the effects of mind-wandering at the state level, by examining the direct consequences of stimulus-independent or off-task thought on subsequent performance, or at the trait level, by correlating individuals' general tendency to mind-wander with other measures.

Although researchers routinely treat mind-wandering as a single undifferentiated construct, some attempts have been made at assessing variations in the content and quality of people's daydreams or mind-wandering episodes. For instance, it has been shown that thoughts about mundane, everyday things are more common than fantasies or worries (Kane et al., 2007; Klinger, 2009, 2013; Klinger & Cox, 1987), thoughts about pleasant topics are more common than negative thoughts (Killingsworth & Gilbert, 2010), and thoughts related to the future are more common than thoughts about the past or present (Baird, Smallwood, & Schooler, 2011; Smallwood, Nind, & O'Connor, 2009). Other content distinctions have distinguished between thoughts about the self and thoughts involving other people (Poerio, Totterdell, Emerson, & Miles, 2015; Ruby, Smallwood, Engen, & Singer, 2013).

Aside from such distinctions in thought content, other qualitative distinctions have been made. For instance, research has made a distinction between task-unrelated thoughts that occur without meta-awareness, that is, without the person consciously noticing that her mind has disengaged from the task or environment, and task-unrelated thoughts that the individuals is aware of (e.g., self-caught mind-wandering)—a distinction that is also referred to as "zoning out" versus "tuning out" (e.g., Dorsch, 2014; Forster & Lavie, 2009; Schooler, 2002; Schooler, Mrazek, Baird, & Winkielman, 2014; Schooler, Reichele, & Halpern, 2004; Schooler & Schreiber, 2004; Schooler et al., 2011; Seli, Carriere, & Smilek, 2014; Smith et al., 2006). A related distinction is that between intentional and unintentional mind-wandering (Dorsch, 2014; Forster & Lavie, 2009; McMillan, Kaufman, & Singer, 2013; Seli, Carriere, & Smilek, 2014). We speculate that that this distinction may, under most circumstances, map directly onto that of mind-wandering with and without meta-awareness, although it is possible that one *becomes* aware of having daydreamed without having had the intention to. Once a person has become meta-aware of this fact, however, we think that he or she will most likely either stop mind-wandering or decide to continue, at which point it becomes intentional.

Variations of kinds of daydreaming have also been assessed at the trait level, by examining differences in people's characterizations of the general topics they tend to daydream about. This research, spearheaded by Singer and colleagues (e.g., Huba, Aneshensel, & Singer, 1981; Singer & Antrobus, 1961, 1963, 1970) and later Giambra (1980, 1989, 1995), led to the identification of three broad "styles of daydreaming": (1) *positive-constructive daydreaming*, which is characterized by predominantly pleasant and highly captivating daydreams that contain vivid imagery, interpersonal curiosity, and future planning; (2) *guilty-dysphoric daydreaming*, which is characterized by ruminative thoughts and unpleasant emotions such as shame and guilt, fear of failure, and thoughts of aggressive impulses; and finally (3) *poor attentional control*, which is characterized by highly frequent yet fleeting daydreams and a general difficulty in focusing one's attention, be it on internal or external events (Singer & Antrobus, 1963, 1970; Singer, 1974). Little research has been done to relate these particular styles of mind-wandering to consequences for cognition and behavior. However, we can draw on other literatures that have examined the effects of related traits, such as the tendencies toward engaging in mood repair or engaging in ruminative thought. In the following discussion, we review a number of findings from the mind-wandering literature and discuss for each of these findings how a closer look at different types of mind-wandering leads to more nuanced theories and predictions.

How Types of Mind-Wandering Affect Task Performance

The most well-established finding from the mind-wandering literature, and probably the one that is the most self-evident from personal experience, is that mind-wandering during a task interferes with task performance. This has been demonstrated for a broad range of tasks, including relatively simple and monotonous tasks requiring sustained attention (e.g., Carriere, Cheyne, & Smilek, 2008; Cheyne, Solman, Carriere, & Smilek, 2009; Mrazek, Smallwood, & Schooler, 2012; Seli, Cheyne, & Smilek, 2013; Smallwood et al., 2004; Smilek, Carriere, & Cheyne, 2010), working memory and intelligence tasks (e.g., Mrazek et al., 2012), reading (e.g., Franklin, Smallwood, & Schooler, 2011; Schad, Nuthmann, & Engbert, 2012; Schooler, Reichle, & Halpern, 2004; Smallwood, McSpadden, & Schooler, 2008; Smallwood et al., 2008; Smallwood, 2011), and performing more complex tasks such as driving or operating aircraft (Casner & Schooler, 2013; Galéra et al., 2012; Yanko & Spalek, 2013).

But is this universally true for all types of task-unrelated thoughts? Evidence suggests that it is not. One line of evidence comes from research distinguishing task-unrelated thoughts occurring with or without meta-awareness. It has been suggested that, while people are aware of only a small proportion of their spontaneous task-unrelated thoughts (e.g., Schooler, Reichle, & Halpern, 2004), meta-awareness may play a crucial role for regulating those thoughts (e.g., Schooler, 2002). Regulation could mean stopping the train of thought and refocusing attention back on one's main task, or engaging in task-unrelated thoughts only at times when this is minimally disruptive or even adaptive.

Support for the notion that meta-awareness plays a role in the regulation of task-unrelated thoughts comes from studies showing that under conditions associated with reduced executive control, such as alcohol intoxication (Sayette, Reichle, & Schooler, 2009) or cigarette craving (Sayette, Schooler, & Reichle, 2010), task-unrelated thoughts are increased, while meta-awareness is reduced. In contrast, meta-awareness seems to increase when individuals are motivated to catch their task-unrelated thoughts (Zedelius, Broadway, & Schooler, 2015). Finally, and most relevant to the relationship between types of mind-wandering and performance, studies have found that task-unrelated thoughts that occur with meta-awareness have less of an impact on task performance than those that occur without meta-awareness (Smallwood, McSpadden, & Schooler, 2007, 2008; Zedelius et al., 2015).

A related factor that may moderate the relationship between mind-wandering and performance is intentionality. It is likely that differences between intentional and unintentional mind-wandering will often map onto differences between mind-wandering with or without meta-awareness. After all, carrying out an "intention" implies awareness (although see Custers & Aarts, 2010), and it is hard to imagine that a person could mind-wander unintentionally while being aware of the fact that he or she is mind-wandering. Thus, in line with the findings on meta-awareness and mind-wandering, it is likely that intentional mind-wandering episodes are more adapted to the demands of the current context (i.e., occurring predominantly when task demands are low), and hence are less disruptive to performance, than unintentional (unaware) mind-wandering episodes (see Wammes, Seli, & Smilek, Chapter 20 in this volume). There is evidence that people mind-wander at "opportune" moments, that is, during relatively easy tasks, more than during demanding tasks (e.g., Casner & Schooler, 2013; Kane et al., 2007; Levinson, Smallwood, & Davidson, 2012). It is not clear that this difference is uniquely driven by intentional mind-wandering, but this would be a plausible hypothesis that deserves further investigation.

The distinctions between aware/unaware and intentional/unintentional mind-wandering may go hand in hand with differences in thought content. That is, although to our knowledge this issue has never been explicitly investigated, we would expect deliberate mind-wandering to resemble the type of mind-wandering Singer and colleagues termed *positive-constructive daydreaming*, and unintentional mind-wandering to be more likely to involve intrusive, negative thought content—fitting the *guilty-dysphoric daydreaming* style. This prediction is based on the premise that we prefer to engage in thoughts we find agreeable, and we are more likely to exert control over our thoughts when we are mind-wandering deliberately and/or with awareness. This possibility warrants further investigation and if supported by empirical evidence would illustrate the potentially important ways in which different forms of mind-wandering foster different types of thought content.

How Types of Mind-Wandering Relate to Working Memory

Research suggests that individuals with larger working memory capacity typically mind-wander less during demanding tasks (McVay & Kane, 2009, 2012a, 2012b; Mrazek et al., 2012; Unsworth, Brewer, & Spillers, 2012; Unsworth & McMillan, 2014; Unsworth, McMillan, Brewer, & Spillers, 2012) and engage in more opportune mind-wandering (e.g., Levinson et al., 2012; Rummel & Boywitt, 2014) than those with smaller working memory capacity. This suggests that executive processes that rely on working memory are involved in the ability to regulate or suppress unwanted task-unrelated thoughts at inopportune moments. However, considering that individuals likely find some types of thoughts worth suppressing more than others, does the relationship between working memory and mind-wandering differ depending on the types of mind-wandering people engage in?

This question was investigated in a recent experience sampling study by Marcusson-Clavertz, Cardeña, and Terhune (2015). They found that, for individuals who tend to engage most often in the kind of intrusive, negative mind-wandering described by the *guilty-dysphoric* style, greater working memory capacity was related to reduced mind-wandering during everyday tasks, indicating successful suppression of unwanted task-unrelated thoughts. For individuals who rarely engaged in the *guilty-dysphoric* style, and for whom task-unrelated thoughts are a much more pleasant experience, the opposite was found. This finding nicely illustrates that mind-wandering is not a homogenous construct, and that different types of mind-wandering need to be understood in relation to individuals' interests and motivations to engage in or avoid certain mental events.

Other research on the relationship between working memory and mind-wandering has focused more on the functions that different types of mind-wandering can fulfill. Building on the notion that future-thought is essential for planning and attaining personal goals, and that mentally simulating possible futures is more complex than recalling the past, Baird, Smallwood, and Schooler (2011) expected that working memory capacity would be differentially related to how much people mind-wander about the past, present, and future. Participants performed a relatively non-demanding task, interspersed with thought-probes that prompted them to describe their task-unrelated thoughts. The results confirmed the prediction. While working memory capacity was unrelated to task-unrelated thoughts about past events, and negatively related to task-unrelated thoughts about the present, higher working memory capacity predicted increased task-unrelated thoughts about future events. These findings, again, illustrate the importance of taking a nuanced approach to understanding the processes involved in different types of mind-wandering and the functions they fulfill for the individual.

How Types of Mind-Wandering Affect Mood

Another key finding in the mind-wandering literature is that compared to being focused on one's current activity, mind-wandering is generally associated with negative mood. For instance, Killingsworth and Gilbert (2010) conducted a large-scale experience-sampling study in which participants were probed randomly several times during their day while going about their everyday life activities, and were asked to report what they were doing at the time of the probe, whether they were focused on their present moment activity or engaged in task-unrelated thoughts, and what mood they were in. The results showed that task-unrelated thoughts were almost exclusively associated with a more negative mood than being focused on the present, regardless of the type of activity participants were engaging in. The negative effect on mood was pronounced when participants reported negative or neutral thoughts, and even when they reported positive task-unrelated thoughts their mood was no better than at times when they were focused on their present-moment activity.

More recent studies, however, indicate that, contrary to Killingsworth and Gilbert's claim that "a wandering mind is an unhappy mind," on some occasions people are happier when their minds are in the clouds. This positive relationship between mind-wandering and happiness is only revealed, however, when differentiating between different types of mind-wandering. For instance, a study by Franklin and colleagues (2013), which used a similar approach to Killingsworth and Gilbert but asked more nuanced questions about positive aspects of people's task-unrelated thoughts (i.e., how interesting, useful, or novel their thoughts were), indicated that task-unrelated thoughts that are experienced as highly interesting in fact led to a more positive mood, a finding that corroborates our common experience. Another study taking the same basic approach found that task-unrelated thoughts with social content and particularly those involving close others are associated with increased happiness (Poerio et al., 2015).

Research conducted in the laboratory found corroborating evidence that mind-wandering doesn't always lead to negative moods. Ruby, Smallwood, Engen, and Singer (2013) measured task-unrelated thoughts during a simple computer task, assessing the valence and content (i.e., self- vs. other-related, past- vs. future-related) of off-task thoughts as well as participants' current mood. They then performed a lag analysis in which they used answers to any given thought probe to predict a participant's mood at the time of the following probe. The results showed that task-unrelated thoughts about the past and involving other people were linked to decreases in mood, but task-unrelated thoughts about the future and about the self were linked to increased positive mood. Moreover, they also found that reports of task-unrelated thoughts in combination with negative mood were predictive of a more positive mood at the time of the next thought probe. This last finding suggests that, while task-unrelated thoughts may often coincide with negative moods, this may not necessarily mean that mind-wandering causes negative moods. Instead, mind-wandering might be a way to repair negative moods.

Yet another study examined the effects of mind-wandering on mood when taking into account the valence of the activity individuals are engaged in while mind-wandering, based on the premise that mind-wandering can be a pleasant escape from boring or negative tasks. Indeed, the results showed that, during an unpleasant task, engaging in positive task-unrelated thoughts was associated with increased positive mood (Spronken, Dijksterhuis, Holland, & Figner, 2015), a finding that is consistent with the mood-repair hypothesis. Drawing on these findings, we theorize that the effects of mind-wandering on mood are likely also dependent on whether the mind-wandering is intentional or unintentional. Given that most people are motivated to maintain a positive mood, and to engage in mood repair when experiencing negative mood (Cialdini et al., 1987; Salovey et al., 1995), we think that deliberate mind-wandering can be a way to elevate one's mood by directing one's attention in a goal-directed way to pleasant or interesting thoughts. This may not be universally true. Chronic ruminators, for instance, who have a habit of engaging in repetitive, self-referential, and typically negative thought (Feldman, Joorman, & Johnson, 2008; Verhaeghen, Khan, & Joormann, 2005; Whitmer & Gotlib, 2013), sometimes report ruminating deliberately, because they believe it will lead them to new and helpful insights about themselves (e.g., Lyubomirsky & Nolen-Hoeksema, 1993; Papageorgiou & Wells, 2003; Smallwood et al., 2003; Simpson, & Papageorgiou, 2003). For the majority of people, however, we expect that deliberate mind-wandering, be it during another primary task or while doing nothing, will be more positive or constructive. In future research, individual differences in people's motives and ruminative tendencies should be taken into account to gain a more complete picture of the effects of mind-wandering on mood.

How Types of Mind-Wandering Affect Creativity

While most research on mind-wandering has focused on demonstrating negative effects of task-unrelated thoughts, researchers have increasingly been considering the possibility that mind-wandering may at times be functional and constructive. Both in and outside the scientific community, it has long been speculated that mind-wandering may have a unique benefit for creativity. Countless anecdotes describe how creative ideas and sudden insights have emerged to artists and inventors from spontaneous mind-wandering. Early studies had found that, when people work on creative problems, taking a break and engaging in some other, unrelated task often improves subsequent creative thought, a phenomenon referred to as *incubation* (for a review, see Sio & Ormerod, 2009). Some have attributed this effect to spontaneous associative thoughts, which are seen as the route to creative insights, or "aha!" experiences (Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Bowers, Regehr, Balthazard, & Parker, 1990; Fiore & Schooler, 2001; Mednick, 1962; Schooler & Melcher, 1995). Thus, implicitly, the effect has been linked to mind-wandering.

Building on this indirect evidence, Baird and colleagues (2012) tested the effect of task-unrelated thoughts on creative performance. In their study, participants performed a creative task—generating unusual uses for common objects—and were interrupted midway through the task to perform an unrelated "incubation" task. This incubation task was either an undemanding task, which left plenty of room for engaging in task-unrelated thoughts, or a more demanding task. Participants assigned to perform the undemanding task (compared to a demanding task) subsequently generated more, and more unique, uses. (They also reported greater task-unrelated thoughts during the incubation task.) Importantly, the increase in creative performance was specific to uses for objects encountered before the incubation period and did not extend to novel objects not encountered before. This suggests that letting the mind wander freely away from the task had a transformative impact on participants' mental representations of task-relevant information.

There is also evidence that mind-wandering at the trait level is associated with increased creativity. For instance, a greater self-reported tendency toward mind-wandering during everyday life activities was found to be associated with increased creative performance on the unusual uses task (Baird et al., 2012) and more self-reported engagement in creative activities (Baas, 2015). Moreover, individuals scoring high in fantasy proneness, defined as a tendency toward long and intense involvement in fantasy and imagination (Lynn & Rhue, 1988; Singer & Antrobus, 1972; Singer, 1975), have been found to be more creative than less fantasy-prone individuals (Lynn & Rhue, 1986). Finally, field research assessing mind-wandering and creative ideation in professional creative writers and elite physicists has shown that many real-life creative ideas indeed emerged in moments when the participants were not actively working on the project or topic the ideas related to, but instead were engaged in other activities (Gable, Hopper, & Schooler, 2017). This finding suggests that engaging in activities and presumably thoughts unrelated to a current project can provide fertile ground for sudden creative insights.

While these findings resonate with the many anecdotal accounts of sudden creative insights in mind-wandering, they appear surprising in the face of the mundane mind-wandering people engage in much of the time, which revolves mainly around current concerns (e.g., Baird et al., 2011; D'Argembeau, Renaud, & Van der Linden, 2011; Klinger, 2009; Klinger, 2013; Klinger & Cox, 1987; Poerio et al., 2015; Smallwood, Nind, & O'Connor, 2009). This type of mind-wandering isn't necessarily creative in nature, and doesn't seem particularly inspiring. In an attempt to resolve this apparent inconsistency, we have argued that mind-wandering can be—but isn't necessarily—facilitative of creativity, and that the relationship depends on the type of task-unrelated thought and the type of creative process a person engages in.

Creative ideas or solutions can be achieved in different ways. Sometimes, an idea or solution comes to mind spontaneously, in a "flash of insight," accompanied by an "aha!" experience

(Bowden et al., 2005). Alternatively, creative problems can be approached in an analytic fashion, through methodic, conscious thought (Smith & Kounios, 1996). In a recent study, we found that mind-wandering relates differently to these two creative processes (Zedelius & Schooler, 2015a). While the tendency to mind-wander frequently during everyday life predicted better performance on a verbal creative problem-solving task overall, this was driven by a benefit for creative insight. Frequent mind-wandering was negatively related to solving creative problems analytically.

Just as the relationship between mind-wandering and creativity seems to depend on the type of creative approach, we proposed that the relationship also depends on the content and style of mind-wandering one engages in (Zedelius & Schooler, 2015b). One important aspect of mind-wandering likely to moderate its impact on creativity is affective valence. Research suggests that positive affect as well as approach-oriented affective states (e.g., joy, but also anger, compared to avoidance-oriented states such as fear, tranquility, and contentment) enhance creative thinking (e.g., Greene & Noice, 1988; Isen, 1990; Isen, Daubman, & Nowicki, 1987; for a review, see Baas, De Dreu, & Nijstad, 2008). One of the reasons why these mood states are theorized to facilitate creativity is that positive mood and approach-oriented emotions are associated with a broadening of the focus of attention, which facilitates cognitive flexibility, or "thinking outside the box" (e.g., Ashby, Isen, & Turken; 1999; Kasof, 1997; Rowe, Hirsch, & Anderson, 2007).

Based on this literature, we expect that types of mind-wandering that are associated with positive affect and approach-oriented emotions should facilitate creativity. The first indirect evidence for this idea has come from a study by Zhiyan and Singer (1996), which showed that the positive-constructive daydreaming style, which is characterized by positive thoughts, is related to openness to experience, a personality trait that has been associated with creativity. However, this research does not directly examine whether there is a direct link between positive and/or approach-oriented task-unrelated thoughts and the facilitation of creative ideation. Moreover, this research does not distinguish between the affective-experiential aspects (i.e., positive mood or affect), and motivational components of mind-wandering, which may each facilitate creativity. In a recent study (Zedelius, Protzko, & Schooler, 2016) in which we assessed various different daydreaming styles, we distinguished between daydreaming that can be characterized as happy or pleasant (e.g., "My daydreams provide me with pleasant thoughts"), which is an aspect of Singer and Antrobus's (1963, 1970) positive constructive daydreaming, and daydreaming that is characterized as personally meaningful (e.g., "I daydream about things that are of great value or importance to me"; see Andrews-Hanna et al., 2013, for a similar treatment of these different aspects). We found that, whereas a tendency for pleasant daydreams did not predict self-reported creative behavior, meaningful daydreaming did. This suggests that daydreaming that can be summarized as positive may facilitate creativity by evoking personally meaningful content rather than positive affect per se, perhaps because meaningful content can be highly motivating (e.g., Elliot, 2006).

It is important to note that daydreaming or mind-wandering about meaningful things is different from rumination. Rumination is typically self-related, and often negative, but is most strongly characterized by its repetitive nature and narrow focus of attention (Grol, Hertel, Koster, & De Raedt, 2015; Smallwood, O'Connor, & Heim, 2006; Smallwood et al., 2003). Therefore, we would expect that types of mind-wandering that are characterized by ruminative thoughts should be negatively related to creativity.

Research on mind-wandering and creativity, thus far, has paid little attention to moderating factors such as the content, valence, and motivational aspects of stimulus- or task-unrelated thoughts. Based on the arguments laid out here, we think that such examination would introduce important nuance to the mind-wandering–creativity link.

How Types of Mind-Wandering Affect Future-Oriented Decision-Making

Mind-wandering, more often than not, involves thoughts about the future—a finding that has led researchers to theorize that it may serve a function for autobiographical planning and preparing for future events and decisions, and may thus not be as maladaptive as it is often made out to be (Baird et al., 2011; Klinger, 2009, 2013; Klinger & Cox, 1987; Poerio, Totterdell, Emerson, & Miles, 2015; Smallwood, Nind, & O'Connor, 2009; Smallwood, Schooler, Turk, Cunningham, Burns, & Macrae, 2011). Indeed, there is some evidence that mind-wandering can aid self-regulation by facilitating future-oriented decision-making (e.g., Smallwood, Ruby, & Singer, 2013). As with the previously discussed findings, however, it is likely that this effect depends at least in part on what types of mind-wandering one engages in.

The benefit of mind-wandering for future-oriented decision-making has been illustrated in the context of delay discounting. Delay discounting is the tendency to prefer or to chose smaller immediate rewards over larger rewards one has to wait for (e.g., Frederick, Loewenstein, & O'Donoghue, 2002). What makes it hard to choose a delayed over an immediate reward, even if the delayed reward is objectively more valuable, is the strong appeal of the immediate reward that needs to be down-regulated. Such down-regulation is effortful and requires self-control (e.g., Metcalfe & Mischel, 1999; Reynolds, 2006). Interestingly, Smallwood et al. (2013) have found evidence that delay discounting is easier for people who mind-wander more. In their study, mind-wandering was measured through experience sampling during two different attention tasks, which differed in difficulty. Before or after the attention tasks, participants performed a delay-discounting task in which they repeatedly chose between two financial rewards, a smaller but immediate reward and a larger reward that was delayed by up to 180 days. The results showed that more frequent mind-wandering during the easy attention task was associated with a decreased tendency toward delay discounting. The authors speculated that habitually dreaming away from the here and now may enable people to forgo the temptation of immediate rewards.

Given that mind-wandering episodes often revolve around the future, the explanation Smallwood et al. (2013) gave for their findings was that individuals who mind-wander more spend more time mentally simulating the future, which makes them more sensitive to the value of future rewards. This explanation is supported by the observation that only mind-wandering during the *easy* but not the more difficult task was predictive of participants' tendency to choose future over immediate rewards. Previous research (Smallwood et al., 2009; Smallwood, Schooler, et al., 2011) has shown that future-related mind-wandering is much more prevalent during easy or passive tasks than during highly demanding tasks. Thus, it seems that task conditions that are conducive to future-related mind-wandering specifically are beneficial for future-oriented decision-making.

Indeed, other studies have found that engaging in episodic future thinking, as opposed to non-episodic thinking (Benoit, Gilbert, & Burgess, 2011) or thinking about things in the present (Lin & Epstein, 2014), leads to more future-oriented choices in delay discounting tasks. And again, other research has shown that engaging in spontaneous thoughts about the future during a delay-discounting task reduced preferences for immediate rewards (Peters & Büchel, 2010). Interestingly, in all those studies, the effect was not driven by future-related thoughts that were explicitly associated with the future reward itself. Lin and Epstein (2014) attributed the benefit of future-oriented thinking for future-oriented decision-making to an increased ability to predict one's own future emotions, a hypothesis that is in line with the findings by Smallwood et al. (2013).

Other research, however, suggests that engaging in positive and not necessarily future-related types of thoughts can also be an effective strategy to resist the temptation of immediate rewards in order to obtain delayed rewards. For instance, Mischel, Ebbesen, and Zeiss (1972) found that, when children could obtain a desired food item by resisting to eat a less desirable but immediately available food, instructions to engage in positive distracting thoughts (i.e., "anything that is fun to think of") substantially increased their ability to wait. Sad thoughts or thoughts directly related to the desired rewards, on the other hand, were not as helpful. The mechanism behind the benefit of positive mind-wandering may be different from that of future-related mind-wandering. Whereas future-related mind-wandering seems to influence how individuals think about or attend to future rewards, positive mind-wandering might instead reduce the relative appeal of the immediate reward. More research is needed to test this possibility. To sum up, the research discussed in this section illustrates that, under conditions giving rise to future-related or positive thoughts, the seemingly maladaptive tendency to escape from the here and now can be functional for planning and future-oriented decision-making.

Practicing Constructive Mind-Wandering

If some types of mind-wandering are less disruptive to performance than others, or are more helpful for attaining desired outcomes such as maintaining positive mood, being creative, or future-oriented decision-making, this raises the important question of whether we can learn to deliberately increase those "constructive" types of mind-wandering. The idea of deliberately and consciously engaging in mind-wandering may seem paradoxical; after all, mind-wandering is typically defined as spontaneous and often task-unrelated, and often occurs without awareness. If one deliberately engages in a particular train of thought, with a desired outcome in mind, doesn't this make the thinking one's primary task, and anything but spontaneous? We think, on the contrary, that it is possible to give direction and purpose to a mind-wandering episode without necessarily removing all spontaneity from the experience. As Fox and Christoff (2014) have pointed out before, spontaneous thinking and meta-cognitive control are not necessarily in conflict, and the interplay of these two modes of thinking may facilitate creative cognition and other mental phenomena. We propose, for instance, that in order to facilitate creative thinking, you may decide to let your mind wander toward a positive or personally meaningful memory or an interesting thought, without controlling where your train of thought will go from there. Or you may let your mind wander freely, and redirect your attention only when you notice that you start to engage in repetitive, ruminative thought. In other words, we think that one can give broad direction to spontaneous thoughts without stifling their spontaneous, associative quality. This could be considered a "mindful" approach to mind-wandering, whereby one aims to be at least intermittently meta-aware of one's thought content (see Fox & Christoff, 2014).

The idea of engaging in deliberative stimulus-unrelated thinking for personal improvement is not new. In types of meditation that revolve around open monitoring, for instance, practitioners are encouraged to observe their spontaneous thoughts with a receptive, accepting attitude, giving no priority to any thought in particular (e.g., Lutz, Slagter, Dunne, & Davidson, 2008). In classic Freudian approaches to psychotherapy, free association has been used as a way to reveal unconscious thought processes (e.g., Kris, 1982). And in modern forms of cognitive or cognitive behavioral therapy, patients are encouraged to become aware of their habitual patterns of thoughts and to change their internal narrative in a more constructive way in order to create changes in their emotions and behaviors (e.g., Blagys, & Hilsenroth, 2002; Gonçalvs, Matos, & Santos, 2009; Hollon & Beck, 1994).

Experimental studies, too, have shown that interventions involving guided thought exercises can lead to benefits. For instance, recalling positive autobiographical memories or vividly imagining positive scenarios can help increase positive mood and reduce negative intrusive thoughts in ruminators or individuals with depressive symptoms (Gillihan, Kessler, & Farah, 2007; Hirsch, Perman, Hayes, Eagleson, & Mathews, 2015; Homes, Lang, & Shah, 2009; Josephson, Singer, & Salovey, 1996; Stokes & Hirsch, 2010). Here, too, different styles of thinking have been shown to have different effects. Hirsch et al. (2015), for instance, confronted ruminators with worrying scenarios and instructed them to either think about the potential negative or positive outcomes of each scenario. Moreover, suspecting that the attempt to fully suppress negative ruminative thoughts would likely backfire, they placed loose constraints on the style of participants' spontaneous thoughts; that is, they instructed them to either think about their worries in the form of mental images or in the form of verbal descriptions. Next, participants were instructed to focus on their breathing for a period of five minutes. After the breath focus period, intrusive thoughts were assessed. The results showed that both thinking in images and focusing on positive outcomes reduced negative intrusive thoughts. Interestingly, thinking in images reduced intrusions even when participants thought about negative outcomes, suggesting that thinking style had a greater impact than specific thought content.

In a similar study (Holmes, Coughtrey, & Connor, 2008), participants read descriptions of a number of positive scenarios and were asked to either reflect on the verbal qualities of the descriptions or vividly imagine the scenarios either from their own (first-person) perspective, or from an observer's (third-person) perspective. Imagination but not verbal analyses of the scenarios led to improved mood. Interestingly, this was true only when participants imagined events from their own perspective. This again suggests that guiding the style of people's mind-wandering can help increase constructive types of mind-wandering in order to increase positive moods.

Other research has examined whether exercises akin to deliberate mind-wandering can be used to improve creativity. Long, Hiebert, Nules, and Lalik (1985), for instance, developed guided "visualization" exercises—essentially instructed mind-wandering—with the goal of improving creativity and in particular creative writing in elementary school students. The students were randomly assigned to two conditions. In the experimental condition, the students engaged in three weekly sessions of guided imagination, in which they were encouraged to first vividly imagine any memories or current experiences that came to mind and then let these images spontaneously "trigger" further images and thoughts. In a control condition, students listened to and wrote stories, without deliberately trying to engage in any related or spontaneous thoughts. After the intervention, students who had engaged in mind-wandering, compared to the control condition, showed improvement in the originality of their creative writing. In a similar study, Jampole, Methews, and Konopak (1994; see also Jampole, Konopak, Readance, & Mosher, 1991) tried to elicit vivid thoughts and mental images by encouraging students to imagine traveling to different places and to imagine all the smells, feelings, and other experiences associated with this travel. Again, compared to control conditions involving reading and writing exercises, students who participated in imaginative thought showed increased creativity.

Following a similar approach, future studies could explore the consequences of different types of mind-wandering for performance, mood, creativity, decision-making, and other outcomes. For instance, building on the evidence that recalling positive autobiographical memories or vividly imagining positive events improves mood (Josephson et al., 1996; Gillihan et al., 2007; Hirsch et al., 2015; Holmes, Lang, & Shah, 2009; Serrano, Latorre, Gatz, & Montanes, 2004; Stokes & Hirsch, 2010), could instructions to deliberately daydream about positive or personally meaningful events or memories be a strategy to improve a person's mood, well-being, and creativity? Could instructions to imagine future scenarios (versus recalling memories or thinking about current concerns) facilitate future-oriented decision-making? If so, this would not only be informative for research on the effects of mind-wandering, it would also have more practical applications. For instance, it may lead to intervention programs training people in recognizing the effects of their tendency to engage in different styles of mind-wandering and possibly invoking constructive types of mind-wandering dependent on current environmental or task demands.

There is currently a great interest in the benefits of mindfulness practices that focus on directing attention to present-moment experiences and increasing meta-awareness of one's experience (e.g., Chambers, Lo, & Allen, 2008; Grossmann, Niemann, Schmidt, & Walach, 2004; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; Mrazek et al., 2013). We think that increased meta-awareness may also benefit attempts to increase constructive mind-wandering. For one, becoming more meta-aware of one's spontaneous thoughts may be the first step to recognizing one's habitual style of mind-wandering and identifying how different types of mind-wandering affect one's mood or behavior. Recognition, as a first step to regulation, is not trivial. Research shows that people routinely fail to recognize when they engage in unwanted thoughts. For instance, in a study by Baird et al. (2013), participants were asked to monitor and catch spontaneous intrusive thoughts of past romantic relationships while performing a task. In addition, participants were probed at random moments and asked about their thoughts. The results showed that participants often reported thinking about the former partner when probed, yet rarely caught those thoughts themselves. There is evidence, however, that meta-awareness of spontaneous thoughts can be increased when people make a conscious effort to catch those thoughts (Zedelius et al., 2015). Thus, we think that making an effort to increase meta-awareness, for instance with the help of mindfulness practice, may enable people to recognize when they are engaging in dysfunctional types of mind-wandering and shift their thoughts toward more constructive types of mind-wandering. Given that people spend a considerable amount of time mind-wandering, such interventions may have potential as a tool for self-enhancement.

Summary and Conclusion

Mind-wandering occupies a large amount of our waking life, and has inspired decades of research examining why and when the mind escapes from the here and now, what the neural signatures of mind-wandering are, and how mind-wandering affects cognition and behavior. In much of this research, mind-wandering has been defined in the broadest sense, encompassing all types of spontaneous, stimulus- or task-unrelated thought, although several lines of research have shed more light on specific aspects of the contents and styles of mind-wandering. In the present chapter, we have focused on discerning distinct types of mind-wandering, characterized by different experiential qualities, emotions, and cognitive processes, and we have examined how these different types of mind-wandering affect cognition and behavior. We have focused on research on the effects of mind-wandering on performance, mood, creativity, and future-oriented decision-making, and have illustrated how differentiating between different types of thought can bring important nuances to our understanding of mind-wandering. We have pointed out what we think are gaps in the current mind-wandering literature and have proposed novel hypotheses for future research that may elucidate how distinct types of mind-wandering—intentional mind-wandering, mind-wandering with meta-awareness, and positive, approach-oriented, personally meaningful, or future-oriented mind-wandering—may uniquely benefit stable performance, positive mood, creative thought, and future-oriented decisions. Finally, we have made a case for adding deliberate mind-wandering to our scientific toolkit to understand and harness the effects of different constructive kinds of mind-wandering. We are only beginning to unravel the richness of spontaneous thought and its diverse consequences.

Acknowledgments

This research was supported by grant RFP-15-09 from the Imagination Institute (www.imagination-institute.org), funded by the John Templeton Foundation. The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the Imagination Institute or the John Templeton Foundation.

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CHAPTER

19 Electrophysiological Evidence for Attentional Decoupling during Mind-Wandering

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Abstract

The tendency to disengage from the immediate environment and to wander off to another time and place is a unique characteristic of the human mind. While much research has focused on the neural origins of such mind-wandering experience, less understood is the mechanism by which the mind facilitates task-unrelated thoughts. This chapter presents electrophysiological evidence demonstrating a widespread attenuation of numerous cognitive responses to external events during mind-wandering, suggesting that this transient modulation of the depth of the cognitive investment in external events may be one potential mechanism in which the mind facilitates these task-unrelated thoughts. The chapter also highlights the utility of resting-state and intracranial EEG as valuable methodology in illuminating the neural mechanisms underlying these internally directed mental experiences.

Key Words: mind-wandering, electrophysiology, task-unrelated thought, disengagement, EEG, intracranial EEG

Despite our embodied presence in the external world and the adaptive value of remaining vigilant to what is physically around us, our attention inevitably and regularly shifts inward to our own musings and reflections. The thoughts that occur during this mind-wandering experience generally reflect qualitative content that is unrelated to and undirected by external task demands. For example, as you are reading through this chapter, you may reminisce about childhood memories, decide between two cities for your next vacation, or fantasize about your favorite sports team winning a championship. However, despite the everyday ubiquity of this phenomenon, only within the last decade has research begun to reveal the neural mechanisms underlying such perceptually decoupled thinking. Unlike many other cognitive phenomena, our thoughts often arise without any concomitant behavioral correlates, highlighting the role that direct measures of neural activity can play in revealing its complex features. In this regard, we review how electroencephalogram (or EEG) has been exploited as a means to understand how mind-wandering alters our engagement with the external environment.

While much research on the topic of mind-wandering has focused on elucidating its subjective content (e.g., Killingsworth & Gilbert, 2010; McVay, Kane, & Kwapil, 2009; Smallwood et al., 2011) and the neural systems mediating its advent (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fingelkurts & Fingelkurts, 2011; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Mason et al., 2007; Northoff et al., 2006), EEG-based measures have been particularly useful for addressing a third and equally vital issue that calls into question our traditional understanding of selective attention. In particular, long-dominant models of selective attention implicitly assume that we are always selecting for or highlighting *something* in the external environment for higher levels of cognitive analysis (e.g., Desimone & Duncan, 1995; Posner, 1980). However, as EEG-based measures have helped reveal, it now appears that not only is attentional selection transiently attenuated during bouts of mind-wandering, but it also involves a temporal coordination across multiple domains of cognitive functions. The third issue concerns how these cognitive domains collectively ebb and flow together over time in terms of the depth of their engagement with events in the external environment (Handy & Kam, 2015; Kam & Handy, 2013).

Terminology

At the outset, it is important to appreciate that a number of different terms or operational definitions have been applied to the phenomenon, including *mind-wandering, task-unrelated thought, spontaneous thought, stimulus-independent thought, self-generated thought*, and *zoning/tuning out*. Critical theoretical differences among these terms can be gleaned (e.g., Christoff, 2011; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Smallwood & Schooler, 2015). For example, task-unrelated thoughts are by definition not related to the ongoing task at hand, but may very well be tied to stimulus inputs in the surrounding external environment, such as the loud noise made by the magnetic resonance imaging (MRI) scanner. Likewise, although stimulus-independent thoughts are not initiated by a currently present external stimulus, they may involve the conscious, metacognitive evaluation of one's task performance (Stawarcyzk, Majerus, Maquet, & D'Argembeau, 2011). Such distinctions may be critical when considering the qualitative nature of these internally directed thoughts, or when investigating which brain regions are active during mind-wandering. However, with respect to our primary issue—how mind-wandering alters our attentional engagement with events in the external environment—the conclusions we draw generalize to most conceptualizations of this mental experience. Hereafter, we will use the two terms most appropriate for the studies discussed in this chapter—*mind-wandering* and *task-unrelated thought*—interchangeably to refer to our empirical phenomenon of interest. Both terms reflect any thoughts that are not currently focused on ongoing task performance, spanning across thoughts that are stimulus-independent and -dependent, spontaneous and deliberate, and that occur with and without awareness.

Evidence for Attentional Disengagement

That our attention to the external environment should disengage during transient bouts of mind-wandering follows from two points. First, the *executive control hypothesis* proposes that mind-wandering decouples our executive resources from the ongoing task, directing them away from our immediate sensory-motor environment to the internal environment in order to facilitate inner trains of thought (Smallwood & Schooler, 2006). Consistent with this hypothesis, disrupted performance on a number of executive tasks has been reported during task-unrelated thoughts, suggesting that when mind-wandering has successfully recruited the necessary executive resources, a limited amount remains for the external task (e.g., Levinson, Smallwood, & Davidson, 2012; Teasdale et al., 1995). Second, mental imagery in different sensory domains has been shown to rely on the same domain-specific brain regions engaged by external stimulus inputs (e.g., Decety, 1996; Kosslyn, Zatorre & Halpern, 2005), indicating that our task-unrelated thoughts and the associated subjective experiences rely on the same domain-specific processes engaged by events in the external world. Melding these ideas together, the attenuation of sensory-motor processing of external events appears to play an imperative role in facilitating the initiation and maintenance of task-unrelated thoughts (Smallwood, 2013). In the following, we summarize the EEG-based evidence supporting this proposal.

Impact on Sensory/Perceptual Processing

The mounting evidence of disrupted behavioral performance on various attentional tasks during mind-wandering (e.g., Cheyne, Carriere, & Smilek, 2006; McVay & Kane, 2009) invites the question of the extent to which such disruption corresponds with attenuation of stimulus processing at the sensory-perceptual level. Toward addressing this question, our event-related potential (ERP) study had participants perform a sustained attention to response task (SART), wherein a target stimulus requiring a simple detection response is presented on a computer screen every two seconds or so, while interspersed between each target was a task-irrelevant visual or auditory "probe" stimulus that participants were told to ignore (Kam et al., 2011). As participants performed the task, we then stopped them at unpredictable intervals and queried them on their attentional state right before the stoppage as either "on-task," or "mind-wandering"—a method of subjective reporting called experience sampling that has shown high validity in capturing global attentional states (Gruberger, Ben-Simon, Levkovitz, Zangen, & Hendler, 2011). The amplitudes of the sensory-evoked responses to the task-irrelevant visual and auditory probes presented within the last 12 seconds prior to mind-wandering versus on-task attentional reports were examined. Consistent with the hypothesis that sensory-perceptual processes in the cortex become less sensitive to external events when we engage in task-unrelated thoughts, the amplitude of the visual P1 component (Figure 19.1A), which is generated in extrastriate visual cortex, was attenuated during mind-wandering states, as was the auditory N1 component (Figure 19.1A), which is generated in primary auditory cortex.

In a similar study, Braboszcz and Delorme (2011) asked participants to focus on their breath as they passively listened to frequent and rare auditory tones as part of a classic "oddball" paradigm, and to report whenever they noticed that their minds had wandered away from their breath monitoring. The sensory processing of both frequent and rare tones was compared between on-task and mind-wandering episodes, via the amplitude of the mismatch negativity (MMN) component, which reflects the pre-attentive sensory-level processing in the cortex associated with the detection of rare auditory stimuli. Consistent with the sensory-level effects of mind-wandering reported by Kam and colleagues (2011), the amplitude of the MMN was found to be reduced during periods of mind-wandering (Figure 19.1B), suggesting that task-unrelated thoughts can impact automatic change

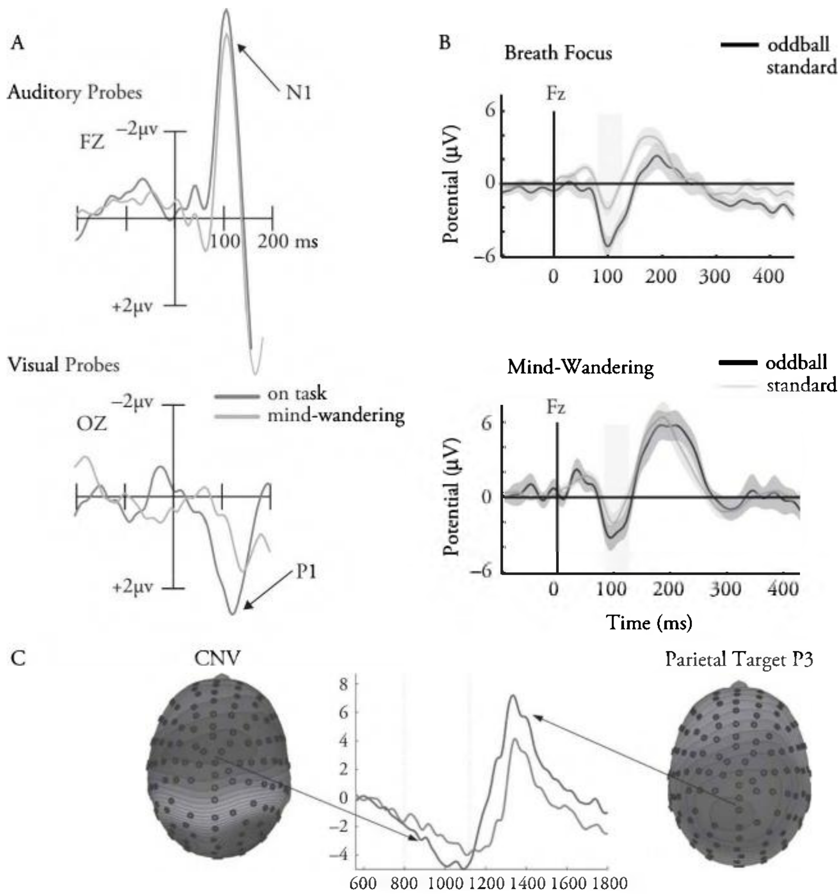

Figure 19.1. Attenuation of external responses during mind-wandering. This pattern of attenuation was observed in several types of responses during task-unrelated thoughts indexed by different measures. (A) Sensory-level processing of auditory stimuli, as indexed by the N1 component as shown at Fz, and visual stimuli, as indexed by the P1 component shown at Oz, was attenuated during mind-wandering based on self report probe-caught measures using experience sampling. (B) Automatic change detection in auditory perception as indexed by the MMN (i.e., the difference between standard and oddball waveforms) is also disrupted during task-unrelated thoughts, as reported by participants during a breath-monitoring task. (C) Performance errors in a target detection task as a proxy for mind-wandering has been associated with reduction in both the P3 and the CNV components, indicative of disrupted target detection and anticipatory response to an expected stimulus, respectively, during mind-wandering. Sources: Kam et al. (2011); Braboszcz & Delorme (2011); O'Connell et al. (2009). (See Color Insert)

detection in auditory perception as well (Braboszcz & Delorme, 2011).

Impacts on Cognitive and Affective Processing

These effects of mind-wandering at the sensory-perceptual level suggest that comparable impacts of task-unrelated thoughts might be observed at higher levels of stimulus evaluation in the cortex. In the first study to address mind-wandering and attentional decoupling using ERPs, experience sampling was used to assess whether participants were in an on-task versus mind-wandering state as they performed the SART as described earlier (Smallwood, Beach, Schooler, & Handy, 2008). Analysis focused on the amplitude of the P3 ERP component elicited by targets in the SART, a component that indexes the general level of cognitive analysis applied to task stimuli. In line with the hypothesis that task-unrelated thoughts broadly disengage our attentional systems from the external stimulus environment, periods of mind-wandering relative to on-task attentional states were found to be associated with a significant decrease in the P3 amplitude.

Consistent with this finding, Barron and colleagues (2011) also reported an attenuated P3 in a three-stimulus visual oddball task in individuals who retrospectively reported higher levels of mind-wandering compared to those who reported lower levels of mind-wandering during task performance. This P3 reduction was observed in response to both infrequent, task-relevant targets and task-irrelevant distractors. Importantly, this finding demonstrates that mind-wandering appears to disrupt cognitive-level processing of rare stimuli, regardless of their relevance to the ongoing task.

Beyond the P3 index of attentional attenuation, target detection in steady-state visual-evoked potential paradigms has also been used to examine how task-unrelated thoughts impact the processing of external stimulus inputs. In one study, the failure to detect targets was considered as an index of mind-wandering (O'Connell et al., 2009). They found, within 4 seconds of the missed target, a reduction in the amplitude of the P3, as well as the contingent negative variation (CNV) component (Figure 19.1C), which reflects the anticipatory response to an expected stimulus. In contrast, the amplitude of alpha over posterior areas increased up to 20 seconds prior to an error, reflecting decreased vigilance to external events. These results indicate that mind-wandering is associated with disrupted target anticipation and detection, as well as decreased alertness. In a second study, MacDonald and colleagues (2011) asked participants to rate their attentional state on a continuous scale and performed trial-by-trial analysis of the neural activity associated with target detection as a function of the reported attentional state. They found decreased P3 amplitudes as well as increased pre-stimulus alpha power over central and posterior midline areas during trials of lower levels of task-focus. Further, pre-stimulus alpha amplitude predicted attentional state on a trial-by-trial basis. Irrespective of the use of an objective or subjective measure of attentional states, these studies converge on the notion of impaired target detection during task-unrelated thoughts (see also Smallwood et al., 2008).

The aforementioned studies indicating disrupted cognitive processing during mind-wandering have generally employed affectively neutral task stimuli. In an ERP study we therefore examined whether task-unrelated thoughts impact the cognitive evaluation of affectively salient stimuli (Kam, Xu, & Handy, 2014). Previous studies have shown that the P3 component elicited by visual images is greater in amplitude when the image contains affectively charged content, relative to comparable images that are affectively neutral in content (e.g., Weinberg & Hajcak, 2011). Building on these findings, we asked a cohort of participants to view images of people's hands in various situations, some of which showed them in painful situations (e.g., a hand getting cut by a knife) or neutral situations (e.g., a hand next to a knife) as we recorded the ERPs generated by the images. Again we used experience sampling, and periodically asked participants to report whether they were on-task or mind-wandering. Our results indicate that the P3 to painful images was significantly reduced during mind-wandering (Kam et al., 2014, Experiment 1).

Although behavioral performance in some of the aforementioned experimental tasks was impaired during mind-wandering states, the neural basis for these behavioral errors remains unclear. Accordingly, we used ERPs to examine whether mind-wandering disrupts performance-monitoring processes in the cortex, as measured by the feedback error-related negativity (fERN) in the context of a time estimation task (Kam et al., 2012). As hypothesized, we observed that the fERN elicited by the trial-by-trial performance feedback was significantly attenuated in the interval prior to mind-wandering reports compared to on-task reports, suggesting that the occurrence of task-unrelated thoughts disengages us from monitoring and adjusting behavioral outputs relevant for successful task performance.

Mechanisms Underlying Attentional Attenuation

Building on these aforementioned findings, a critical question concerns the neural mechanisms underlying this broad spectrum of attentional attenuation during mind-wandering. Using experience sampling during the SART, Baird and colleagues (2014) examined the extent to which mind-wandering modulates phase synchronization or coherence of neural oscillations associated with task stimuli. They found decreased phase synchrony in the theta band over parietal areas across trials within the P1 time-window during mind-wandering intervals (Figure 19.2A). Importantly, phase synchronization in the theta band positively correlated with P1 amplitude, highlighting the potential role of phase-locking of theta band oscillations in the sensory attenuation of external stimuli during mind-wandering.

Paralleling such findings, Kirschner and colleagues (2012) performed source localization on scalp EEG data in order to investigate the spatial distribution of neural activity during task-unrelated thoughts. They examined more broadly the neural mechanisms that give rise to the transient functional coupling within the default mode network (DMN), which has been shown to be active during mind-wandering (e.g., Christoff et al., 2009; Fox et al., 2015). Two separate experiments employing the SART tested the hypothesis that inter-regional synchronization facilitates functional coupling between brain networks. The authors found increased phase synchronization in theta, alpha, and gamma bands across regions of the DMN during episodes of mind-wandering (Figure 19.2B). Together with the findings of Baird and colleagues (2014), these studies converge on the notion that mind-wandering attenuates sensory responses in both the auditory and visual domains, a process that is associated with phase synchronization between regions within the DMN.

Given such effects as revealed by EEG-based measures, one theory has proposed that the lateral prefrontal cortex (lPFC) may be critically involved in modulating fluctuations in these attentional states (Smallwood, 2013). The lPFC has been implicated in attentional control and the regulation of competing stimulus inputs (Nagahama et al., 2001; Rowe, Toni, Josephs, Frackowiak, & Passingham, 2000), suggesting its potential role in facilitating both externally and internally directed attentional states (Dixon, Fox, & Christoff, 2014; Vincent, Kahn, Snyder, Raichle, & Buckner, 2008). Importantly, the lPFC has been shown to be recruited during both externally and internally directed attentional processes (Christoff et al., 2009). Future research in this area would benefit from examining this region as a promising candidate for facilitating the switching between attentional states.

Beyond Attentional Attenuation During Mind-Wandering

Empirical studies of mind-wandering typically involve external stimuli associated with an experimental task. However, these experimental designs make it difficult to isolate the neural indices of mind-wandering itself. An alternative approach is to directly record EEG data while the participant is not engaged in any external task. Such an experimental condition is typically referred to as the "resting state." Resting-state analyses in the fMRI literature have revealed that the brain is intrinsically organized into different functional networks (Yeo et al., 2011). As it is now widely recognized that the brain is not idle at rest, a wealth of cognitive processes may be engaged during these resting states, modulated by the varying thoughts that emerge, which could be investigated using resting-state EEG—a topic to which we turn in the subsequent section.

Electrophysiological Index of Thoughts Occurring During Rest

In the aforementioned literature, most studies employed a similar approach to data analysis, in which the electrophysiological response was time-locked to an external stimulus and compared between on-task and mind-wandering states. However, in EEG data recorded during rest, there is no regularly occurring task-related external stimulus. Accordingly, instead of examining event-related potentials time-locked to a stimulus, the amplitude or power at different frequency bands averaged across the recording period may be used as an index of the strength of neural activity associated with a particular attentional state. To then surmount the absence of an external stimulus, one common approach involves establishing a relationship between patterns of EEG activity at rest and behavioral performance in a subsequent task, to see how the former correlates with or predicts the latter. Another approach is to associate resting-state EEG activity with activity in the DMN (e.g., Gusnard & Raichle, 2001). Briefly, the DMN is a network

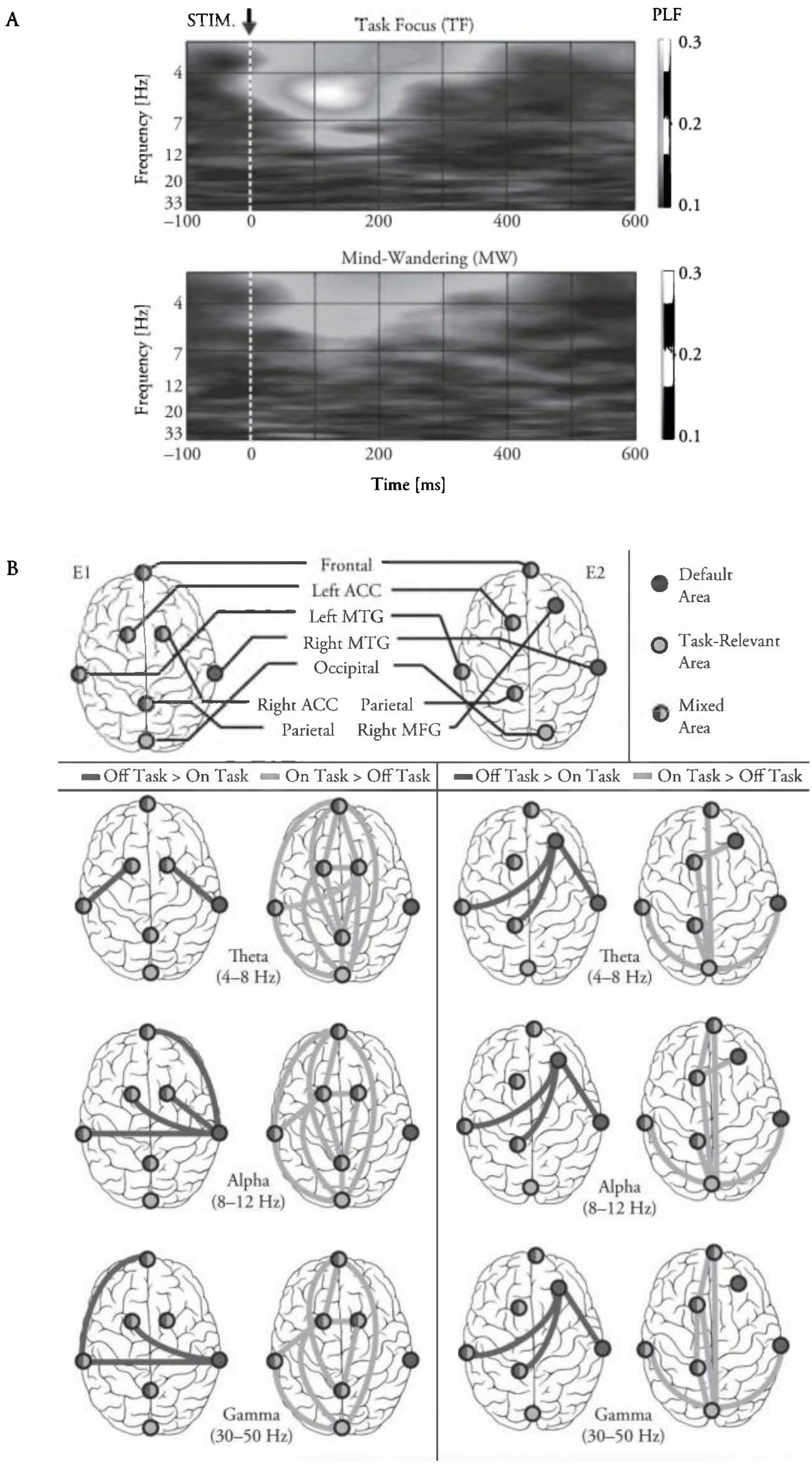

Figure 19.2. Neural mechanisms underlying attentional attenuation during mind-wandering. (A) Decreased phase synchrony in the theta band within parietal cortex was observed during episodes of mind-wandering, highlighting the potential role of phase-locking of theta band oscillations in the sensory attenuation of external stimuli during mind-wandering. (B) The increased phase synchronization in theta, alpha, and gamma bands across regions of the DMN during mind-wandering suggests the role of inter-regional synchronization in facilitating functional coupling within the DMN. Sources: Baird et al. (2014); Kirschner et al. (2012). (See Color Insert)

of regions that is generally less active during externally directed cognitive tasks than during rest (e.g. Greicius, Krasnow, & Menon, 2003; Gusnard & Raichle, 2001) as well as mind wandering (e.g., Mason et al., 2007; Christoff et al., 2009; Fox et al., 2015). The spatial distribution and functions of the DMN as it relates to task-unrelated thoughts are outlined in more detail in Chapter 13 by Andrews-Hanna, Irving, Fox, Spreng, & Christoff in this volume.

One commonly used electrophysiological measure during resting waking states is EEG power averaged across frequency bands. This measure is derived from the raw EEG signal by performing a time-frequency analysis, which transforms the signal into the frequency domain, usually by means of the Fourier transform. Once in the frequency domain, the signal can then be decomposed into different frequency bands. The amplitude of the signal within a specified frequency range can be squared in order to obtain the band power. This measure indexes the strength of neural activity within the specified range of frequency bands. Using simultaneous fMRI and EEG recording during wakeful rest, Laufs and colleagues (2003) found that beta power (17–23 Hz) was positively associated with activity in retrosplenial, temporoparietal, and dorsomedial prefrontal cortices, regions generally considered to lie within the DMN. Likewise, both alpha (8–12 Hz) and beta (13–30 Hz) oscillations showed positive correlations with activation of the DMN in another study recording simultaneous fMRI and EEG (Mantini, Perrucci, Del Gratta, Romani, & Corbetta, 2007). Building on this relationship, one study focused on the spatial distribution of EEG frequency oscillations at rest (Jann, Kottlow, Dierks, Boesch, Koenig, 2010), revealing that DMN activation positively correlated with alpha (10.5–14 Hz) oscillations over posterior occipital electrodes and low beta (14–18.75 Hz) oscillations over parietal electrodes. In addition to increased regional activation, beta power has also been shown to account for variance in the functional connectivity of BOLD signal within the DMN (Hlinka, Alexakis, Diukova, Liddle, & Auer, 2010). This series of studies converge on distinct electrophysiological signatures of neural activity during rest that are corroborated by robust correlations with spatially distributed DMN activity.

While scalp EEG provides excellent specificity in the time domain, inferences must be made with regard to the source of neural activity subserving task-unrelated thoughts. Intracranial EEG circumvents this issue, as electrodes are placed directly on or within the cortex in patients undergoing pre-surgical monitoring for intractable epilepsy. As with EEG, this method has superb temporal resolution; importantly, it also has great spatial resolution, allowing one to better localize the source of neural activity as it measures activity directly from the cortical surface or deep structures of the brain. As this is a relatively new and rare method in research, only one study to our knowledge at the time used this method to study neural dynamics during rest (Foster & Parvizi, 2012). In focusing on the posteromedial cortex, a core region of the DMN, they found increased theta oscillations (4–7 Hz), as well as coupling between the phase of theta oscillations and the amplitude of high gamma (70–180 Hz), during the resting state. Interestingly, this modulation occurred at slow time scales, similar to those reported in resting-state networks at approximately 0.1 Hz (e.g., Nir et al., 2008). These results reveal that the transient coupling between low frequency and high frequency neural activity within the posteromedial cortex (as part of the DMN) may be one potential mechanism underlying mind-wandering in humans.

Future Directions

Here we elaborate on two emerging lines of research that are crucial for a more complete understanding of the neural mechanisms underlying the phenomenon of mind-wandering. First, among electrophysiological studies of resting waking states, none has explored whether the EEG signature of mind-wandering is modulated by its phenomenal or subjective content. Of interest, several behavioral studies have attempted to characterize the different types of task-unrelated thoughts commonly experienced, and have found that our thoughts tend to be future oriented (Smallwood et al., 2011), and reflect personal issues (Klinger & Cox, 1987; McVay, Kane, & Kwapil, 2009). A crucial question then concerns how the electrophysiological signatures of our thoughts would change as a function of thought content. The extent to which electrophysiological measures are sufficiently sensitive to differentiate types of thoughts (e.g., reminiscing on a childhood experience versus contemplating an abstract concept) is an exciting avenue for future research.

Second, in terms of methodology, intracranial EEG is proving to be a useful tool for revealing the underlying mechanisms of spontaneous thoughts and their associated neural networks. In addition to electrocorticography (ECoG), where activity is recorded from the cortical surface, activity can also be recorded in deep structures of the brain like the amygdala and anterior insula using stereotactically implanted depth electrodes (sEEG). While both methods offer high temporal and spatial specificity, it is important to note that the invasive nature of these methods introduces its own limitations. This includes potential differences in cognitive functions between neurologically healthy brains and epileptic brains, as well as recording only from parts of the brain that meet strict clinical criteria as being necessary to localize the source of epilepsy. Nonetheless, with electrode coverage that is appropriate for the cognitive process of interest, ECoG and sEEG can reveal the source of neural activity with high spatial resolution. Another advantage concerns the detection of high gamma activity (usually indexed between 70 and 200 Hz), which has been linked to neuronal firing rate and has been shown to reflect spiking of population neuronal activity (Miller, 2010). Therefore, high gamma activity as captured by intracranial EEG is a promising measure to reveal coupling with lower frequencies within regions during mind-wandering, as well as concomitant long-range synchronization between functional brain networks.

Conclusion

Collectively, the EEG-based evidence we review here indicates that transient periods of spontaneous thought are associated with slow temporal fluctuations in the depth of attentional engagement with events in the external environment. Notably, beyond simply documenting such effects, there are a number of clinical disorders that have been tied to abnormal levels of sensory-perceptual and cognitive attenuation that also have clear links to spontaneous thinking. These include major depressive disorder (e.g., Spasojevic and Alloy, 2001; Watkins and Teasdale, 2001) and compulsive fantasy (Bigelsen and Schupak, 2011)—which can be characterized by abnormal increases in the amount of time disengaged from the external environment in order to engage in stimulus-independent thought—as well as attention deficit hyperactivity disorder, which can be characterized as an abnormal increase in the amount of time engaged in the external environment and stimulus-dependent thoughts (e.g., Fassbender et. al., 2009). We suggest that these disorders can be considered as having a common component rooted in pathologies of our transient engagement with the external environment as revealed by EEG-based studies of mind-wandering and other forms of spontaneous thought.

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CHAPTER

20

Mind-Wandering in Educational Settings

Jeffrey D. Wammes, Paul Seli, *and* Daniel Smilek

Abstract

Recently, there has been a growing interest in exploring the influence of mind-wandering on learning in educational settings. In considering the available research on the topic, one might draw the following conclusions: the prevalence of unintentional mind-wandering in classroom settings is high; mind-wandering rates increase over time in lectures; and mind-wandering interferes with learning. Although research in the extant literature provides ample support for these conclusions, much of this research was conducted in the laboratory, while participants viewed video-recorded lectures. More recently, however, researchers have examined the effects of intentional and unintentional mind-wandering in live-classroom settings, and, as this chapter reveals, such research has produced some results that are at odds with those produced in laboratory-based studies. The chapter discusses these recent findings in the context of the aforementioned potential conclusions, and concludes that findings from the laboratory do not readily generalize to real-world educational settings.

Key Words: mind-wandering, learning, education, lecture, laboratory

It has been well established that people's ability to learn relies heavily on the extent to which they pay attention while learning. Indeed, studies examining mind-wandering in educational settings have revealed that mind-wandering often undermines learning and hinders one's ability to remember lecture material (see Schacter & Szpunar, 2015 for a review). These findings are particularly disconcerting because research has also found that students' rates of inattention during lectures can be quite high (e.g. Cameron & Giuntoli, 1972; Schoen, 1970). Given the evidence indicating that mind-wandering has negative implications for learning, and given the high frequency at which students engage in such behaviors, it is not surprising that there has recently been an increase in the number of studies examining the influence of mind-wandering in a variety of educational settings. One of the main goals of this work has been to elucidate the causes and consequences of mind-wandering, and in some cases, to attempt to minimize its occurrence (e.g. Szpunar, Khan, & Schacter, 2013).

The majority of research examining mind-wandering in educational settings has been conducted in laboratory-based studies, wherein participants watch video-recorded lectures and report on their cognitive states (i.e. "mind-wandering" or "on task") when prompted by infrequent "thought probes." The general findings from such studies are that inattention and mind-wandering increase over time, and that higher rates of mind-wandering are associated with poorer retention of the material presented in the lecture (Lindquist & McLean, 2011; Risko, Anderson, Sarwhal, Engelhardt, & Kingstone, 2012; Risko, Buchanan, Medimorec, & Kingstone, 2013; Seli, Wammes, Risko, & Smilek, 2016; Young, Robinson, & Alberts, 2009). Importantly, this inclination toward inattentiveness has been found to extend beyond the laboratory, and has also been observed in massive open online courses (MOOCs), wherein research has shown that most video lectures are abandoned (i.e., exited) within 6 to 8 minutes of their onset (Kim, Guo, Seaton, Mitros, Gajos, & Miller, 2014). This suggests that, to accommodate the average learner's attention span, the optimal length of a lecture ought to be 6 to 8 minutes (at least for lecture presented in video formats).

Based on the foregoing findings, one might be tempted to draw three general conclusions: (1) the prevalence of unintentional mind-wandering in classroom settings is high; (2) mind-wandering rates increase over time, which is sometimes taken as a reflection of a basic cognitive limitation in humans; and (3) mind-wandering interferes with learning and performance. Here, we review findings relevant to these three potentially flawed conclusions and explore their generality and veracity by reviewing recent findings from two of our own studies, each of which examined mind-wandering and performance throughout an entire semester in an actual live undergraduate course (Wammes, Boucher, Seli, Cheyne & Smilek, 2016; Wammes, Seli, Cheyne, Boucher & Smilek, 2016; Wammes & Smilek, 2017). In what follows, we begin by briefly outlining the details of our two studies, after which we move on to discuss how the results of these studies contribute to our understanding of mind-wandering, and how they inform the three potential conclusions outlined in the preceding.

A Brief Outline of Our Two Studies

In the first study that we conducted, students who were enrolled in a live undergraduate course were periodically presented with thought probes throughout almost every lecture across the entire term. The probes were used to obtain self-reports indicating whether, just before each probe was presented, students were focused on the task, intentionally mind-wandering, or unintentionally mind-wandering. At the end of each class, students were given quiz questions that were derived from material presented just before and after they were probed. Additionally, we collected various relevant self-report measures, including the students' prior knowledge of the course content, their motivation to perform well in the course, their grade point average (GPA), and their actual scores on course exams. In a follow-up study conducted during the following term (again, in a live undergraduate course), we modified the response options for our probes such that participants were asked to use a five-point scale to indicate whether they were completely on task, experiencing a mixture of both on-task thought and mind-wandering, or completely mind-wandering just before the presentation of each thought probe. We will now consider the three proposed conclusions described earlier in the context of our findings from these studies.

Is there a high prevalence of unintentional mind-wandering?

The finding that students frequently engage in mind-wandering while watching video-recorded lectures is consistent with the broader literature on mind-wandering. Indeed, studies in this broader literature have shown that people mind-wander roughly 30%–60% of the time when they are queried about their attentional focus (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; McVay & Kane, 2009; Seli, Carriere, Levene, & Smilek, 2013; Thomson, Seli, Besner, & Smilek, 2014), and these high rates of mind-wandering have been found to occur across a variety of contexts. For example, high rates of mind-wandering have been observed while people are engaged in everyday activities (Killingsworth & Gilbert, 2010; Kane et al., 2007), while they complete tasks measuring sustained attention (e.g., Thomson, Seli, et al., 2014), and while they are driving (Yanko & Spalek, 2013a, 2013b). One of the primary reasons such findings have been of interest is because the mind-wandering observed in all of these studies was believed to occur unintentionally, despite people's best efforts to focus on the task at hand (e.g., Bixler & D'Mello, 2014; Blanchard, Bixler, Joyce, & D'Mello, 2014; Carciofo, Du, Song, & Zhang, 2014; Qu et al., 2015; Rummel & Boywitt, 2014; Wilson et al., 2014). Of course, if people experience high rates of unintentional mind-wandering during important activities (e.g., during undergraduate lectures), then the prospects for ameliorating the problem seem rather dire. Indeed, it is not altogether clear how people might go about reducing the occurrence of a phenomenon that occurs despite their best intentions. Put differently, because the occurrence of unintentional mind-wandering is, by definition, beyond one's control, it seems unlikely that people will be able to effectively dampen these spontaneously occurring thoughts.

That said, a growing body of evidence now suggests that mind-wandering can be subdivided into intentional (or deliberate) and unintentional (or spontaneous) types (e.g., Carriere, Seli, & Smilek, 2013; Forster & Lavie, 2009; Giambra, 1995; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Risko, Purdon, & Smilek, 2016; Seli, Risko, & Smilek, 2016; Seli, Risko, Smilek, & Schacter, 2016; Seli, Wammes, et al., 2016; Seli, Smallwood, Cheyne, & Smilek, 2015). Whereas unintentional mind-wandering occurs despite one's best intentions to focus on the task at hand, intentional mind-wandering involves the deliberate disengagement from the task, wherein one *allows his or her mind to wander* away from the task toward unrelated inner thoughts. Importantly, the finding that mind-wandering can occur with intention raises the possibility that at least some of the mind-wandering measured in previous studies (in which this distinction is ignored) might have been intentional in nature. Of particular interest for our purposes here, it may be the case that at least some of the instances of mind-wandering that were reported in previous work examining mind-wandering in educational settings occurred with intention, even though researchers have largely assumed that such mind-wandering occurred unintentionally. This would be of great importance because it would suggest that theoretical accounts of mind-wandering in educational settings need to be modified to accommodate intentional mind-wandering. Also, perhaps more important, it would suggest that researchers who are interested in reducing the occurrence of mind-wandering in the classroom should pay special attention to reducing intentional mind-wandering, rather than exclusively focusing on methods of reducing unintentional mind-wandering.

In the first of our two live-lecture studies (Wammes, Boucher, et al., 2016; Wammes, Seli, et al., 2016), we were interested in examining two issues raised by the foregoing. First, we were interested in directly assessing overall rates of mind-wandering in a live classroom to determine whether, here, we would observe rates of mind-wandering that were comparable to those reported in laboratory-based studies that used video-recorded lectures. Second, we wanted to determine the extent to which any mind-wandering that we observed occurred with intention. To address these issues, we intermittently presented students with thought probes during the majority of the live lectures, and asked them to report whether they were on task, intentionally mind-wandering, or unintentionally mind-wandering just prior to the presentation of each probe. To provide a response to each thought probe, participants used an "i>clicker," which is a handheld remote that can collect button-press responses in an online manner. In *every* lecture, across the entire term of a second-year course on Physiological Psychology, between 0 and 3 thought probes were presented, and participant responses were collected.

In examining the overall prevalence of mind-wandering during live lectures, we were not altogether surprised by our results. Our live-lecture study showed rates of mind-wandering that were comparable to those that had been previously reported in laboratory-based studies that examined rates of mind-wandering while participants watched video-recorded lectures (e.g., Risko et al., 2012; Seli, Wammes, et al., 2016; Szpunar et al., 2013). Specifically, we found that, on the whole, students reported mind-wandering (whether intentional or unintentional) about 34% of the time when thought probes were presented. Much more surprising, however, were the findings concerning the intentionality of mind-wandering. Interestingly, in contrast to the commonly held assumption that reports of mind-wandering reflect the unintentional drifting of one's attention away from the task, our results showed that students in the live lecture frequently engaged in intentional mind-wandering. In fact, we found that students actually engaged in more intentional mind-wandering (roughly 20% of the time when probed) than unintentional mind-wandering (roughly 15% of the time when probed). Given that the thought probes used in this study were presented at random intervals, this result suggests that participants spent 20% of the lecture time *deliberately* disengaged from the lecture in the service of focusing on their unrelated inner thoughts.

The finding that students so frequently deliberately disengage from live lectures is of critical importance for any strategies aimed at reducing rates of mind-wandering in the classroom. Indeed, under the conventional view that mind-wandering strictly occurs without intention, efforts aimed at reducing mind-wandering would likely be tailored specifically to reducing the unintentional type. Such strategies might rely on exogenously maintaining or capturing attention by increasing the salience of the presented material (MacLean et al., 2009; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), perhaps by including stimulating videos, increasing speaking volume, or ensuring that the presentation slides are colorful and visually stimulating. If mind-wandering were largely unintentional, then, by definition, the student would have no control over his or her mind-wandering and would be left powerless and at the whim of the level of stimulation provided by the lecturer. Thus, from the student's perspective, the prospects of reducing unintentional mind-wandering would be rather grim. However, the finding that a large portion of overall mind-wandering in live lectures is intentional suggests another set of avenues for reducing mind-wandering (see Wammes, Boucher, et al., 2016; Wammes, Seli, et al., 2016).

One of these new avenues involves increasing student motivation. Indeed, as noted earlier, rates of intentional mind-wandering are associated with motivation, such that individuals who are less motivated to attend to the lecture more frequently engage in this type of mind-wandering (Seli, Cheyne, et al., 2015). Accordingly, using incentives to increase student motivation may decrease rates of intentional mind-wandering, which should in turn lead to improvements in comprehension and retention. Another new avenue of intervention involves the use of intermittent tests. Indeed, recent work (Szpunar, Jing, & Schacter, 2014) has suggested that providing students with intermittent tests throughout a lecture might provide feedback about the extent to which the students comprehend the material. This might in turn counteract students' overconfidence in the extent to which they have learned the material. Given that students who are overconfident in their knowledge of the lecture material should be particularly inclined to intentionally disengage from the lecture, correcting overconfidence via intermittent testing might lead to reductions in intentional mind-wandering. Indeed, if students are made aware of the fact that they actually have less knowledge about the lecture material than they assume, then they may feel more inclined to refrain from intentionally disengaging from the lecture.

Mindfulness training also provides an interesting new avenue for potential intervention. Mindfulness training involves practicing an unwavering focus on the present moment, without allowing any one thought to lead to emotional response, or any sort of elaborative process beyond the present thought. In the context of mind-wandering research, however, the most commonly used form of mindfulness training instructs the participant to focus on a particular aspect of their sensory experience (e.g. breathing, posture; Mrazek, Franklin, Phillips, Baird & Schooler, 2013; Mrazek, Smallwood, & Schooler, 2012). Although previous work has shown that mindfulness training is associated with improvements in various cognitive faculties, including working memory (Chambers, Lo, & Allen, 2008; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010) and visuospatial processing (Kozhevnikov, Louchakova, Josipovic, & Motes, 2009; MacLean et al., 2010), only more recently has evidence shown that mindfulness training can be used to effectively minimize the occurrence of mind-wandering. For instance, recent work has shown that eight minutes of mindful breathing resulted in reductions in errors as well as response time variability in the Sustained Attention to Response Task (SART) (Mrazek et al., 2012). Follow-up work has also demonstrated that just two weeks of mindfulness training leads to improved standardized test scores, increased working memory capacity, and most important, decreased mind-wandering in those who are prone to mind-wandering (Mrazek et al., 2013). More extended mindfulness training has also been found to reduce mind-wandering while reading (Zanesco et al., 2016). Taken together, these findings suggest that mindfulness training may be a promising method with which to reduce mind-wandering in various scenarios, and it may be the case that such training is effective in reducing mind-wandering in the classroom. Indeed, research is already underway on the subject, with promising results (for reviews, see Mrazek, Zedelius, Gross, Mrazek, Phillips, & Schooler, 2017; Weare, 2013). It remains unclear, however, whether mindfulness training might have an impact on intentional mind-wandering, unintentional mind-wandering, or both.

One final method with which rates of intentional mind-wandering might be reduced is to simply educate students on the negative consequences of intentional mind-wandering, and to encourage them to avoid engaging in this cognitive experience (see Wammes, Boucher, et al., 2016; Wammes, Seli, et al., 2016). Although research has not yet explored this possibility, it may be the case that students are largely unaware of the negative consequences of mind-wandering, and as such, they may frequently intentionally disengage from lectures under the assumption that doing so will not be consequential. Thus, informing students about the negative consequences of mind-wandering might prompt them to be more attentive during class.

Having identified the practical implications of our lecture studies in terms of improving attentional engagement in live lectures, we should also consider the implications of our findings for the broader literature on mind-wandering, which has examined the causes and consequences of mind-wandering in contexts other than the classroom. We believe that the findings we have discussed suggest several directions for future research on mind-wandering.

First, our findings suggest that it is important for all research on the topic of mind-wandering to abandon the general assumption that reports of mind-wandering reflect only unintentional types of mind-wandering, and to instead query participants about both unintentional and intentional mind-wandering (see also Seli, Risko, Smilek, & Schacter, 2016). We note with considerable excitement that this practice is already being adopted in recent studies of mind-wandering (Phillips, Mills, D'Mello, & Risko, 2016; Seli, Risko, & Smilek, 2016, Seli, Wammes, et al., 2016). Second, our findings suggest that it will become important for researchers to examine whether intentional and unintentional mind-wandering share similar or different relations with other psychological traits. This research direction is also well under way (e.g., Seli, Carriere, & Smilek, 2013; Seli, Smallwood, et al., 2015; Seli, Risko, Purdon, et al., 2017). For example, it has been shown that people with attention deficit hyperactivity disorder (ADHD) and healthy control participants differ in their levels of unintentional mind-wandering, but not in their levels of intentional mind-wandering, as measured by both thought probes and questionnaires (Shaw & Giambra, 1993; Seli, Smallwood, et al., 2015). More recently, a similar pattern of results has been observed in individuals reporting high levels of obsessive-compulsive disorder (OCD) symptomatology (Seli, Risko, Purdon, et al., 2016); that is, individuals scoring high on measures of OCD report more spontaneous, but not deliberate, mind-wandering in their everyday lives relative to individuals who score lower on these measures of OCD. Moreover, research has shown that individuals who report high levels of mindful awareness in everyday life also report higher levels of intentional, but not unintentional, mind-wandering (Seli et al., 2014). Given these emerging findings, it will be important for future research on mind-wandering to determine the similarities and differences in the mechanisms underlying intentional and unintentional mind-wandering, which will in turn allow for a more nuanced understanding of this prevalent phenomenon.

Does Mind-Wandering Increase over Time?

The consensus in the extant literature seems to be that, across a wide variety of tasks, inattention (and also mind-wandering) tend to increase over time on task (for reviews, see Smallwood & Schooler, 2006; Thomson, Besner, & Smilek, 2015). For instance, early work on the topic has reported that inspection workers—whose job is to examine the quality of industrial products—showed reductions in efficiency (20%–30%) within an hour of beginning a shift. This implied that the workers were unable to remain vigilant over extended periods of time on task (Wyatt & Langdon, 1932). Similarly, subsequent work empirically tested the suspicion that radar operators—who work extended shifts during which they monitor screens for infrequent blips that might represent enemy submarines—show declines in efficiency over time (Lindsley & Anderson, 1944). Results indicated that their shifts should not be longer than 30–45 minutes, as this was the time frame during which attention (as measured by detection efficiency) began to wane (Lindsley & Anderson, 1944). Perhaps the most well-known study addressing inattention over time is that reported by Mackworth (1948), who had participants observe a moving clock-hand and detect infrequent instances where the hand moved twice the distance that it had ordinarily moved. As one might expect, performance dropped substantively over time, with sizable decrements occurring within the first 30 minutes of task performance. This general finding of a "vigilance decrement" (i.e., decreases in performance over time in sustained-attention tasks) has since proven reliable in many different paradigms (e.g., Adams, 1956; Bakan, 1955; Colquhoun, Blake, & Edwards, 1968; Fisk & Schneider, 1981; Frankman & Adams, 1962; Helton & Russell, 2011; Molloy & Parasuraman, 1996; Mackworth, 1950, 1968; Nuechterlein, Parasuraman, & Jiang, 1983; Parasuraman, 1979, 1984; Parasuraman, Warm, & Dember, 1987; Parasuraman, Warm, & See, 1998; Temple et al., 2000; Warm, 1984).

Importantly, the aforementioned findings have led some to conclude that vigilance decrements are inevitable, and reflect a basic limitation of the human cognitive system (e.g., Grier et al., 2003; Helton & Russell, 2011; Helton & Warm, 2008; Muraven & Baumeister, 2000; Nuechterlein et al., 1983; Smit, Elling, & Coenen, 2004). For instance, proponents of the *resource depletion theory* (e.g., Helton & Russell, 2011; Helton & Warm, 2008) posit that sustaining attention over time requires the engagement of cognitive resources, and furthermore, that one's pool of cognitive resources is finite and limited. In particular, the theory holds that sustained-attention tasks require continuous mental effort, so the limited pool of cognitive resources is continually depleted or "drained." To exacerbate the issue, the pool of resources does not have an opportunity to be "replenished" because the continuous nature of sustained-attention tasks does not permit any breaks. Accordingly, the continued reduction in available resources over time leads to notable performance decrements.

Researchers in the mind-wandering literature have observed a pattern of results analogous to the pattern reported in the vigilance literature, such that rates of self-reported mind-wandering tend to increase over protracted periods of task engagement (e.g., McVay & Kane, 2012; Teasdale, Segal, & Williams, 1995), and this increase often co-occurs with a decrease in performance (Cunningham, Scerbo & Freeman, 2000; McVay & Kane, 2012; Seli, Cheyne, & Smilek, 2012; Smallwood et al., 2004). Recent work has directly tested whether the increases in mind-wandering that accompany time-on-task were associated with decreases in performance, and found that more marked increases in rates of mind-wandering were associated with steeper declines in performance measures, suggesting a close coupling between mind-wandering and declines in performance (Thomson, Seli, et al., 2014).

Set against the background of the general vigilance and mind-wandering literatures, it is perhaps not surprising that, within the specific contexts of video and staged live lectures, mind-wandering rates (or rates of inattention) tend to increase over time (Farley, Risko & Kingstone, 2013; Risko et al., 2012; Risko et al., 2013; Stuart & Rutherford, 1978; Young et al., 2009). Also in line with the foregoing general findings, research has indicated that inattention in educational settings is closely associated with impairments in later retention of lecture material (Cameron & Giuntoli, 1972; Lindquist & McLean, 2011; Risko et al., 2012; Schacter & Szpunar, 2015; Schoen, 1970). Taking into account the consensus of the foregoing research on vigilance, mind-wandering, and more specifically on mind-wandering during lectures, it seems an obvious prediction that, if measured during an actual live lecture in an authentic university course, mind-wandering rates would also increase over time.

Surprisingly, however, when we explored this possibility across two full-term studies within live lectures, we discovered no evidence of such an increase. As noted earlier, in our first study (Wammes, Boucher, et al., 2016) we probed students during class and asked them to indicate whether they were (1) on task, (2) intentionally mind-wandering, or (3) unintentionally mind-wandering just prior to the presentation of each probe. Probe responses were then aggregated across the entire term, and separated into four 12-minute segments that spanned the entirety of an average lecture. In examining these data, there was no evidence to indicate an increase in mind-wandering rates over time. In fact, there was a small but significant decrease in mind-wandering rates from the third to the fourth quarter of the lecture, which was driven primarily by a decrease in unintentional mind-wandering (Wammes, Boucher, et al., 2016).

In the wake of this study, whose results were inconsistent with much of the previous work on the topic (e.g., Risko et al., 2012), we reasoned that perhaps an increase in mind-wandering (i.e., a vigilance decrement) does in fact occur during live lectures, but that our dichotomous thought probe (i.e., "on task" or "mind-wandering") was not sensitive enough to detect this increase. Specifically, we thought it was possible that the depth, or intensity, of students' mind-wandering might increase as time passes in the lecture, but that this variation in the depth of mind-wandering might not be captured by the rather crude dichotomous thought probe that we used in our first study. Moreover, given that some previous work suggests that people can indeed remain vigilant for nearly 45 minutes (e.g., Lindsley & Anderson, 1944), it is possible that we simply had not observed a lecture that was sufficiently long to elicit increases in rates of mind-wandering over time. With this in mind, we conducted a follow-up study across another entire semester of an undergraduate course (Wammes & Smilek, 2017), in which we modified the thought probe such that it indexed the depth of mind-wandering. The rationale was that, if participants were asked to indicate the degree to which they were mind-wandering (rather than simply indicating whether they were or not), then we might find that participants plunge into deeper states of mind-wandering as time elapses in the lecture—a pattern that would not have been observable with our coarser dichotomous probes. Thus, in our second study, upon presentation of each thought probe, we asked participants to indicate whether they were (1) completely on task, (2) mostly on task, (3) both on task and mind-wandering, (4) mostly mind-wandering, or (5) completely mind-wandering. As in our earlier work, probe responses were then aggregated and divided into quarters of the lecture. Importantly, this course consisted of 80-minute lectures, which allowed us the added benefit of exploring changes in mind-wandering behaviors over larger time scales in lectures. Thus, rather than four 12-minute segments, the lecture was divided into four 18.5-minute segments. Contrary to our hypothesis, our results showed no consistent evidence for time-on-task effects, and the average depth of mind-wandering was largely stable across quarters of the lecture (Wammes & Smilek, 2017). So, again, we found no evidence of an increase in mind-wandering (or depth of mind-wandering) over time in a live lecture.

At this point, it is important to provide clarification to ensure that the conclusions we drew from these studies are not misunderstood. First, based on our findings, we are *not* arguing that mind-wandering does not increase over time in *some* (or even *most*) undergraduate lectures. Second, we do not wish to argue that the time-related mind-wandering increments shown in the context of video lectures are somehow spurious (in fact, we have replicated those findings in our own laboratory; Wammes & Smilek, 2017). Rather, we wish to advance the claim that, at least in some live undergraduate lectures, mind-wandering increments do not occur. In other words, we provided evidence that mind-wandering increments are not a *necessary* outcome of time on task by highlighting two instances where increments *did not* occur. As there are still some undergraduate courses that employ two- to three-hour long lectures, it may be possible that mind-wandering increments would occur in these cases. Future work will be needed to determine whether these lengthier lectures are more likely to elicit increases in mind-wandering.

So, why is it that our studies of mind-wandering in live lectures failed to produce a mind-wandering increment over time in an average class? We have already made the case that our findings were unlikely to be an artifact of poor measurement sensitivity in our design. But what else could explain our findings? One likely possibility is that when students are actually enrolled in a real course (as in our experiments), the stakes are simply higher. In a laboratory study, the implications of a student's mind-wandering are largely negligible once he or she has left the laboratory (i.e., there are no serious consequences of mind-wandering); in an actual course, students are formally evaluated on their retention of lecture material. This renders mind-wandering during these lectures considerably more consequential than mind-wandering in a laboratory study. Accordingly, it is possible that the participants in our live-lecture study were much more intrinsically motivated to complete the "task" (i.e., learn from the lecture) than those whom one would traditionally find enrolled in a simulated-lecture experiment. This explanation is consistent with previous research suggesting a modulatory role of increased motivation in reducing mind-wandering rates (Antrobus, Singer, & Greenberg, 1966; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Wammes, et al., 2016; Unsworth & McMillan, 2013). Moreover, some accounts of the vigilance decrement posit that motivation and task value might play an important role in sustained-attention performance (e.g., Kurzban, Duckworth, Kable and Myers, 2013). For example, Hancock (2012) has argued that vigilance decrements occur when one's motivation to complete a particular task is mostly extrinsic (i.e., driven by external factors), and furthermore, that vigilance decrements can be drastically reduced or eliminated when people are intrinsically motivated (i.e., driven by internal personal value) to complete the task. Similarly, Hockey (2013, p. 134) has distinguished between "have to" and "want to" tasks, arguing that performance declines over time occur primarily in tasks that we "have to" complete, but not in tasks that we "want to" complete. With this, it seems likely that motivation played a key role in our finding that mind-wandering did not increase over time.

Does Mind-Wandering Result in Decreases in Task Performance?

Another commonly held assumption is that episodes of mind-wandering are associated with poorer task performance, including poorer retention of material presented in lectures. The idea that episodes of mind-wandering might influence performance during laboratory tasks pops up several times in the historical literature. Perhaps one of the earliest reports of the negative effects of off-task thought on performance comes from Hermann von Helmholtz. According to Schmidgen (2002, p. 144), when discussing his possible sources of measurement errors during his studies of reaction times while exploring the speed of nerve conduction, Helmholtz (1850, p. 4) reported the following: "If at the time of perceiving the signal the thoughts are occupied with something else, and if the mind has to recall to itself what kind of movement one must carry out, it [the reaction] takes much more time." Similarly, in the late 1960s, Antrobus (1968) showed that participants' ability to classify different tone frequencies was negatively associated with their propensity to report "stimulus-independent thoughts" (i.e., mind-wandering). Subsequent work employing comparably mundane tasks, including the SART (Christoff et al., 2009; Smallwood et al., 2004), and the Metronome Response Task (MRT) (Seli, Cheyne, & Smilek, 2013), has demonstrated that performance is similarly impaired during periods of mind-wandering. This trend seems to apply in more complex and engaging tasks as well. For instance, mind-wandering that occurs while people encode words in a memory paradigm is associated with impairments in subsequent retrieval efforts (e.g., Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Thomson, Smilek, & Besner, 2014). Similarly, when retrieving studied words from memory, increases in mind-wandering are associated with increases in false alarms (Smallwood et al., 2003). Experiments measuring narrative comprehension while reading also suggest that instances of mind-wandering are associated with lower scores on later text-comprehension tests (Schooler, Reichle, & Halpern, 2004; Smallwood, McSpadden, & Schooler, 2007; Unsworth & McMillan, 2013).

Taken together, the aforementioned findings provide compelling evidence to suggest that mind-wandering has negative effects on successful task performance. However, there are notable exceptions to this trend, which indicate that the simple conclusion that mind-wandering is always associated with performance decrements is too strong a position to take. For instance, Thomson, Besner, & Smilek (2013) measured mind-wandering rates during word reading and Stroop tasks while systematically varying task difficulty within each task. Mind-wandering rates were sensitive to the difficulty of the task, such that participants were more likely to mind-wander in the easiest iteration of the task. Interestingly, though, these fluctuations in mind-wandering rates were not associated with any changes in performance, in either response times or error rates. Thomson et al. (2013) suggest that this may reflect a situation in which participants are optimally dividing their attention between the primary task and mind-wandering, such that the resources one allocates to the primary task are sufficient to preclude performance declines, while the remaining resources are allocated to mind-wandering (Thomson et al., 2013). Consistent with this idea, previous work has demonstrated that individuals with high working-memory capacity (which might be akin to one's pool of available "resources") spend more time mind-wandering during tasks with low demands (Baird, Smallwood, & Schooler, 2011; Levinson, Smallwood, & Davidson, 2012; Rummel & Boywitt, 2014).

It is also worth considering that, although mind-wandering can undermine primary task performance, some work has suggested that it may serve longer-term goals by facilitating perspective taking in relationships, complex problem-solving and decision-making, and future planning (e.g., Baars, 2010; Baird et al., 2011; Baumeister & Masicampo, 2010; Ruby, Smallwood, Sackur, & Singer, 2013). This more adaptive form of mind-wandering may be the sort that occurs during university lectures. It seems plausible, then, that although drifting to task-unrelated thoughts may lead to poorer immediate performance within a lecture, the long-term effects may not be as substantial, as students may be engaging in mind-wandering to allow them to elaborate upon learned material.

Most studies of mind-wandering within a lecture environment, however, have demonstrated that mind-wandering is typically associated with reduced performance (see Szpunar, Moulton & Schacter, 2013, for a review). In one such example, Lindquist and McLean (2011) explored the frequency at which "task-unrelated images and thoughts" (TUIT; i.e. mind-wandering) occurred during an introductory psychology lecture. During one selected lecture, an alarm sounded five times throughout the lecture. In response to this alarm, participants circled "yes" or "no" on a handout to indicate whether they were or were not experiencing TUIT at the time of the alarm. Results indicated a TUIT rate of 32.9%, and these rates were negatively associated with general academic ability and people's propensity toward note-taking (Lindquist & McLean, 2011).

Later work using video lectures showed comparable results, such that mind-wandering was negatively associated with retention, and that as mind-wandering rates increased over time, retention of material presented in the lecture suffered (Risko et al., 2012; Risko et al., 2013). At a broader level, recent work required participants to record everyday attention failures in a diary over the course of a week, including when and where the lapse in attention occurred (Unsworth, McMillan, Brewer & Spillers, 2013). Interestingly, these attention failures were most frequently reported when participants were in educational settings (including while studying and attending to lectures). Moreover, this specific subset of attention failures was negatively associated with standardized test scores, indicating that individuals who more frequently mind-wander are often also poorer academic performers—a finding that is concordant with previous work (e.g., Lindquist & Mclean, 2011; Risko et al., 2012; Risko et al., 2013). Furthermore, in our recent work, rates of both intentional and unintentional mind-wandering were negatively associated with the retention of material presented in a video lecture (Seli, Wammes, et al., 2016).

The most logical conclusion one might draw from the foregoing results is that performance will always suffer when a student mind-wanders during lectures. However, most research on the topic involves video lectures, staged lectures, or single live lectures. Thus, we sought to test whether this assumption applies to a live university course, and did so by observing and collecting data in a real university course over the entire term. In addition, we sought to evaluate whether the same effect on performance would be observed for both intentional and unintentional episodes of mind-wandering. Specifically, it was possible that intentional mind-wandering (as opposed to unintentional mind-wandering) might not be as strongly associated with long-term retention failures, as participants could be adaptively mind-wandering to allow them to better integrate presented material.

Before outlining the results of our study, we should revisit the specific details of the study. Recall that, in our study, participants were intermittently presented with thought probes that asked them to use their i>clicker to report on their current mental state (i.e., "on task," "intentionally mind-wandering" or "unintentionally mind-wandering"). In addition, quiz questions at the end of every lecture were used to gauge participants' retention of presented material. Finally, participants allowed us access to their actual exam grades for analysis. Although these are the most critical details of our study, there is one final detail (omitted from our earlier description of this study) that is important for understanding the results that we present in the following. In particular, the quiz questions that we gave students were drawn from material that was presented either on the slide immediately preceding, or immediately following each thought probe (Wammes, Seli, et al., 2016). This feature of our design is particularly important because it allowed us to explore the relation between mind-wandering behaviors and performance at a number of different levels. Specifically, our design allowed us to answer the following questions: (1) In the case that a participant were to report that he was intentionally mind-wandering, how well would he retain information that was presented *while* he was mind-wandering? (2) If a participant mind-wanders more frequently in general, does this affect her overall quiz accuracy or exam scores? And (3) are the effects of mind-wandering on exam scores mediated by performance on in-class quiz scores? In other words, does one's propensity to mind-wander directly influence his quiz scores, which in turn influences exam scores? Or, alternatively, is the relation between mind-wandering propensity and exam scores independent of quiz scores?

Results of our study showed that quiz questions derived from material that was presented while people reported that they were intentionally mind-wandering were answered with significantly less accuracy than questions that asked about material that was presented while people were on task. Similarly, quiz questions based on material that was presented while people were unintentionally mind-wandering were answered with marginally less accuracy than questions that asked about material that was presented while people were on task. Finally, accuracy on quiz questions that were associated with periods of intentional mind-wandering did not differ from those that were associated with periods of unintentional mind-wandering. What these findings suggest, then, is that information presented *while* a participant is mind-wandering (whether intentionally or unintentionally) is not retained as well as information that is presented while he or she is on task. Interestingly, correlation and regression analyses revealed that rates of intentional, but not unintentional, mind-wandering were significantly (uniquely) associated with in-class quiz scores. Conversely, these analyses showed that unintentional, but not intentional, mind-wandering rates were (uniquely) predictive of later exam scores. To further explore these relations, we conducted a mediation analysis, where we sought to determine whether rates of mind-wandering (both intentional and unintentional) influenced final exam scores indirectly via performance on in-class quiz scores, or only directly (i.e., without the influence of in-class quiz scores). In other words, we tested the hypothesis that intentional and unintentional mind-wandering rates might be associated with decreased quiz scores, which would in turn be associated with decreased final exam scores. Intentional mind-wandering was only related to later exam scores *indirectly* through in-class quiz performance, whereas unintentional mind-wandering was only *directly* related to final exam scores (Wammes, Seli, et al., 2016). Taken together, these findings suggest that, although intentional mind-wandering can be detrimental in the short term, the long-term effects are not as apparent and only play an indirect role through their association with short-term quiz scores. On the other hand, unintentional mind-wandering, although slightly less harmful in the short term, has significant negative effects on later exam scores.

Conclusion

To begin this chapter, we suggested that one could draw three potentially erroneous general conclusions based on the extant literature examining mind-wandering in educational contexts: (1) the prevalence of unintentional mind-wandering in classroom settings is high, (2) mind-wandering rates increase over time, which is sometimes taken as a reflection of a basic cognitive limitation in humans, and (3) mind-wandering interferes with learning and performance. In our studies, we demonstrated that, although there was a notable proportion of unintentional mind-wandering in the classroom, more than half of all mind-wandering that occurred was actually intentional in nature. Our data also showed no increase in mind-wandering over the course of live lectures (both 50 minute and 80 minutes in length). Finally, we showed that mind-wandering interfered with learning and performance, although our conclusions were more nuanced than this: specifically, whereas intentional mind-wandering led to more short-term impairments in performance on the immediate quiz questions, unintentional mind-wandering was more tightly linked with long-term performance deficits on course exams.

These findings, especially those showing no increase in mind-wandering over time in a lecture, strongly suggest that there may be important differences between studies conducted in the laboratory and studies conducted in live lecture settings. Given that studies on attention and retention in the classroom have important and far-reaching implications for educational structuring and for the development and implementation of methods aimed at improving students' attention, it is critical to consider the differences between the results obtained in the laboratory and those obtained in live lectures, and to determine what, precisely, these differences mean. Interestingly, most of the mind-wandering that students reported in our studies was intentional in nature. Given that mind-wandering has previously been assumed to be largely unintentional (e.g., Bixler & D'Mello, 2014; Blanchard et al., 2014; Carciofo et al., 2014; Qu et al., 2015; Rummel & Boywitt, 2014; Wilson et al., 2014), the finding that mind-wandering during live lectures was largely intentional demands a shift in the strategies one might employ to reduce the occurrence of mind-wandering in the classroom. The available evidence suggests that intentional mind-wandering is more closely associated with motivational problems than unintentional mind-wandering (Seli, Cheyne, et al., 2015; Seli, Wammes, et al., 2016). Thus, strategies that increase one's intrinsic motivation to pay attention during class might be more effective than a strategy that might be used to address unintentional mind-wandering, such as mindfulness meditation training.

The findings we discussed here (specifically those that demonstrate inconsistencies between laboratory studies and veridical lectures) are important to consider when extrapolating laboratory findings to real life. There are clearly some aspects of the dynamic relation between mind-wandering and academic performance that might not be effectively captured in staged, stand-alone, or video lectures. Thus, moving forward, it would be advisable for researchers to conduct studies in both video-recorded and live lectures so they can fully ascertain the trends in and effects of mind-wandering in educational settings.

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PART V

Creativity and Insight

CHAPTER

21 Interacting Brain Networks Underlying Creative Cognition and Artistic Performance

Roger E. Beaty *and* Rex E. Jung

Abstract

Cognitive neuroscience research has begun to address the potential interaction of brain networks supporting creativity by employing new methods in brain network science. Network methods offer a significant advance compared to individual region of interest studies due to their ability to account for the complex and dynamic interactions among discrete brain regions. As this chapter demonstrates, several recent studies have reported a remarkably similar pattern of brain network connectivity across a range of creative tasks and domains. In general, such work suggests that creative thought may involve dynamic interactions, primarily between the default and control networks, providing key insights into the roles of spontaneous and controlled processes in creative cognition. The chapter summarizes this emerging body of research and proposes a framework designed to account for the joint influence of controlled and spontaneous thought processes in creativity.

Key Words: creativity, cognitive neuroscience, default network, control network, brain connectivity, cognition

Creativity is a seemingly complex and mysterious construct, and the neuroscience of creativity has proven similarly elusive in its quest to capture creativity in the brain. Seminal meta-analyses reported activations of brain regions spanning most of the cortex, raising questions about whether creativity can be reliably distilled to a discrete area of the brain (Arden, Chavez, Grazioplene, & Jung , 2010; Dietrich & Kanso, 2010). These inconclusive findings also fueled enduring questions surrounding the role of cognitive control in creative thought, as several studies reported activation of brain regions linked to both cognitive control and spontaneous thought. Many studies implicated regions of the brain's default network, a set of brain regions associated with spontaneous and self-generated cognition (Beaty et al., 2014; Ellamil, Dobson, Beeman, & Christof, 2012; Jung, Mead, Carrasco, & Flores , 2013; Takeuchi et al., 2011, 2012; Wei et al., 2014). On the other hand, a similarly large literature implicated regions of the executive control network, a set of regions linked to focused attention and cognitive control (Benedek et al., 2014a; Ellamil et al., 2012; Fink et al., 2012; Jung et al., 2013; Takeuchi et al., 2010). Notably, a majority of past research assessed the isolated contribution of individual brain regions, so whether these regions interacted to support creative thought remained unclear.

Networks of the Brain and Relevance to Creative Cognition

The human brain is comprised of several interacting large-scale networks (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). Networks consist of brain regions that are spatially distributed but correlated with one another through structural or functional interactions. Such networks are often studied using resting-state functional magnetic resonance imaging (fMRI), a technique that involves acquiring spontaneous fluctuations in blood- oxygen- level- dependent (BOLD) signals as participants relax, awake in the scanner, without performing a cognitively engaging task. Critically, networks identified at rest have been shown to contribute to basic cognitive and perceptual processes in task-based fMRI, suggesting an interaction between default and executive control networks across human cognition (Cocchi, Zalesky, Fornito, & Mattingley, 2013). Here, we focus primarily on functional networks with potential relevance to creative cognition and artistic performance, namely the default and executive control networks.

The first network to be described in the neuroimaging literature was the so-called default mode network or default network (Raichle et al., 2001; Shulman et al., 1997). The default network consists of midline and posterior inferior parietal brain regions, and its activity is associated with self-referential or "self-generated" thought, including mind-wandering, daydreaming, episodic memory retrieval, episodic future thinking, and mentalizing, among others (Andrews-Hanna, Spreng, & Smallwood, 2014; Buckner, Andrews-Hanna, & Schacter, 2008; Stawarczyk & D'Argembeau, 2015). The default network is thus characterized by internally focused mental activity that occurs in the absence of external stimulation (i.e., stimulus-independent thought; Giambra, 1995). Several neuroimaging studies have reported activation of default regions during both creative cognition and artistic performance (for reviews, see Beaty, Benedek, Silvia, & Schacter, 2016a; Gonen-Yaacovi et al., 2013; Wu et al., 2016). In light of the default network's role in imaginative thought (e.g., daydreaming), researchers hypothesize that its activation during creative thinking tasks reflects spontaneous or self-generated thought (Abraham, 2014; Beaty et al., 2014; Benedek et al., 2014a; Chen et al., 2014; Chen et al., 2015; Ellamil et al., 2012; Jauk, Neubauer, Dunst, Fink, & Benedek , 2015; Jung et al., 2013; McMillan, Kaufman, & Singer, 2013; Mok, 2014).

The executive control network is another core network of the brain. Comprised of lateral prefrontal and anterior inferior parietal regions, the control network shows activation during experimental tasks that require externally-focused attention and cognitive control, such as working memory, response inhibition, task-set switching, and goal maintenance (Seeley et al., 2007). Regions of the control network have been implicated in structural and functional neuroimaging studies of creativity (Wu et al., 2016), consistent with behavioral research reporting associations between executive processes and creative cognition (Beaty & Silvia, 2012, 2013; Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014b; Gilhooly, Fioratou, Anthony, & Wynn, 2007; Jauk, Benedek, Dunst, & Neubauer, 2013). Cognitive control is thought to benefit creative cognition via top-down monitoring and goal maintenance during complex search processes. In the absence of such control, creative thought may rely solely on the spontaneous generation of ideas that do not necessarily adhere to a given task goal, akin to the production of mere novelty without corresponding usefulness.

The default and control networks were initially characterized by their antagonistic relationship with one another. Seminal resting-state fMRI studies demonstrated a negative association or "anti-correlation" between regions of the default and control networks (Fox et al., 2005). Moreover, the default network shows task-induced deactivation during experimental tasks that require focused external attention and cognitive control (e.g., working memory), which corresponds with activation of the control network (Seeley et al., 2007). Because the default network is associated with mind-wandering and other spontaneous thought processes, researchers have hypothesized that default network deactivation reflected the suppression of task-unrelated thoughts during cognitively demanding tasks (Anticevic, Cole, Murray, Corlett, Wang, & Krystal, 2012).

More recently, however, the notion that the default and control networks always work in dynamic opposition has been questioned. Indeed, several recent studies have reported cooperation of the default and control networks during cognitive tasks that involve both goal-directed and self-generated cognition, such as autobiographical future planning (Spreng & Schacter, 2012; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010) and mind-wandering (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015). Autobiographical future planning, for example, involves the construction of a detailed mental representation about a future goal state (Spreng et al., 2010). In this context, the default network is thought to provide episodic content, while the control network directs and integrates this information into a coherent and realistic mental representation to be implemented in the external world. In the following, we provide evidence that creativity similarly involves such goal-directed, self-generated thought, by illustrating the cooperative role of the default and control networks during creative cognition and artistic performance.

Brain Networks and Creative Cognition

Brain network research has provided key insights into the neural basis of higher-order cognition, including core human attributes such as intelligence and personality (Beaty et al., 2016b; van den Heuvel, Stam, Kahn, & Pol., 2009). A network approach can reveal the extent to which the interaction of distributed brain regions gives rise to various cognitive processes. Several recent studies have embraced network methods to examine network interactions underlying domain-general creative cognition (e.g., divergent thinking). As noted earlier, seminal research on the structural and functional correlates of creative thought yielded a rich but largely inconsistent body of work (Arden et al., 2010; Dietrich & Kanso, 2010). Such work implicated a diffuse set of brain regions associated with a range of cognitive processes. Critically, researchers often reported the involvement of both default and control network regions, raising questions about whether creative thought was more a product of spontaneous thought or cognitive control (Jung et al., 2013). Moreover, the extent to which creative cognition involved cooperation among default and control network regions remained unclear, as these networks have shown both cooperation and competition during resting-state and task-based fMRI (Cocchi et al., 2013).

To address this question, a recent study explored brain network dynamics underlying performance on a divergent thinking task (Beaty, Benedek, Kaufman, & Silvia, 2015). Using a task paradigm similar to past research (e.g., Fink et al., 2009), the authors asked participants to think of alternate uses for common objects (i.e., divergent thinking) or to simply think about the physical properties of objects; the resulting task contrast revealed brain regions engaged during the creative transformation of objects while controlling for activity related to simple semantic processing and/or mental imagery. Whole-brain functional connectivity analysis was used to contrast differences in voxel-to-voxel connectivity between the two tasks. Notably, this approach could not provide information about which specific brain regions were correlated during performance of the task, nor could it reveal potential temporal differences in connectivity between regions across the task duration. Thus, a series of *post hoc* analyses were conducted using regions of interest (ROIs) identified in the whole-brain analysis.

The whole-brain results revealed a network of regions that showed connectivity differences during divergent thinking compared to the control task. This network included several core hubs of the default (precuneus and posterior cingulate cortex [PCC]) and control (right dorsolateral prefrontal cortex [dlPFC]) networks, among other regions (see Figure 21.1A). To confirm the network affiliation of these voxel clusters, the authors conducted resting-state functional connectivity analysis, using the peak coordinates of the ROIs from the whole-brain analysis; this analysis used resting-state fMRI data from an independent sample of age-matched participants. The results confirmed the hypothesized resting-state network affiliation of the three ROIs: both the precuneus and PCC showed positive coupling with other regions of the default network (medial prefrontal cortex [mPFC] and bilateral inferior parietal lobe [IPL]) and salience network (anterior cingulate cortex [ACC] and bilateral insula); in contrast, these regions showed negative coupling with the control network (i.e., dlPFC and bilateral anterior IPL). Likewise, the right dlPFC showed positive coupling with other regions of the control network and negative coupling with default regions.

Having confirmed the network affiliation of the ROIs, the authors then examined their connectivity with other regions during the divergent thinking task, using both static and dynamic network analysis. Regarding static connectivity, the results showed increased functional connectivity between the default ROIs and regions of the control and salience networks (see Figure 21.1B). Similarly, the right dlPFC showed increased connectivity with regions of the default network. To determine whether these patterns of connectivity were constant (static) or dynamic, the authors employed a temporal connectivity analysis that divided the task into several two-second time bins, corresponding to the fMRI acquisition time (i.e., TR). Results revealed a dynamic pattern of coupling that unfolded across the task duration (see Figure 21.1C). Both the PCC and precuneus showed early coupling with salience network regions (i.e., bilateral insula) and later coupling with control network regions (i.e., dlPFC), pointing to delayed interaction between default and control regions. This temporal pattern was mirrored in the dlPFC, which only showed connectivity differences later in the task, including coupling with default regions (PCC and left IPL). Taken together, the results point to a cooperative and dynamic contribution of the default and control networks to divergent thinking.

The notion that creative cognition involves interactions of the default and control networks received further support from two recent studies (Green,

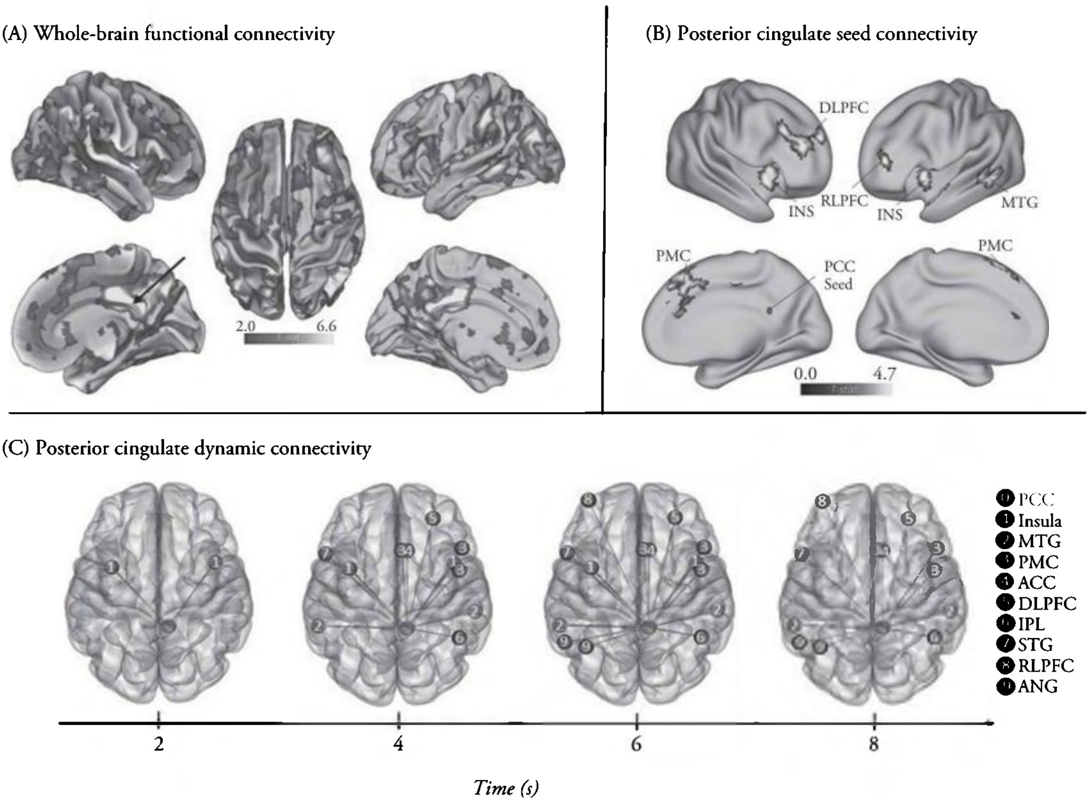

Figure 21.1. (See Color Insert) Default network interactions during divergent thinking. (A) A whole-brain network associated with divergent thinking, including several default regions (e.g., posterior cingulate). (B) The posterior cingulate shows increased coupling with control (e.g., dorsolateral prefrontal cortex) and salience (e.g., insula) network regions across the task duration. (C) Temporal analysis reveals early coupling of the posterior cingulate with salience regions and later coupling with control regions, among others. ACC = anterior cingulate cortex; ANG = angular gyrus; DLPFC = dorsolateral prefrontal cortex; IPL = inferior parietal lobe; MTG = middle temporal gyrus; PMC = pre-motor cortex; RLPFC = rostrolateral prefrontal cortex; STG = superior temporal gyrus.

Cohen, Raab, Yedibalian, & Gray, 2015; Mayseless, Eran, & Shamay-Tsoory, 2015). Green and colleagues adopted the classic verb generation task, which involves generating verbs (i.e., actions) in response to a series of presented nouns (i.e., things). The task was modified to assess creative cognition by asking participants to "think creatively" when generating verbs, or to simply generate a typical verb in response to nouns; latent semantic analysis was then used to quantify the semantic distance between the nouns and verbs in each condition. Results showed that compared to generating typical verbs, generating creative verbs was associated with greater activation in several brain regions, including the mPFC, a core hub of the default network. Critically, a functional connectivity analysis revealed that, as the semantic distance between the nouns and verbs increased in the creative condition, the mPFC showed stronger coupling with the dorsal anterior cingulate cortex (dACC)—a brain structure commonly associated with executive control. These findings suggest that the ability to flexibly combine conceptual information involves increased cooperation of brain regions linked to spontaneous thought and cognitive control.

Additional support for this proposal comes from another recent fMRI study of divergent thinking (Mayseless et al., 2015). This study sought to assess brain activity and functional connectivity associated with the originality of divergent thinking responses—defined as the relative rarity of the response. Similar to other task paradigms (Beaty et al., 2015; Fink et al., 2009), participants were presented with common objects and were asked to either generate alternate uses (i.e., divergent thinking) or to generate physical characteristics of the objects. Participant responses were coded for originality by trained raters, permitting an analysis of brain activity and connectivity related to the ability to generate uncommon ideas. Results showed that originality scores were associated with increased activation of default network regions, including the mPFC and the PCC. Moreover, a functional connectivity analysis showed that originality was related to greater coupling of the dACC with the occipital-temporal region. Taken together with the results of Beaty et al. (2015) and Green et al. (2015), these findings provide support for the cooperative role of brain regions involved in cognitive control and spontaneous thought during creative cognition. Moreover, it highlights a possible progression of functional connectivity from networks linking novelty generation (i.e., default network) with focused attention (i.e., salience network), and progressing to networks associated with the implementation of ideas (i.e., control network).

This neuronal progression from novelty generation to implementation/execution is at the core of the major advance provided by network perspectives within the creativity neurosciences. Additionally, the integration of various brain networks in the execution of creative ideas likely explains the lack of specificity apparent in previous reviews focused on static measures of discrete brain-behavior correlates of creative cognition. These reviews, which covered structural, functional, and lesion studies, all showed widespread patterns that lacked sufficient specificity—whether by virtue of hemisphere, lobe, or region—regarding how creative cognition is organized in the human brain (Arden et al., 2010; Dietrich & Kanso, 2010). Just as creativity has been hypothesized to involve discrete stages of preparation, incubation, illumination, and evaluation (Poincare, 1913), its manifestation in the human brain involves the dynamic interaction of networks that plausibly underlie these broad cognitive constructs.

Brain Networks and Artistic Performance

A growing body of research has explored the brain basis of artistic performance. But like the literature on domain-general creativity, this literature was initially marked by seemingly contradictory findings. Neuroimaging studies of musical improvisation, for example, reported activation of regions within the default and control networks (see Figure 21.2), raising questions about whether improvisation involved more or less cognitive control (Beaty, 2015). In a striking illustration of this paradox, Limb and Braun (2008) and Berkowtiz and Ansari (2008) published results within the same year with widely diverging conclusions. While Limb and Braun (2008) reported widespread deactivation of control network regions and increased activation of default regions, Berkowitz and Ansari (2008) reported increased activation of several regions involved in cognitive control. Such conflicting findings raised questions about whether musical improvisation required cognitive control, spontaneous thought, both, or neither.

To address this paradox, a recent study assessed brain network interactions during musical improvisation (Pinho, Ullén, Castelo-Branco, Fransson, & de Manzano, 2016). Professional pianists improvised on an MRI-compatible keyboard during two experimental conditions. One condition presented a specific set of piano keys (or "pitch sets"); participants used only these keys to generate melodic

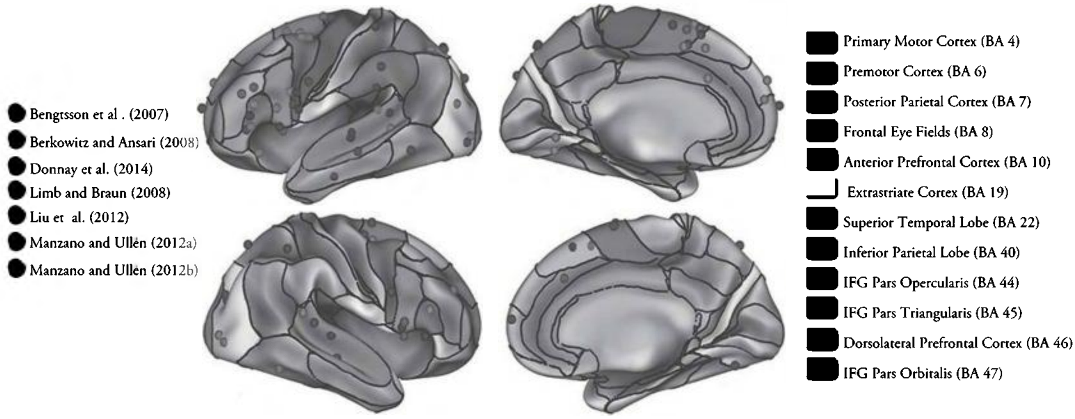

Figure 21.2. (See Color Insert) Visualization of brain activation peaks reported in fMRI studies of improvisation. Highlighted regions indicate areas with activation reported in at least two of the seven studies included in the figure. Note that several activations are located within regions of the default network (anterior prefrontal cortex) and control network (dorsolateral prefrontal cortex).

sequences. The other condition presented emotional cue words (e.g., "joy"); participants were asked to express the given emotion during improvisation. The authors used functional connectivity analysis with the dlPFC as a region of interest to assess its interaction with other brain regions during each condition. Compared to the emotion condition, the "pitch set" condition revealed increased connectivity between the dlPFC and regions associated with motor planning control (e.g., pre-supplementary motor area). Conversely, the emotion condition was associated with increased coupling between the dlPFC and regions of the default network (e.g., mPFC and PCC). These findings suggest that improvisation involves cooperation between control and default network regions during the strategic expression of emotion.

Further evidence for the cooperative role of the default and control networks comes from a recent study of poetry composition (Liu et al., 2015). Here, professional poets were asked to spontaneously generate new lines of poetry in one condition, and then to revise their previously generated poetry in another condition. To explore brain networks associated with both conditions, the authors used independent component analysis (ICA)—a data-driven method used to identify spatially and temporally distinct clusters of brain regions (i.e., networks). ICA revealed brain networks associated with overall task performance; one included default network regions, and another included control network regions. During idea generation, the default and control network clusters were negatively correlated. During idea revision, however, the correlation between the networks increased significantly. Thus, the results demonstrate task-specific differences in network dynamics underlying two key aspects of poetry composition, with default-control network coupling associated with the strategic revision of spontaneously generated ideas.

Brain network dynamics also have been explored during artistic drawing (Ellamil, Dobson, Beeman, & Christoff, 2012). This study employed a similar paradigm as the poetry composition study to examine network interactions involved in the generation and evaluation of visual art. Using an MRI-compatible drawing pad, semi-professional visual artists generated (sketched) ideas for a book cover based on a series of descriptions, and then evaluated these sketches in a separate condition. Results revealed that idea generation recruited several regions of the default network, whereas idea evaluation simultaneously recruited regions of both the default and control networks. Critically, a functional connectivity analysis revealed increased coupling between default and control regions during idea evaluation. These findings are consistent with the poetry composition study of Liu et al. (2015), and suggest that the default and control networks show increased cooperation when artists engage in the critical evaluation of self-generated ideas. Such work is also consistent with the interaction of default and cognitive control networks during creative cognition, with generative aspects being associated with decoupling, and implementation (e.g., planning and goal maintenance) components being associated with increased coupling between default and control networks (Beaty et al., 2015).

Cognitive Control, Spontaneous Thought, and the Creative Brain

In this chapter, we explored the contribution of large-scale brain networks in creative cognition and artistic performance. Across both domain-general and domain-specific contexts, we provide consistent evidence that creative thought is a product of dynamic interactions between the default and control networks. In general, we contend that the default network influences creative idea generation via spontaneous and self-generated thought, while the control network constrains and directs this process via top-down monitoring and executive control. This proposal is consistent with a growing number of studies showing default-control network coupling during goal-directed, self-generated thought. Taken together, this research helps to resolve long-standing questions in the creativity literature regarding the contributions of cognitive control and spontaneous thought in creative cognition. It also provides a path forward toward research designed to better understand the generative and evaluative components underlying creative expression.

We described evidence from several recent fMRI studies reporting default-control network coupling during domain-general creative cognition (Beaty et al., 2015; Green et al., 2015; Mayseless et al., 2015). For example, Beaty and colleagues showed increased functional connectivity between regions of the default and control networks during divergent thinking, and a temporal connectivity analysis revealed dynamic coupling of these regions at different stages of the task. In this context, default network activity may reflect the spontaneous retrieval of information from episodic and semantic memory, and its coupling with the control network may in turn reflect executive mechanisms recruited to monitor, direct, and integrate such information into coherent and goal-congruent responses. Without sufficient top-down control, idea production may rely solely on spontaneous thought, which could result in the retrieval of salient but unoriginal concepts from memory (or alternatively, highly original but not relevant concepts).

Behavioral research has shown that common (and thus unoriginal) ideas tend to occur at early stages of divergent thinking, as people recall known uses for objects from memory (Gilhooly et al., 2007). However, this effect is markedly attenuated in people with greater executive resources (Beaty & Silvia, 2012), suggesting that cognitive control is required to inhibit salient conceptual information and manage complex search processes. At the other extreme, psychopathology (e.g., schizophrenia) can be characterized by highly original but irrelevant ideas (e.g., neologisms), resulting from insufficient top- down control narrowing information flow to meet task demands. Although this evidence comes from behavioral research, it may help to account for neuroimaging findings that reported executive network coupling with default regions during divergent thinking. Similarly, dysregulation between default and cognitive control networks may help to explain the tantalizing (but controversial) overlap between creative cognition and psychopathology (Abraham, 2015; Jung, Grazioplene, Caprihan, Chavez, & Haier, 2010; Jung, 2014).

Default-control network cooperation has also been reported during artistic performance, but such coupling appears to depend on task goals and constraints. On the one hand, Liu et al. (2015) reported a negative association between these networks during the spontaneous generation of poetry. On the other hand, Ellamil et al. (2012) found increased connectivity between default and control regions when visual artists evaluated their ideas, and Pinho et al. (2016) found a similar pattern when pianists were asked to tailor their improvisations based on specific emotional cues. In both studies, artists were given an explicit task goal that required them to constrain their thought process, presumably leading to increased top-down processing stemming from the control network. Conversely, Liu et al. (2015) simply asked poets to spontaneously generate poetry and did not impose specific goals, which might have relaxed top-down constraints, possibly reflected in deactivation of the control network. Thus, the control network's coupling with the default network appears to depend on the extent of goal-directed processing required for a given creative task.

Conclusion and Future Directions

Although the default and control networks have shown consistent involvement in neuroimaging studies of creative cognition, the specific cognitive functions underlying their activity remain unclear. This lack of clarity presents an opportunity for neuroimaging researchers to add significant understanding to this nascent field. Because the default network is associated with various self-generated thought processes, an important direction for future research is to determine which of these processes are relevant to creative cognition. Recent behavioral research points to a role for episodic memory in divergent thinking (Addis, Pan, Musicaro, & Schacter, 2016; Madore, Addis, & Schacter, 2015), suggesting that people may draw upon and flexibly combine episodic content to construct novel mental representations (Madore, Gaesser, & Schacter, 2014; Madore & Schacter, 2016; Schacter & Madore, 2016). In addition, investigation of the mechanisms underlying control network activity in creativity presents a vast number of opportunities regarding such issues as timing, sequencing, and intensity at various stages of the creative process. Are the interactions between default and cognitive control networks similar for creative pursuits in the arts and sciences? Are they the same across males and females, as well as younger versus older individuals? Can these interactions be modified through external behavioral, pharmacological, or electrical stimulation? Ultimately, we believe a critical direction for future research is to further characterize the brain network dynamics that give rise to creative cognition and artistic performance. In our view, this line of research shows the greatest promise in understanding the roles of cognitive control and spontaneous thought within the creative brain.

Acknowledgments

R. E. B. was supported by grant RFP-15-12 from the Imagination Institute (www.imagination-institute.org), funded by the John Templeton Foundation. The opinions expressed in this publication are those of the authors and do not necessarily reflect the view of the Imagination Institute or the John Templeton Foundation.

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CHAPTER

22 Spontaneous and Controlled Processes in Creative Cognition

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Abstract

Creative cognition has long been hypothesized to rely on spontaneous as well as controlled cognitive processes. This chapter starts by giving a brief overview of pertinent dual process models of creative thought. It then reviews empirical research supporting the relevance of controlled and spontaneous processes in creative cognition (mostly defined by divergent thinking and insight problem solving). The relevance of controlled processes is mainly supported by verbal protocol studies and individual differences research on executive functions and intelligence. The relevance of spontaneous processes is mainly supported by research on incubation and neuroscientific investigations. The chapter concludes by considering potential ways of interaction between goal-directed, controlled thought and undirected, spontaneous thought, both from the short-term perspective of immediate creative problem solving as well as from the long-term perspective of extended creative work.

Key Words: creativity, divergent thinking, insight, cognitive control, executive function, mind wandering, incubation, neuroscience, brain, dual process model

How do creative ideas arise? Are they the result of spontaneous, undirected thought, or rather of structured deliberation? History provides many examples of famous scientists or artists who had important spontaneous insights while not focused on the problem: for instance, the mathematician Henri Poincaré discovered the relationship between Fuchsian and non-Euclidian geometry when going on travels (Poincaré, 1913), and Kekulé was inspired regarding the Benzene ring structure while being half asleep (Rothenberg, 1995). A close look at the work habits of famous creative people reveals, however, that they also often followed strict daily routines to facilitate their creative process (Currey, 2013). The psychologist Burrhus Skinner and the writer Thomas Mann are just two examples of highly prolific individuals who have created their work on the basis of precisely scheduled writing periods. These reports provide anecdotal evidence for the relevance of both spontaneous and controlled processes in creative cognition.

In this chapter, we first revisit pertinent theoretical accounts in creativity research that embrace dual-process models of human cognition. We then review empirical evidence from cognitive and neuroscience research on the role of spontaneous and controlled processes in creative thought. Finally, findings are integrated to infer potential modes of interplay between spontaneity and control at different time scales: a short-term perspective considers moments of active engagement in creative thought, and a long-term perspective considers creative work on complex, extended projects.

Theoretical Accounts

Dual process models of cognition assume two types of thought, which are typically named Type 1 and Type 2 thinking processes (e.g., Evans, 2008; for earlier accounts speaking of System 1 and System 2 processes, see Stanovich, 1999). Type 1 processes are described as automatic, rapid, effortless, unconscious, and associative in nature, meaning that a stimulus will elicit associations to relevant information in long-term memory. Type 2 processes are described as controlled, analytic, slow, conscious, and effortful, and are related to working-memory processing (Kahneman, 2011). Thinking can also be classified as either undirected or goal-directed (Christoff, 2013). Undirected thought can be defined as the "thought flow that comes to mind unbidden and without effort" (Christoff, 2013, p. 321). It hence represents a spontaneous form of thought, as observed during mind-wandering, for instance. Goal-directed thought involves conscious representations of desired states and deliberate efforts to attain them. It requires cognitive control for the maintenance of task focus, for the development of mental strategies, and for task monitoring and the evaluation of outcomes.

Dual-process models also have a long tradition in creativity research (for recent reviews, see Allen & Thomas, 2011; Sowden, Pringle, & Gabora, 2015). Guilford's (1956) *structure of intellect* model distinguishes between convergent and divergent thinking. While convergent thinking reflects goal-directed reasoning and related mental operations, Guilford (1959) conceived divergent thinking as "the kind that goes off in different directions" (p. 381). Though he viewed divergent thinking as the cognitive basis of creative cognition, Guilford (1966, 1976) acknowledged that creativity essentially requires both divergent *and* convergent thinking. Another prominent dual-process account of creative cognition is the *blind variation and selective retention* (BVSR) model (Campbell, 1960; Simonton, 2011; see also Simonton, Chapter 10 in this volume). The BVSR model views creative cognition as analogous to evolutionary selection: it is proposed that new ideas are generated as "blind" variants (BV), and the most appropriate ideas are subsequently selectively retained (SR). Similarly, the *geneplore* model (Finke, Ward, & Smith, 1992) assumes that creative thought encompasses two iterative states: a *generation phase*, which leads to the formation of "preinventive structures" by means of memory search and formation of associations, and an *exploration phase*, when ideas are tested for applicability to different contexts. In contrast to the BVSR model, the *geneplore* model assumes that idea generation can be an active and goal-directed cognitive process that is characterized by both Type 1 and Type 2 processes.

Theoretical accounts of creative cognition hence acknowledge the relevance of both spontaneous and controlled processes, which can be loosely mapped to the conceptualizations of Type 1 and Type 2 thinking, or undirected and goal-directed thought. Spontaneous and controlled processes are typically associated with generative and evaluative functions, respectively, which are thought to interact in the forging of creative ideas. Can these intuitive theoretical accounts be supported by empirical research? This question will be addressed in the next section, which reviews the evidence for involvement of both controlled and spontaneous processes in creative thought.

Empirical Evidence

The Empirical Study of Creative Thought

Creative thinking can be defined as a mental process that leads to novel and meaningful representations, such as imaginations, ideas, or insights (Diedrich, Benedek, Jauk, & Neubauer, 2015; Runco & Jaeger, 2012). There are two central paradigms in the investigation of creative thought: creative idea generation and insight problem-solving. Creative idea generation is usually studied using divergent thinking (DT) tasks, which pose open-ended problems and prompt participants to produce different creative solutions within a given time (Guilford, 1967; Runco, 1999). A common example is the alternate uses task, which asks participants to find creative uses for common objects like a car tire within a period of two to three minutes, though many other tasks are used as well. Performance in DT tasks can be scored for fluency (i.e., number of ideas) and for creativity of ideas. The creativity of ideas or products can be evaluated by of a set of judges (Kaufman, Plucker, & Baer, 2008). DT ability represents the ability to generate creative ideas on demand, and therefore is viewed as an indicator of creative cognitive potential (Benedek, Mühlmann, Jauk, & Neubauer, 2013; Runco, 1999; Silvia et al., 2008).

Divergent thinking ability must not be confused with creativity in terms of real-life creative achievement, which refers to the creative accomplishments of a person. Creative idea generation (as assessed with DT tasks) can rather be conceived as a domain-general cognitive process inherent in all complex forms of creative performance, from scientific work to artistic performance (Benedek & Jauk, 2014). This notion is supported by a positive correlation between divergent thinking ability and real-world creative achievement (Jauk, Benedek, Dunst, & Neubauer, 2013; Kim, 2008; Plucker, 1999). For example, higher DT ability is associated with more creative performance in specific domains such as music (Beaty, Smeekens, Silvia, Hodges,

& Kane, 2013; Benedek, Borovnjak, Neubauer, & Kruse-Weber, 2014b) and dance (Fink & Woschnjak, 2011).

The second common approach in the study of creative thought is insight problem-solving. This approach poses problems that often cannot be solved in a straightforward way due to inadequate initial problem representations, leading to an impasse of thought (e.g., the candle problem; Dunker, 1945). To solve these problems, the problem representation needs to be restructured (Weisberg, 1995), and successful restructuring can be accompanied by a subjective experience of insight (Gilhooly & Murphy, 2005). A specific task type that is also commonly employed in the study of insight is remote associates problems, as originally used in the Remote Associates Test (RAT) (Mednick, 1962; cf. Kounios & Beeman, 2014). Remote associates problems present three unrelated concepts (e.g., cottage, blue, cake) and ask for a solution word that provides an unexpected connection between them (cheese: cottage cheese, blue cheese, cheesecake). Creative idea generation and insight problem-solving tasks differ most notably in the response type. While creative idea generation tasks have an indefinite number of potential solutions that vary in their creative value, insight problem-solving tasks typically have only one correct solution. These approaches hence focus on two variants of creative thought, acting in solution spaces of vastly different size.

Controlled Processes in Creative Cognition

Evidence for the involvement of cognitive control in creative thought comes particularly from verbal protocol studies and from individual differences research. Verbal protocol studies ask participants to think aloud during task performance. This method gives insight into the conscious processes that take place between stimulus and response and hence is used to identify relevant cognitive strategies and operations. For example, Gilhooly, Fioratou, Anthony, and Wynn (2007) showed that performance of the alternate uses tasks involves several strategies, such as the recall of uses from memory, or the production of uses guided by specific object properties, or the disassembly of objects. Critically, some of these strategies turned out to be far more effective than others for the generation of novel solutions.

An analysis of response guesses in remote associates problems showed that people adopt systematic strategies in this task as well: initial guesses mostly refer to one of the three cues and from there proceed locally in semantic space (Smith, Huber, & Vul, 2013). Similarly, verbal protocol studies of insight tasks revealed dissociable procedures during problem-solving, including the application of knowledge, heuristics, and restructuring based on information gained during failed efforts (Fleck & Weisberg, 2004, 2013). Interestingly, the commonly hypothesized sequence of impasse-restructuring-insight preceded only a minority of solutions.

Verbal protocol studies illustrate that creative thinking, as observed during creative idea generation and insight problem-solving, involves conscious goal-directed strategies. The posed problem establishes a more or less well-defined goal (e.g., find creative uses for a car tire), and the adoption of a specific strategy implies further sub-goals (e.g., identify relevant object characteristics). Meeting these sub-goals leads to the generation of candidate solutions (e.g., a lamp shade is round—maybe a car tire could be used as a lamp shade?), which then become evaluated with respect to the task constraints imposed by the task goal (e.g., solutions should be novel and meaningful in order to qualify as being creative). The findings of verbal protocol studies hence illustrate that creative thinking can take place in a very goal-directed way.

Further evidence for the role of controlled processes in creative thought comes from research that employed an individual differences approach. In the individual differences approach, correlations of low-level cognitive abilities (e.g., working memory capacity) with high-level cognitive abilities (e.g., divergent thinking ability) are used to infer the involvement of the low-level process in the high-level process. In other words, if people with higher working-memory capacity generate more creative ideas, it is assumed that working memory is relevant to creative idea generation. Following this approach, consistent positive correlations between creative potential and intelligence (a proxy of executive control) support the relevance of cognitive control in creative thought (e.g., Batey & Furnham, 2006; Cramond, Kim, & VanTassel-Baska, 2010). Findings generalize to different facets of intelligence, including Gf, Gc, and Gr (Beaty & Silvia, 2013; Cho, Nijenhuis, van Vianen, Kim, & Lee, 2010; Jauk, Benedek, & Neubauer, 2014; Silvia, Beaty, & Nusbaum, 2013), and also to different measures of creative potential including divergent thinking (e.g., Jauk et al., 2014; Nusbaum & Silvia, 2011), generation of creative metaphors (Silvia & Beaty, 2012; Beaty & Silvia, 2013), production of humor (Greengross & Miller, 2011; Kellner &

Benedek, 2017), and insight problem-solving (Beaty, Nusbaum, & Silvia, 2014; Lee & Therriault, 2013). An early meta-analysis estimated the average relationship between intelligence and creativity to be only of modest magnitude (Kim, 2005). More recent evidence, however, suggests that this relationship is much more pronounced than previously assumed (i.e., correlation coefficients around .40 to .50) when considering latent correlations (Jauk et al., 2014; Silvia, 2008), when creativity is measured by DT creativity rather than mere fluency (Benedek, Franz, Heene, & Neubauer, 2012; Jauk et al., 2013), and when DT tasks explicitly instruct participants to be creative rather than to produce many different ideas (Nusbaum, Silvia, & Beaty, 2014). Above-average intelligence is sometimes seen as a necessary condition for high creativity, which is evidenced by higher intelligence-creativity correlations in the lower range of the intelligence spectrum (Jauk et al., 2013; Karwowski et al., 2016).

Individual differences research has also begun to elucidate the functional role of intelligence for creative thought. Nusbaum and Silvia (2011) had participants perform the alternate uses task and instructed half of their sample to use a specific strategy when they got stuck during idea generation (i.e., consider the disassembly of objects). They found that Gf predicted creativity of ideas more strongly in the strategy group than in the no-strategy group, suggesting that Gf facilitates the implementation of a useful but cognitively demanding strategy during creative idea generation. Another study by Nusbaum, Silvia, and Beaty (2014) showed that intelligence predicted creativity more strongly when people were instructed to be creative rather than to be fluent, again indicating that intelligence may be particularly relevant for enacting more demanding top-down strategies during creative thought. Finally, intelligence was found to be associated with higher creativity of ideas, particularly at the beginning of idea generation, suggesting that intelligence is relevant for the effective suppression of initial common ideas in favor of generating more creative ideas right from the start (Beaty & Silvia, 2012).

The relationship between cognitive control and creative thought is also evident at the level of executive functions such as working memory and inhibition. Some studies reported positive correlations between working-memory capacity and divergent thinking ability (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014d; De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012; Oberauer, Süß, Wilhelm, & Wittmann, 2008), but others found no significant relationship (Lee & Therriault, 2013; Smeekens & Kane, 2016). Notably, higher working memory capacity was shown to predict the creativity of musical improvisation, particularly at later trials, suggesting that working memory facilitates sustained task-directed effort in highly demanding improvisation tasks (De Dreu et al., 2012). Divergent thinking ability has also been related to higher cognitive inhibition as measured with Stroop, Navon, or random motor generation tasks (Benedek et al., 2012; Edl, Benedek, Papousek, Weiss, & Fink, 2014; Golden, 1975; Groborz & Necka, 2003; Zabelina, Robinson, Council, & Bresin, 2012), and to higher shifting ability (Pan & Yu, in press). Yet other work suggests that creativity is particularly related to a flexible engagement of cognitive control (Dorfman, Martindale, Gassimova, & Vartanian, 2008; Kwiatkowski, Vartanian, & Martindale, 1999; Vartanian, Martindale, & Kwiatkowski, 2007; Zabelina & Robinson, 2010; cf. Vartanian, 2009).

To recap, verbal protocol research has illustrated some of the conscious strategies that are involved in creative problem-solving, suggesting that creative thinking can be pursued in a goal-directed way. Individual differences research further points to specific executive mechanisms that are related to higher creativity. Working memory and cognitive inhibition are primary resources for the control of attention (Kane, Bleckley, Conway, & Engle, 2001), and are known to support goal-directed processes such as the active maintenance of task-relevant information and the controlled search from memory (Unsworth & Engle, 2007). Cognitive control hence can be assumed to facilitate the implementation of goal-directed processes in creative thought.

Spontaneous Processes in Creative Thought

The observation that creative ideas not only arise during deliberate idea generation, but also pop up at unexpected times and places, is a major argument for the involvement of spontaneous processes in creative thought. This phenomenon has been acknowledged in models of the creative process (e.g., Wallas, 1926), which commonly include a *preparation* phase (initial problem-solving attempts that lead to an impasse), followed by an *incubation* phase during which the problem is temporarily abandoned. The end of incubation is marked by a moment of *insight*, followed by a final *verification* phase when the solution is checked. Empirical research has been very interested in the role of incubation for creative problem-solving. In a typical experimental procedure, participants work on a creative task, followed by a distraction task (i.e., incubation period) before the original task is presented again. Performance gains in the post-incubation task are then considered the result of incubation effects.

A growing body of empirical evidence supports the value of incubation periods. For instance, a few minutes of task-unrelated thought—as opposed to prolonged task engagement or immediate responding—have been shown to lead to more remote associations and more creative solutions in divergent thinking (e.g., Dijsterhius & Meurs, 2006). Meta-analytic findings suggest that incubation effects are robust and are found for divergent thinking as well as insight problem-solving (Sio & Ormerod, 2009). Incubation gains are especially pronounced when participants are confronted with distraction tasks that are cognitively undemanding (Baird et al., 2012; Sio & Ormerod, 2009), conceptually unrelated to the creative problem (Ellwood, Pallier, Snyder, & Gallate, 2009), or reflect different stimulus modalities (i.e., verbal vs. figural; e.g., Gilhooly, Georgiou, & Devery, 2013). Notably, incubation effects are observed not only after short incubation tasks, but also after extended incubation periods, such as following a nap (Cai et al., 2009) or a night of sleep (Wagner, Gais, Haider, Verleger, & Born, 2004).

What are the mechanisms underlying the incubation effect? It is widely acknowledged that incubation can lead to *relaxation* (Knoblich, Ohlsson, Haider, & Rhenius, 1999), *uptake of facilitating cues* from the environment (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995), *forgetting of fixating elements* (Smith & Blankenship, 1991), or *set shifting* (Schooler & Melcher, 1995). All of these mechanisms help to "refresh" the current mindset, and to overcome proactive interference from previously salient but irrelevant goals and constraints. These accounts, however, capitalize on the transient loosening of task-focused attention and hence reflect *passive* mechanisms, rather than an active involvement of spontaneous thought (see also Hélie & Sun, 2010; Ritter & Dijsterhuis, 2014). In this context, it is interesting to note that incubation research has considered only on-task performance thus far, but not spontaneous off-task ideas or insights as reported in the anecdotes that inspired this line of research.

Despite the passive mechanisms that may promote incubation effects in creative cognition, specific incubation findings suggest an active involvement of spontaneous processes during creative incubation (Ritter & Dijksterhuis, 2014). For example, incubation gains are stronger when distractor tasks are unrelated to the creative task at hand (Ellwood et al., 2009; Gilhooly et al., 2013). These findings indicate that incubation periods benefit from a disengagement of task-relevant cognitive systems (i.e., verbal versus numerical), which might give rise to unconscious processes in this system, but not necessarily facilitate the refreshing of mindset. Further evidence for the involvement of active unconscious processing during incubation comes from a study showing that incubation gains are stronger when participants are aware of the post-test following the incubation period (Gallate et al., 2012). It seems that the awareness of the uncompleted task triggers additional processes that cannot be easily explained by passive mechanisms. It also has been proposed that incubation effects are related to increased mind-wandering in the incubation period (i.e., spontaneous thoughts that are related to neither the distractor task nor the creative task; Baird et al., 2012). However, this finding was not replicated in later research (Smeekens & Kane, 2016), and mind-wandering during creative task performance has been shown to be detrimental to creativity (Hao, Wu, Runco & Pina, 2015), as it is in most areas of cognitive performance (Mooneyham & Schooler, 2013; but see Zedelius and Schooler, Chapter 18 in this volume, for a nuanced discussion). In sum, research on the incubation effect shows that interruptions of goal-directed task performance can have positive effects on creative thought, which might be due to both active spontaneous processes as well as passive mechanisms (refreshing of mindset).

Potentially more direct support for the involvement of spontaneous processes in creative thought comes from cognitive neuroscience research. It relies on a relationship between spontaneous thought and activation of the default mode network (DMN). The DMN is highly active in the absence of goal-directed thought (i.e., when people are instructed to rest and not think of anything in particular; Fox & Raichle, 2007; Gusnard & Raichle, 2001). DMN activation has been specifically observed during mind-wandering (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012; Mason et al., 2007) and related mental processes such as self-generated thought and prospection (Andrews-Hanna, Smallwood, & Spreng, 2014; Schacter, Addis, & Buckner, 2007; Spreng, Mar, & Kim, 2009), although these processes recruit other brain areas as well (Fox, Spreng, Ellamil, Andrews-Hanna,

& Christoff, 2015). Neuroscience research on creativity has also accumulated robust evidence for the involvement of the DMN in creative thought (Gonen-Yaacovi et al., 2013; Jung, Benedek, Dunst, & Neubauer, 2013; Mok, 2014; see also Beaty and Jung, Chapter 21 in this volume). Functional magnetic resonance imaging (fMRI) studies comparing brain activation between divergent and convergent thinking tasks (e.g., generating creative object uses vs. generating typical object characteristics) consistently report higher activation of not only core DMN regions such as the posterior cingulate cortex and the posterior inferior parietal cortex, but also other regions, including particularly the left lateral prefrontal cortex (Abraham et al., 2012; Benedek et al., 2014a; Fink et al., 2009; Mayseless, Eran, & Shamay-Tsoory, 2015). Tasks with higher creativity-related demands hence show a higher DMN involvement. As for most cognitive tasks, however, DMN activation is generally lower during creative thinking when compared to rest (e.g., Benedek, et al., 2014c). A possible interpretation of this result is that creative thinking tasks generally involve controlled, goal-directed thought processes, but the more creative the task, the higher the involvement of spontaneous, undirected processes.

Importantly, DMN involvement during creative thought is not merely an effect of internally directed attention. Although creative cognition is often largely independent from sensory stimulation and hence implies an internal focus of attention—which is reflected in brain parameters such as increased posterior electroencephalogram (EEG) alpha activity (Benedek, Bergner, Könen, Fink, & Neubauer, 2011; Benedek et al., 2014e; Fink & Benedek, 2013, 2014)—a recent study showed that DMN activation during creative thought is not related to an internal versus external focus of attention, but rather to higher levels of constructive, self-generated thought (Benedek et al., 2016).

Creative thinking thus is characterized by brain activation in the DMN, as well as prefrontal regions that are part of the executive control network (ECN). Further investigations of the functional coupling of these networks revealed that the DMN and ECN do not act independently, but actually cooperate during creative thought (Beaty, Benedek Silvia, & Schacter, 2016). This is a compelling finding, since the DMN and ECN often show an antagonistic relationship (Anticevic et al., 2012; Fox et al., 2005). Increased coupling of DMN and ECN has been observed for different creative domains, including creative idea generation (Beaty, Benedek, Kaufman, & Silvia, 2015), creative drawing (Ellamil, Dobson, Beeman, & Christoff, 2012), poetry composition (Liu et al., 2015), and musical improvisation (Pinho, Ullén, Castelo-Branco, Fransson, & de Manzano, 2016). These findings show that creative cognition involves the activation and cooperation of brain networks linked to spontaneous thought and cognitive control (for a more detailed account of this emerging literature, see Beaty and Jung, Chapter 21 in this volume).

Additional evidence comes from the analysis of interindividual differences in DMN function and structure. For example, the DMN and ECN show higher resting-state connectivity in more creative individuals (Beaty et al., 2014). Creative people have also been found to show less deactivation of the DMN during a working-memory task (Takeuchi et al., 2011). Similarly, people scoring high on schizotypy (a trait related to creativity; e.g., Batey & Furnham, 2006) showed attenuated DMN deactivation during a divergent thinking task (Fink, Weber, et al., 2014). On a brain structural level, higher creativity is consistently associated with higher gray matter density in DMN regions, especially the precuneus (Chen et al., 2015; Fink et al., 2014; Jauk et al., 2015; Kühn et al., 2014; Takeuchi et al., 2010). These neurophysiological findings indicate that the association between creativity and spontaneous thought might even manifest at a trait level, a notion also partially supported by recent behavioral research (Baird et al., 2012; Smeekens & Kane, 2016; Zedelius & Schooler, 2015).

The Interplay of Spontaneous and Controlled Processes in Creative Cognition

We have shown in the preceding that theoretical accounts and empirical evidence agree that both spontaneous and controlled processes contribute to creative thought. An important question now is how these processes actually interact in their contribution to creativity. To address this question, it seems reasonable to distinguish between a short-term and a long-term perspective. The short-term perspective considers the interplay of spontaneous and controlled processes during active engagement in creative thought, as when we are sitting at the workplace, determined to tackle a specific problem (e.g., writing or designing). The long-term perspective acknowledges that complex creative tasks will not lead to satisfactory solutions within a few minutes, but require extended but intermittent engagement over days, weeks, or longer. Complex creative problems (e.g., creating a scientific theory, or writing a book or a play) typically consist of many interrelated problems, and advancing some of them may not yet solve the overarching problem.

A Short-Term Perspective

How do spontaneous and controlled processes interact when we are actively looking for a creative idea? Active idea generation might be generally conceived as a goal-directed process, but there are good reasons to assume that spontaneous, undirected processes are substantially involved as well (Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014). First of all, goal-directed and undirected thinking need not be understood as mutually exclusive states, but thinking can also reside somewhere along the continuum between these extremes (Christoff, 2013; Fox & Christoff, 2014). Goal-directed thinking is often conceived of in a hierarchical way; that is, even when the overall goal is clear, certain subgoals can be underspecified. For example, we may decide to think of a clever metaphor that illustrates an argument, but only have a vague hunch of how to find it. Verbal protocol analyses show that people engage in different conscious strategies during creative problem-solving, but they also indicate that a substantial proportion of ideas just come in an unmediated way (Gilhooly et al., 2007), or are accompanied by a subjective experience of spontaneous insight (Gilhooly & Murphy, 2005). People are often unable to verbalize their strategy, which suggests that no fully conscious strategy was pursued. Moreover, some people engage in very basic strategies like self-cuing, which involves the simple repetition or imagination of the problem, a quite undirected strategy that might be apt to stimulate spontaneous ideas. Finally, some strategies turn out to be ineffective and lead us to an impasse of thought (Fleck & Weisberg, 2004). These considerations indicate that an active engagement in a creative task does not necessarily imply that thinking is fully goal-directed throughout the task.

Second, even when we have picked a strategy that entails a clear plan of action, we cannot expect that cognitive processes are always under our full control. For example, when we decide to perform a controlled retrieval with given constraints (e.g., generate things that are round), the outcome of this task is not fully predictable. We cannot simply achieve a systematic and exhaustive search; rather, our recall is typically incomplete and sometimes even wrong (Schacter, 1999). Search of memory involves associative mechanisms (Collins & Loftus, 1975), and exerting top-down control means, at best, guiding these processes—not replacing them with an analytic search. Conscious resources are simply far too limited to monitor and control all ongoing cognitive processes (Marois & Ivanoff, 2005). This is not necessarily a disadvantage for creative thought: uncontrolled, spontaneous processes can actually become a source of creativity, as in the process of reconstructive interference, where contextual interference during recall can foster creative associations (Gabora & Ranjan, 2013). Under some conditions, reduced control might even be beneficial for creativity (Amer et al., 2017; Chrysikou et al., 2014; Wiley & Jarosz, 2012). Individual differences in semantic memory structure are yet another bottom-up mechanism that is hypothesized to support creativity (Mednick, 1962), although this remains a point of empirical debate (Benedek & Neubauer, 2013; Kenett, Anaki, & Faust, 2014). We hence can conclude that active engagement in creative thought involves cognitive control, but is not continuously goal-directed and does not imply full control, therefore leaving ample room for a fruitful interplay with spontaneous thought. This may actually be true to some extent for all kinds of problem-solving, but it appears particularly true for creative problem-solving, because creative problems commonly are ill-defined (Mumford, Reiter-Palmon, & Redmond, 1994).

We might further generalize this point in saying that creative problem-solving can vary in its level of goal-directedness. The level of goal-directedness may depend on the actual task, the problem-solving stage, and maybe even individual factors such as cognitive styles. For example, an impasse of thought is a common characteristic for insight tasks but not for divergent thinking tasks. Insight tasks thus may be considered relatively less goal-directed. The better we understand the relevant cognitive operations and strategies involved in a task, the better we will be able to estimate the relative relevance of controlled and spontaneous processes.

A central question is how spontaneous and controlled processes cooperate in creative thought: Do they alternate in successive phases, or engage in actual simultaneous interaction? Some theoretical accounts suggest shifts between generative and evaluative phases, with generative phases producing candidate solutions that are evaluated for appropriateness in an iterative fashion until one solution is eventually approved (e.g., Finke et al., 1992). On the other hand, dual-process models commonly assume that Type 1 processes take place in an automatic fashion and Type 2 processes are additionally recruited to monitor and potentially overrule Type 1 processes, suggesting that these processes can occur in parallel and interact directly. The functional coupling of brain networks associated with spontaneous thought and cognitive control during creative thought (e.g., Beaty et al., 2015) seems to corroborate the view of direct interaction, but the degree of coupling also depends on the problem-solving stage (Beaty et al., 2014; Ellamil et al., 2012; Liu et al., 2014). Moreover, creative individuals appear to be better able to flexibly shift between convergent and divergent thinking demands, as expressed in higher EEG alpha (de-)synchronization during the respective task demands (Jauk, Benedek, & Neubauer, 2012; cf. Vartanian, 2009; Zabelina & Robinson, 2010). This suggests a more nuanced view, implying that spontaneous and controlled processes show actual simultaneous interaction, but their respective predominance may vary across time and individuals.

A Long-Term Perspective

Complex creative problems are usually not solved within a few minutes and hence are particularly likely to lead to an impasse. They require putting down the problem after some time without a satisfactory solution. This is the kind of creative problem-solving that has been associated with the intriguing anecdotes of spontaneous insights coming suddenly to eminent figures in the arts and sciences, which have inspired incubation research. To date, incubation research has made important advances in showing that periods of task-unrelated thought can facilitate creativity (Ritter & Dijksterhuis, 2014), which points to the existence of unconscious, spontaneous processes that may not be goal-directed but still are goal-relevant. However, it also seems that incubation research has thus far hardly addressed the phenomenon at the heart of those anecdotes, namely, *why, when,* and *how* thoughts spontaneously return to an unsolved problem and eventually unveil a solution. These spontaneous thoughts occur unbidden but can nonetheless be largely conscious. This is what likely happened to Poincaré when boarding the bus and to Kelkulé when drifting into sleep. Most of us also know this phenomenon well from personal experience: Our mind wanders to an unsolved problem, while we are actually concerned with something else, and we might only become aware of it when we suddenly notice that thoughts have brought us to an unexpected idea. To better understand the role of spontaneous thoughts in creative cognition, we need to understand why this happens and why it can be conducive to creativity.

Why and when does it happen? Mind-wandering typically concerns personally significant events (Singer, 1966; see also Klinger, Marchetti, & Koster, Chapter 17 in this volume). It can take the form of ruminations concerning the past, and of thoughts regarding the future—both positively and negatively hued (Smallwood & Schooler, 2015). An unsolved problem, to which we have devoted much time and effort without any success, can clearly be conceived of as an event of high personal significance. Moreover, unsolved problems have been shown to be more salient and available for recall than solved problems (Yanif & Meyer, 1987; Zeigarnik, 1927). Unsolved problems hence have the power to spontaneously attract our attention. Mind-wandering has been previously associated with cognitive failure, in terms of ruminations and worries that interfere with the task at hand. However, spontaneous thoughts that address unsolved problems can be viewed as a very adaptive, functional mechanism of our brain. More generally, mind-wandering can be seen as spontaneous mental simulations that build on previous experience to better prepare us for the future, which are relevant for personal planning and creativity (Baird, Smallwood, & Schooler, 2011; McMillan, Kaufman, & Singer, 2013; Smallwood & Schooler, 2015).

When does it happen? In the popular science literature, the occurrence of spontaneous insights has been associated with three or four "Bs" that variably include bed, bathroom, bus, bars, or boring meetings. Anecdotal reports include further activities that do not necessarily start with the letter *b*, like going for a walk, ironing, or watching cows (Currey, 2013). Many of these activities have in common the fact that they are cognitively undemanding and therefore can be executed largely automatically. Systematic evidence supports the observation that spontaneous insights can be linked to undemanding activities that leave lots of attentional resources free (Sio & Ormerod, 2009). It is an intriguing question whether free attentional resources are a necessary condition for having spontaneous thought processes, or maybe only for becoming consciously aware of them. It has been hypothesized that spontaneous thought can take place without any conscious awareness, as in dreaming (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013), and first-person reports from probe-caught mind-wandering suggest that people lack meta-awareness of these processes as much as half of the time (Christoff et al., 2009). One might therefore further speculate whether mind-wandering represents a state in which we consciously witness cognitive processes that can also take place unconsciously, but which enter conscious attention when it is not occupied with other goal-directed activities (Dixon, Fox, & Christoff, 2014; Wiggins & Bhattacharya, 2014).

The other important question is why spontaneous thought can be fruitful for creativity. First of all, spontaneous thought, like mind-wandering, is an *internal affair*—it relies on available semantic and autobiographical knowledge and thus is largely independent from sensory information (Smallwood, 2013). We can therefore assume that spontaneous thoughts will only advance problems that can be effectively processed in mind. This is usually true for creative thought, which essentially relies on imagination and an internal focus of attention (Benedek et al., 2014e). Creative ideas build on existing knowledge and represent a forging of new connections between previously unrelated concepts (Koestler, 1964; Mednick, 1962). Moreover, the implementation of the idea also requires external attention, for expressing (e.g., writing, designing, playing, or manufacturing) what has been envisaged in the mind's eye or ear. Importantly, this means that spontaneous insights do not come out of nowhere; presumably all relevant building blocks of knowledge are previously available and are waiting to be combined. The creative combination or recombination of this preexisting knowledge implies a proper understanding of the problem and its domain, however, which often requires extensive deliberate training in a given field (Weisberg, 1993).

Second, spontaneous thought is assumed to take place in a more free-associative and less monitored way than goal-directed thought. It hence allows more radical and playful variations that might be screened out during goal-directed deliberation (see Simonton, Chapter 10 in this volume). Since spontaneous thoughts are undirected, they may often represent irrelevant or inappropriate solutions with respect to a given problem. However, if they happen to be relevant and appropriate, they likely involve more radical novelties than ideas from previous goal-directed deliberations. Spontaneous thought may therefore be conducive to creativity in introducing novelty and variations, which happens in a largely undirected way but probably not completely blindly (Gabora & Kauffman, 2016; Simonton, Chapter 10 in this volume). Spontaneous variations will not represent a full combinatory variation of available knowledge, but rather novel first-order combinations of a restricted set of information, representing what has been called the *adjacent possible* (Kauffman, 2000).

What can we infer about the actual interplay of spontaneous and controlled thought from the long-term perspective of extended creative work on a given problem or project? While we can schedule the time and amount of goal-directed work we want to devote to a problem, it is—by definition—impossible to ensure that the problem is also addressed by spontaneous thoughts in terms of mind-wandering. Nevertheless, deliberate work represents an important precondition for spontaneous work for at least two reasons. First, deliberate work is needed to analyze a problem and to acquire all relevant information needed to solve it. Second, intense deliberate work on a problem makes it salient and personally relevant, and hence makes it much more likely to appear as content in subsequent problem-related mind-wandering (Singer, 1966).

Aside from ways in which goal-directed work may stimulate relevant spontaneous thought, we may additionally speculate that regular engagement in certain cognitively undemanding activities (e.g., going for a walks) might increase psychological receptiveness to potentially productive spontaneous thought. Because spontaneous thoughts are volatile, making use of them requires goal-directed actions. Many artists and scientists are well aware of this and hence are prepared to take notes when ideas come to them so that they are not lost (Currey, 2013). Controlled, goal-directed thinking is of course further needed to elaborate, verify, and finally implement creative ideas; some spontaneous ideas appear exceptional at first, but not all withstand the test of explicit verification.

The benefits of the interplay between goal-directed and spontaneous thought in creative problem-solving might be illustrated by analogy with the optimization process of *simulated annealing* (Kirkpatrick, Gelatt, & Vecchi, 1983; cf. Martindale, 1995). Simulated annealing describes a technique for approximating a global optimum in complex problems that feature excessively large search spaces and cannot be solved in an analytical way. It generally aims at finding a minimum in a goal-directed way (like a marble rolling down to the local minimum of a landscape), but also introduces (spontaneous) random variations and temporarily accepts less optimal solutions (like giving the marble a push to jump somewhere else). Unlike other (fully goal-directed) brute-force algorithms, simulated annealing thus provides a mechanism to avoid getting trapped in a local minimum (which may correspond to a state of mental fixation). As *pushes* get weaker over time, the system will eventually converge on the global minimum. As in metallurgic annealing, where shifts between heating and cooling are used to achieve an overall more optimal configuration of the material, shifts between controlled and spontaneous thought can be conducive to creative problem-solving by providing a means to escape (local) impasses of thought and thereby eventually reach creative (global) solutions.

Extended creative work can have many iterative phases of (predominantly) controlled, goal-directed, and spontaneous thought. Creative people embrace the creative potential of both states and are skilled at integrating them in their work habits (see Dobson, Chapter 23 in this volume). Future empirical research on the interplay of spontaneous and controlled thought, from both short-term and long-term perspectives, will allow us to more fully appreciate the intricate cognitive mechanisms involved in creative cognition.

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CHAPTER

23 Wandering and Direction in Creative Production

Charles Dobson

Abstract

The broad field of creative production offers many anecdotal books devoted to various methods for generating ideas. Most of these pay scant attention to such difficulties as figuring out an initial direction; sorting out which ideas are worth pursuing, and preventing a critical frame of mind nurtured by years of schooling from stymying the flow of ideas. With the literature missing much of what would be useful in everyday practice, and lacking the research that would answer basic questions, some productive professionals have developed unusual habits through years of trial and error. Many of these seem to involve shifting back and forth between a focus on wandering or going somewhere new, and a focus on direction or arriving at a specific place.

Key Words: creativity, innovation, invention, failure, evaluation, design, criticism, fuzzy, creative process

I will summarize here some tentative conclusions from three decades of observing what helps and hinders the creative practice of experienced professionals and inexperienced students. At the same time, I will describe what seems to be going on using the spatial metaphor of wandering, because it is useful in trying to understand the peculiarities of creative production.

The focus will be largely on creative processes in design. Many of these processes are also important in the arts, including fine art, music, and literature. But the arts present additional difficulties to anyone trying to understand creative production, stemming from a lack of performance constraints, and disagreement over the criteria for evaluating new work. By design, I mean the synthesis of new and useful form in a wide range of different fields. Thus designing can be about creating a new and more efficient engine, a new and less volatile financial system, a new and easier way to understand software, or a new and more encompassing scientific theory. Two principal criteria for evaluating design work are its newness, and its ability to perform its intended job. Newness is an essential part of modern historical cultures. Without it, stasis would prevail, and every element of culture would be today and in the future what it was in the past.

Design problems are characterized by being ill defined. They are not problems that can be solved through a set of rules, practices, or formulas. If the task is to weigh a pumpkin, or tune a guitar, the final destination is clear, and the way to get there, well established. But if the task is to create a new and more efficient engine, the final result is not clear at all. You might have some idea of how it might perform, but what would this new engine look like, and how would it operate? Design problems by their very nature require wandering, because you're not sure where you're going, or how to get a satisfactory result, or what a satisfactory result would be.

In teaching creative problem-solving, I try to encourage students to emulate the creative behaviors of first-rate professionals. It is important to note the difference between emulating their behavior and emulating their products. It is easy to emulate their products, but far more difficult to figure out how they go about doing what they do. When interviewed, creatives typically quote from textbooks on creative thinking, offering descriptions that do not match what they actually do. The only reliable way to begin understanding creative behavior is through direct observation. This entails video recording the actions of creative people as they work, while they verbalize the stream of thoughts going through their minds. Unfortunately, very little of this kind of observation has been undertaken in design or the arts.

Alternating, Intermittent Movement

The most notable characteristic of creative behavior seems to be alternating, intermittent movement. It is unpredictable movement, that goes backward and forward, and stops and starts. It shifts from one activity to another, from enthusiasm to reluctance, and from one focus to another.

Generate and Evaluate

The most important form of alternating movement is between the state of mind associated with generating ideas and that associated with evaluating ideas. To generate ideas, designers will try to switch off their voice of judgment. To evaluate ideas, they will try to switch it on. One of the most effective activities in creative production is the rapid movement between generating and evaluating, a process I call *flip-flop thinking.* Being able to move rapidly back and forth between two completely different and incompatible states of mind is an unusual ability that, when observed, looks unusual. One minute a person will be physically up, animated, laughing, her eyes will be wider, and out will come a stream of ideas. The next minute she will be physically down, sober, quiet, serious, and reflective, questioning the value of what she just produced. And then it begins again. When working well, it is a self-triggering, iterative process that keeps going. Watching a person do this well is rather like watching someone taken over by a form of mania. For this reason, some advertising agencies keep their best creatives in back rooms where clients will not be disturbed by seeing them in action.

Flip-flop thinking seems to be a higher-frequency version of the divergent and convergent phases that describe an idealized creative process (Jones, 1992). The divergent phase is where a number of ideas are produced. The convergent phase is where these ideas are evaluated and the weakest are discarded. If the divergent phase looks like this <, and the evaluative phase looks like this >, an idealized picture of the creative process is an iterative sequence that looks like this: <><><><><> . . . . Of course, real creative processes are not linear, and are far messier.

Verbalized flip-flop thinking in full flight is something to behold. The most productive creatives can generate such a rapid stream of options and evaluations, that their speech struggles to keep pace with their thoughts. By comparison, a beginning design student, after generating a few predictable options, moves slowly, with many pauses and periods of silence. Any evaluation at this stage leads to further slowing or stalling. Someone who is good at flip-flop thinking does not regard evaluation as a slow or stop sign, but a sign that points in another direction and still more possibilities.

I should add that flip-flop thinking is not common, even among experienced creatives. I suspect that those who can do it well have had a lot of practice, prompted by recognition of its usefulness. Far more common are those who can generate a stream of ideas, but are less interested in which ones are any good. They like the thrill of generating a lot of interesting possibilities, and often want to keep on iterating without homing in on a final result. To be productive, these people usually require a second person to provide the steering that comes from good evaluation. Sometimes this person is a creative director, sometimes a husband or wife, sometimes a work partner. These opposites, when working as complements, produce an externalized version of flip-flop thinking that can move a project quickly along because they consist of a creative engine coupled with a means of steering.

Methods of Controlling Evaluation

A voice of judgment, switched partly on, is the default for most people. Because of this, one must take steps to switch it off in order to generate ideas. Failure to do so, slows, stops, or makes timid idea generation.[1] A number of well-established methods are available to suppress the voice of judgment. The first is to begin with warm-up exercises, such as "barnyard," described in James Adam's book, *Conceptual Blockbusting* (2001). Barnyard is such a silly exercise that everyone ends up laughing—and one's critical voice heads for the "back forty." Another approach is to ban criticism, which is easier to enforce in a group setting. Brainstorming, an ideas-generating technique made popular by Alex Osborne (1979), requires that group members refrain from any kind of criticism and instead try to build one another's ideas, no matter how screwy they might seem. Another way to control evaluation is to work fast, without stopping. Writers can overcome a creative block by handwriting non-stop, keeping a pen in hand constantly moving. For songwriters, the advice in *The Frustrated Songwriter's Handbook* (Coryat, 2006) is to write 20 songs in one day. For design students, a version of "walk-and-talk" seems helpful. Students pair up and choose a quiet route and a destination about a half hour away. On the way out, one person, focused on one project, generates a steady stream of "what-ifs" while speaking into an audio recorder. If all is going well, the other person just listens. If the speaker goes silent, the other person tries to restart the stream by asking provocative "why-not" questions, or "what-about" perspective-changing questions, or "tell-me-more" questions that invite variations on previous "what-ifs." Once they reach their destination, they switch places. On the way back, the listener, now the speaker, generates a stream of "what-ifs" for the project they are working on.

Several long-term practices can also help control evaluation. Some of the most inventive design students I have observed seem to spend time during class breaks producing jokey streams of "what-if" ideas in their area of study. They seem to do this as a way of entertaining themselves and their friends. Inventive joke-making brings to mind Arthur Koestler's book, *The Act of Creation* (1990), which focuses on the relationship between humor and invention. It also brings to mind the way children once entertained themselves by making up fantasy worlds—before the arrival of the Dark Age of Screens.

Apart from joking, something else seems to be going on with these students. Most books on creative thinking suggest various ways to generate an abundance of ideas because, as the saying goes, the best way to produce a good idea is to produce a lot of ideas and throw away those that are no good. But the ability to generate a lot of ideas requires a lot of practice. This requires more time than comes from just the occasions when one needs to come up with an idea. For this reason, the most creative people are those who incorporate invention into everyday life. In doing so, they get far more practice than anyone else, and get better at it than anyone else. The best students I encountered in design were simply practicing in their spare time. So how do you incorporate creative practice into everyday life? It isn't difficult. One method is to view food preparation as an occasion for invention. It is an opportunity to make cheap, fast prototypes and quick tests. The added benefit is more interesting food that is more interesting to make, if you can overlook the frequent but inexpensive failures.

Another way to modify the tendency to evaluate is to modify one's identity. This approach comes from sociologist Charles Cooley's concept of the "looking-glass self." According to Cooley (1902), we define ourselves according to how we see ourselves reflected back to us in the way others treat us. In several design studio classes, I identified students who seemed to regard themselves as conservative or uncreative. As part of a studio project, I asked them to change their appearance, including their clothing, so that they looked unusual. Because many people associate an odd appearance with inventiveness, I thought other students might begin to see these students as inventive, which would help these students see themselves as inventive. This seemed to be what happened. Other students started to view them as "edgy," and the work of these students actually became more inventive. Altering the "presentation of self" seems to hold some promise for controlling evaluation, although this small trial had no controls, no follow-up, and no criteria for what constituted improvement.

Methods of Improving Evaluation

While suppressing evaluation is a necessary part of improving idea generation, unrestrained evaluation is necessary for steering. Here again, students seem to have difficulty. Where professionals can be ruthlessly critical of their own work, less confident students often mount a defense when they should be critical. Familiarity with the skills and knowledge that constitute a chosen field serves as a foundation for evaluation. In the arts, being familiar with great works from the past and present provides a basis of comparison, and a way to avoid retracing well-trodden paths.

A simple way to improve evaluation is to ask a person with good judgment to say what is wrong. They must know they are being asked for an honest evaluation, and not praise. The question, "What do you think?" is too ambiguous. The best way to obtain accurate evaluation is to provide several alternatives, and then ask which one is best. Choosing from several options avoids the uneasiness that comes with having to critique a single option.

The most common way to evaluate an idea is to let it sit. I am constantly surprised at how a seemingly terrific idea will look quite hopeless the next morning. The difficulty of evaluating an idea right after it has been generated is the difficulty that makes flip-flop thinking so difficult. Letting a project sit, then returning to it, then letting it sit again, is what makes creative production intermittent. Woven into this is the stop-and-go sequence associated with incubation and illumination.

Incubation and Illumination

A common occurrence in creative production is the way a good idea will suddenly pop into consciousness, often at an inopportune time. Usually described as incubation and illumination, there is general agreement on what is needed to make it work. First, one must spend time trying hard to solve the problem at hand. Then, one should stop working and do something that requires no focused mental activity. Finally, one should have a ready means to record ideas when they pop up (often early in the morning while running water), otherwise they will be lost. With incubation and illumination, there is an alternation between focus and effort, and no-focus and no-effort. It may be that making an effort and getting nowhere creates frustration that drives the subconscious to search for a solution. The setup for incubation and illumination is all-important. A quick or paltry initial effort will not provide enough frustration to drive incubation, making illumination unlikely. Tight schedules will not provide enough time for incubation, making illumination unlikely. The student habit of leaving projects to the last minute does not provide enough time for incubation. Constantly busy people usually fail to provide enough time when not concerned with anything in particular, making illumination unlikely. Incubation can be sidetracked by a focus on the next project, concerns about children, or an emotional slight. All of these will easily displace the background activity that leads to illumination.

Zoom In and Zoom Out

Zooming is a term Bruce Archer[2] borrowed from photography to describe the way designers move back and forth between a close-up, or part view, and a whole view of a potential solution. Thus someone designing online election software might alternate between looking at bits of code, and looking at what a user has to do to vote. Related to zooming is the alternating movement between specific and general. A more specific view would be looking at various ways a group might run an internal election; a more general view would be looking at various ways a group might work together. Also related to zooming is the process of shifting focus around different parts of a whole solution. Thus an architect might move between the exterior and the interior of a building, between circulation patterns and interior spaces, and between a plan view and a structural system. A songwriter might move between melody, harmony, rhythm, and lyrics. People with less experience seem to move around less.

Analysis and Synthesis

Yet another activity common in design is the alternating movement between analysis and synthesis. Typically, analysis separates wholes into parts, while creative synthesis brings together parts to make new wholes. As with many of these alternating pairs, a cultural bias seems to favor one member of the pair at the expense of the other. Our educational system, for instance, spends far more time teaching analysis than it does creative synthesis.

Question and Answer

One of the most important abilities in design is the ability to ask good questions. Some designers say that asking questions may be the only service they provide a client. If the questions are good and probing, they may provide enough direction for a client to rethink a product or fix an intractable problem. A good question is one that has no easy answer. Often it is so basic that it uncovers conventions or assumptions no one had thought about. Whatever its nature, a good question is one that generates wondering, or wandering in search of an answer. And the process should not stop with one answer; a good answer should generate more questions, and then more answers, round and round.

The majority of university students I have encountered seem to have little facility for asking questions. With curiosity so diminished from childhood, by the time they reach university they seem to have grown into a diminished species. One would think that encouraging the ability to ask questions would be a principal concern of primary and secondary school educators, given the constant stream of articles in the popular press about the importance of research and innovation. I cannot imagine a more important educational initiative than figuring out a way to reward students for asking questions.

Prototype and Test

Experienced creatives constantly ask themselves one question: "Am I on the right track?"

Often the only way of arriving at a reliable answer is to make a prototype, and try it out. For this reason, innovative companies have made an alternating pattern of rapid prototyping and quick tests the main activity of new product development. The successes and failures that arise steer projects toward products that work as intended. Without sufficient prototyping and testing along the way, a finished result will be tested on users, and may fail. I remember giving a project to industrial design students that asked them to design a push scooter before these became commercially available. Every one of their final designs crashed within a matter of a few feet. A cheap quick prototype along the way would have identified the main problem, and focused their design efforts on the issue of steering.

In his book *How Designers Think*, Bryan Lawson describes the importance of failures. He shows that designers are unique in that they approach design problems by trying to quickly solve them. The failures that inevitably occur tell them what they don't know, and that tells them where to focus their research (Lawson, 2005). Those who have little design training will typically undertake far too much unfocused research at the beginning of a project. Excessive or irrelevant research often leads well-intentioned young designers to become bogged down, unable to find a way out of the dense fog created by too much irrelevant information.

Building and testing prototypes resembles asking and answering questions, which resembles generating and evaluating ideas. One of the characteristics of creative production is that processes overlap and are interwoven, so that doing one well will often help another. So while testing seems to fall into the category of evaluation, arriving at a good, cheap, quick test requires invention, because the usual ways of testing are so often slow and expensive.

Fail and Fail

Genuine creative production inevitably results in multiple failures. Even with the simplest projects, I go through at least three or four failures before arriving at something that works, versions I call Mark 1, Mark 2, Mark 3, Mark 4. I think of them as similar to the Mercury rockets the United States built during the space race that toppled over and blew up on the launch pad. It's important to recognize that failure is part of creation, and that trying to avoid failure is a serious obstacle to creating anything new. Experienced professionals tend to see failure as helpful. Encouraged by what they have learned, they will speed up. Those with less experience tend to see failure as a setback. Discouraged by their inability to succeed immediately, they will defer to an existing solution, or slow down, or stop at one option. Innovative companies that focus on rapid prototyping call for failing fast, failing often, and failing forward. Not every failure is helpful. Failures must be "above the waterline"—they should not sink the project or the company—and should help to propel a project toward a useful result. Generating ideas for prototypes must be combined with candid evaluation, partly by considering the consequences of failure.

In some places there is little incentive to try anything new because failures are not tolerated. Governments are one of those places. Staff are reluctant to innovate because they know that the elected politicians, who are their bosses, will have to take the heat for any perceived failure. Fear of repercussions, and a pervasive culture of control that goes with the very nature of government, makes it a poor environment for creative problem-solving. This deficiency deserves some attention from activists, because the task of solving our most pressing problems rests in the hands of government.

Being Rather Lost

When working on a problem, many people do not like being lost. They don't like wandering about, trying to figure out where to go next. For this reason, they often decide quickly what the final result should look like, then head straight for it. Experienced designers recognize that any potential solution should be held lightly. They are wary of making a beeline in the direction of an early idea, no matter how attractive it may be. New information arriving along the way should be allowed to alter a destination. For less experienced designers, uneasiness about wandering, looming deadlines, and a lack of confidence in their ability to generate ideas all seem to contribute to premature clarity and to hanging on to the first idea as if it were a life preserver. Sometimes hanging on will yield a great result; more often, it will get in the way of considering better possibilities. If it leads to a refusal to respond to real-world obstacles, it can send an entire project down the drain. Premature clarity—sometimes called *premature congratulation*—is very common. The antidote for premature clarity is getting used to getting lost.

Making It New

I'm Not Going There

Outstanding creative people often have a pervasive contrary attitude to the world as given. They don't want to create more of what exists, and they don't want to emulate the great work of others. The best don't even want to produce more of their own successful work. Their contrary stance treats Terra Incognita as the place to be. In the early part of their careers, most creatives focus on emulation, as they try to understand and succeed in the mainstream. The Beatles, for instance, based many of their early songs on the music of Buddy Holly. Eventually, most get tired of emulation and try to define their own voice. In doing so, they turn away from safe and successful work. Now the only option is to go where they have not gone before. The result may be a disaster, but it will be new. Consider the career of leading abstract painter Philip Guston, who suddenly dropped abstraction in 1970 and began painting clumsy, cartoon-like figures. The shift shocked the art world, and was widely ridiculed, notably by the *New York Times* art critic Hilton Kramer in an article entitled *A Mandarin Pretending to Be a Stumblebum* (1970).

Constraints

Constraints can both help and impede creative production. It is tempting to believe that everything will be easier without constraints. More often, the opposite is true. The first constraint is the knowledge, skills, and goals that belong to your chosen domain of practice. The time that it takes to become familiar with one domain makes it difficult to become sufficiently familiar with another to make a significant contribution. Another constraint is available time. Every writer understands the importance of a project deadline; with an unlimited amount of time, nothing gets done. Architects often say that context and performance constraints define the problem. Celebrated architect Frank Gehry said that the strict acoustical requirements of Disney Hall helped him design the building. Just the opposite happened when he was asked to design a house with zero constraints. "I had a horrible time of it," he said. "I had to look into the mirror a lot. Who am I? Why am I doing this? What is this all about?" (Sturt, 2013). Lack of resources is another helpful constraint. With too many resources, there are too many options to consider. As Twyla Tharp says in her book *The Creative Habit*, "Whom the gods wish to destroy, they give unlimited resources" (2003).

Most constraints should be seen as guides that can help the emergence of form. When absent, constraints need to be found. If they can't be found in the project or the situation at hand, they may be found by zooming out to a larger view and questioning goal, category, or field constraints. Italio Calvino took this route when he decided to replace the linear structure of the novel with the relational structure of a three-dimensional array. This led him to the circular recursive work for which he is known, such as his book *If on a Winter's Night a Traveler*. In *Creativity from Constraints*, Patricia Stokes quotes Calvino: "For me the main thing in the narrative is not the explanation of an extraordinary event, but the order of things that this extraordinary event produces in itself and around itself; the pattern, the symmetry, the network of images deposited around it is in the formation of a crystal" (Stokes, 2006).

It is good practice to examine field-defined constraints because they impose overarching goals. Consider the state of visual fine art today. A large number of leading artists focus on creating what is called conceptual art—art that is good to think. Marcel Duchamp established the trend by panning "retinal art"—art that is made for the eye. The trouble with the goal of "good to think" is that it imposes almost no constraints. Just about anything can be converted to conceptual art by attaching it to a philosophical or critical theory text. Thus many contemporary artists have been left to wander in a desert of deep thought, trying to illustrate texts they don't quite understand. In *Hold It Against Me*, Jennifer Doyle suggests a different goal for visual art (2013). Like Robert Hughes in *The Shock of the New* (1991), she suggests that art should provoke an emotional response. This is a real constraint, one that would make visual art more engaging and relevant to a wider public. Nevertheless, it faces an uphill battle, partly because of the supposed depth of conceptual art, partly because visual art training has become increasingly more academic.

Making It Wrong

A more explicit form of contrariness is the deliberate attempt to "make it wrong," the mantra of German designer John Bielenberg. This sounds like another call for making mistakes, but it's not the same thing. Wrong is not normal, not familiar, not right, not comfortable. It relies on the clarity of the world as it is, to suggest options for a world that isn't. French ad man Jean-Marie Dru spelled out a similar process in his book *Disruption* (1996). For Dru, the first and most difficult step for any designer is to identify conventions. The next step is to ask disruptive questions about why that convention exists, and then to ask "what-if" and "why-not" questions about alternatives. This approach undoes the familiar world, turning something fixed into something fluid. Consider an ordinary chair. Why are chairs bilaterally symmetrical? Why is the seat always at the same height? Why do chairs with backs only have one, why not two? Why are chairs just for sitting, why can't they accommodate sleeping? Sitting for long periods contributes to weight gain. Why not a chair that requires physical activity, a chair-exercise-machine? Why are chairs always self-supporting stand-alones; why can't they have two legs or one and be supported by something nearby? An ordinary chair is hemmed in by dozens of conventions, all of which can be questioned.

Making the Words Different

More than anything else, words define the world that is. So making the world new requires overcoming the stereotyping that comes with words. Ask anyone to design a chair, and immediately a picture of a generic chair pops into mind. Because of this, design instructors will sometimes create projects for students that avoid the usual labels. They will try to make the objective less specific; instead of saying, "Design a chair," they might say, "Design a device for supporting the human body." Words not only frame problems, they suggest where to go for solutions. If current solutions are not working, a good strategy is to change the frame by changing the words. Sometimes all that is needed is a thesaurus to alter one or two key words. At other times it may be necessary to identify an established frame that is not working, and gather support for a convincing replacement. Let's suppose the problem is drug abuse. If we describe the problem as illegal drugs flowing into the country, solutions will be sought in intercepting traffickers. If we describe it as a medical problem, solutions will be sought in benign substitutes, antidotes, and safe injection sites. Different words create different frames that suggest different solutions.

Making the words different is sometimes necessary just to recognize that there is a problem. Disadvantaged people easily become inured to their situation. In *Pedagogy of the Oppressed* (2000), Paolo Freire encouraged disadvantaged groups to improve their conditions by engaging in naming and renaming exercises. Michael Newman, in his book *Teaching Defiance*, gives an example. "So a Freirian educator, using a drawing of an alleyway and a shantytown, might encourage a group of people to focus on the water lying in the streets, and to rename it dirty water, then sewage, then a health hazard for their children, then an example of bureaucratic indifference, then yet another example of the differences between the rich and the poor sectors the city, then an example of injustice." As the group begins the process of renaming, what it took for granted becomes a problem, but "[o]nce the cycle has begun, there may be no turning back. The world will of necessity be different" (Newman, 2006).

Making Metaphors, Similes, and Analogies

If we were to create a metaphor to describe the role of words, we might say that they pin everything in place, fixing the world that is. Different words loosen the pins, allowing shifts in point of view. Metaphors, similes, and analogies go a step further. They bridge categories that language normally keeps separate. This is very helpful when the task is to make the world new, so experienced designers will often start with a metaphor or an analogy. Many designers will ask, how has nature solved the problem? They will then start thinking of ways to adapt nature's approach to the problem at hand. This process of "biomimicry" has yielded thousands of technical innovations (Benyus, 2002). For example, bumps called tubercles on the flippers of humpback whales have been adapted to wind turbines, where they improve efficiency by increasing lift and reducing drag (Fish, Weber, Murray, & Howle, 2011).

The use of metaphor seems to be far more evident in the practice of experienced professionals. Most students have difficulty stepping away from the literal. This leaves them trapped by words, unable to benefit from the way metaphor can open up possibilities. Let's say you wanted to improve the performance of a hospital. A literal approach would require a study of various hospital functions and a search for external models that represent best practices. Without excluding this approach, you could include a metaphor framed as a question: "How can we make this place more like a mother?" This would shift the focus from physical repair to emotional care, and shift seeing the hospital as an institution toward seeing it as a temporary home. In any case, the metaphor would take the designer somewhere that a straightforward approach would not. Thinking with metaphors, seeing resemblances across different planes of reality, makes reality more fluid and makes possible the cross-fertilization that can occur when we begin to see the relationships between things we normally keep apart.

The potential of Wandering Outside Your Field

Those who study creative production like to underline the fact that the most valuable work is done, not within fields, but between fields. Since most people come attached to a field, a profession, or a trade, the challenge is to avoid being hemmed in by the vocabulary that defines their territory. To do this requires identifying what is inside your field, and surveying what lies just outside. Let me provide a simple example. Inexpensive, cool, efficient, and long-lasting light emitting diodes (LEDs) were available for decades before they were incorporated into lighting systems. Lighting designers ignored them because they belonged to the field of electronics, which lay outside the field of lighting. Because abundant opportunities lie in the spaces between, smart designers explore work from other places, other times, other categories, and other fields. In going outside their chosen field, they choose to wander; their surroundings will be unfamiliar and the language strange. They won't know where they are going or what they might find.

Less Directed Wandering

Sometimes the best strategy is for a creative to give up conscious control and become an agent of the subconscious.

Autopilot

Everyone will be familiar with stories of uncontrolled creative production that have produced rather good results. There is the story of the playwright who says, "I create the characters, then they take over and decide what happens in the play." And the sculptor who says, "I don't create work in stone—I only reveal what is already there." These creatives have learned to trust their instincts, enabling them to work on what I call "autopilot." They aren't consciously thinking about where they are going, or whether the result is any good; they are simply hosting the emergence of form. On autopilot, they are not aware of their surroundings or the time; when they switch off autopilot, they're often surprised at the late hour. Autopilot requires enough practice and technical know-how that production can proceed unselfconsciously. If a person working with ceramics does not understand the nature of clay and runs into basic problems of cracking or collapsing, they must address these problems consciously. Autopilot seems to have some relationship with what Martin Heidegger calls "dasein," a state where there is no separation between subject and object, no subject consciously controlling an object (Heidegger, 1962). Everyone who drives a car has experienced this integration of subject and object when making a journey without consciously thinking of what they were doing. Autopilot also seems to be related to the Buddhist concept of "no-mind" or "mushin," (Soho, 1986) and Mihaly Csiksgentmihalyi's concept of "flow" (2013).

Play

Play is an activity that is carried out for its own enjoyment. Professional creatives all recognize the importance of play, but most admit they don't allow it enough time. To encourage play, innovative companies such as Google allow employees paid time just to pursue whatever might catch their fancy. Ideally we would all find time to step out of our roles as adults, advisors, teachers, and parents, and revert to being children again—motivated, not by what needs to get done, but by sheer curiosity.

Jamming

We've already talked about altering perspective by altering the words used to frame a problem. Jamming is another technique that focuses on words, but here the creative has less control. With jamming, the objective is to create interesting clashes that will steer a project in a new direction. This makes jamming especially good for getting out of ruts, and for restarting projects that have run into a dead end. To begin word jamming, a person makes selections at random from lists of concrete words, and then creates different pairs of these words to see what results. To avoid being stuck with the literal—and often very odd—result of two collided words, those who use word jamming will explore the potential of interesting pairs by taking them through a stream of associations until they arrive at something that relates to the problem at hand. Students who try word jamming for the first time are often surprised at how arbitrary pairs of words can be so useful in generating ideas for a specific project. Edward de Bono, who has written many books on creative thinking, has turned to writing short manuals that consist of nothing more than word lists and different ways of choosing and combining words from the lists (De Bono, 2008).

Working Half Awake

A commonly reported feature of incubation and illumination is that it often occurs just before going to sleep or just before waking up. The recognized setup for incubation and illumination—a strong effort to solve a problem—helps to bring forth ideas while half awake. A liminal state seems to provide opportunities for ideas to arise, possibly because of the absence of conscious controls. Some creatives also recommend a drink to achieve the same result, sometimes just before going to bed, being careful to drink enough, but not too much, depending on one's tolerance for alcohol.

Lucid dreaming is another half-awake process that seems useful in solving problems (see Windt and Voss, Chapter 29 in this volume). Here one is said to be conscious of being in a dream while in the dream. Lucid dreaming can be learned with dedicated practice, and those who can bring it about also say they can keep it going while in the dream. They recommend that beginners try to extend the period of waking up in the morning. Interesting ideas that occur while waking up have a good chance of being recorded, if they can actually wake the sleeper. Here is Paul McCartney describing the origins of the song "Yesterday": "I had a piano beside my bedside, and I must have dreamed it, because I tumbled out of bed and put my hands on the piano keys and I had a tune in my head. It was just all there, a complete thing. I couldn't believe it" (Russell, 1995). The difficulty when falling asleep is the absence of an opportunity to record what comes up. To address this issue, some people tell themselves to remember their dreams before going to sleep. Thomas Edison had another method: He allowed himself to fall asleep in his favorite armchair with a tin plate on the floor on either side. In each hand, he would hold a steel bearing suspended above each plate. Just as he fell asleep, he would drop one or both bearings onto the plates. This would wake him up, whereupon he would write down whatever he was thinking about at the time (Michalko, 2001). Research labs, innovation centers, music schools, and other places that nurture creatives should consider adding places where people can sleep so that during the day they can take advantage of being half awake. An added benefit would come from the ability to nap: everyone would be more alert when fully awake.

A Black Box

What goes on in the minds of creative people when they work is still largely a black box. Some hints of what might be happening can come from observing them in action, but these will be guesses, leaving both creative practitioners and teachers wondering if they really know what they are doing. For researchers, this black box is a land of opportunity. By venturing here, they will be true explorers. Whatever they find will be prized by those who regard creative thought as one of the most difficult and important human capacities.

Notes

1. Perhaps the most convincing research on the effects of evaluation has been done by Teresa Amabile, who looked at the way marks stifled the creative output of students.
2. Bruce Archer was an engineer, a former teacher at the Royal College of Art, and an advocate for design in general education.

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CHAPTER

24

Flow as Spontaneous Thought: Insight and Implicit Learning

John Vervaeke, Leo Ferraro, *and* Arianne Herrera-Bennett

Abstract

Flow is an experience encountered in many areas of human endeavor; it is reported by athletes and artists, writers and thinkers. Paradoxically, it appears to involve significant energy expenditure, and yet it is reported to feel almost effortless. It is a prototypical instance of spontaneous thought. The flow experience has been extensively documented and studied by many scholars, most prominently Csikszentmihalyi, who characterized it as "optimal experience." This chapter builds on the work of Csikszentmihalyi and others by providing a cognitive scientific account of flow, a framework that organizes and integrates the various cognitive processes and features that serve to make flow an optimal experience. In particular, it is argued that flow is characterized by a dynamic cascade of insight, coupled with enhanced implicit learning. This model seeks to integrate the phenomenological accounts of flow with the existing body of cognitive research.

Key Words: flow, Csikszentmihalyi, implicit learning, insight, cognition

Many of us have experienced an unusual sense of proficiency or aptitude while being engaged in an engrossing task. This is particularly common in athletic pursuits (although not unique to them), where it is known as "being in the zone." People report that time seems to pass differently, self-consciousness fades, and there is a sense of grace within the deep engagement with the task. This is the phenomenon of *flow*, introduced by Csikszentmihalyi in the 1960s, which has received extensive attention in psychology and surrounding fields. Observed within a wide array of activities, including art and science (Csikszentmihalyi, 1996), aesthetic experience (Csikszentmihalyi & Robinson, 1990), sports (Jackson, 1995, 1996), and creative writing (Perry, 1999), flow is prevalent across differences in culture, gender, socioeconomic status, occupation, and age—and is described nearly interchangeably, irrespective of language (Csikszentmihalyi, 1996). Such a robust, culturally universal phenomenon is rarely observed in psychology. In addition to this universality, the flow phenomenon is also intriguing precisely because it seems to enhance and improve human experience. Beyond well-documented long-term benefits such as physical and mental well-being (Clarke & Haworth, 1994; Massimini & Carli, 1988; Mayers, 1978; Wells, 1988), there remains a subjective sense that engagement in flow-generating activities is intrinsically desirable. Individuals seek the flow experience for its own sake, sometimes at extreme costs, perceiving their performance as pleasurable and successful regardless of any further achievements (Nakamura & Csikszentmihalyi, 2002). Flow, by virtue of being both a robust psychological universal and a source of immediate and long-term value to individuals, clearly stands out as important and deserving of better and more meaningful understanding.

Flow arises in a *spontaneous* fashion when the right balance of skill and challenge meet. The experience unfolds in a non-deliberative fashion in which people report that although there is a considerable expenditure of energy, the process feels effortless. We will argue that this spontaneity is neither coincidental nor epiphenomenal. Instead, it is rooted in self-organizing cognitive processes that exhibit spontaneous structural and functional reorganization in a developmental fashion. Finally, this spontaneity is different from both deliberative, inferential thought, and implicit, automatic cognition; it is neither reflection nor reflex. We will argue that it is a self-perpetuating dynamical system of insight and implicit learning.

Objective

The literature on flow is extensive, with the benefits and qualities of flow being well and thoroughly examined. What we seek to do, in part, is to try to situate flow in a larger theoretical landscape. We seek to supplement phenomenological explanations of flow with cognitive explanations of its phenomenology. We hope to propose a framework for better understanding of the mechanics of the flow state. In so doing, we hope to demonstrate the larger relevance and applicability of the existing understanding of flow to other related psychological phenomena.

It appears that flow is inherently highly desirable; however, few accounts have sought to explain *why*, beyond invoking long-term positive but indirect psychophysiological effects (generally as an argument for evolutionary feasibility). One cannot sufficiently explain the prevalence of the flow phenomenon solely in terms of its long-term evolutionary viability; the long-term phylogenetic advantage has to be translated into immediate ontogenetic incentive. The resultant benefits that occur as a result of flow do not explain *why* the immediate flow process itself is so strongly sought out. This does not debate the fact that flow seems to yield evolutionarily adaptive benefits. In fact, it argues that flow is an intrinsic evolutionary mechanism present in the brain for its massively adaptive function. However, in order to effectively answer *why* flow occurs, one must first give a thorough account of exactly *what* is taking place during the flow process.

Hence, the goal of this chapter is to propose a comprehensive cognitive scientific analysis of flow. This elucidation begins with a description of the process that mediates flow experiences, supplemented by an account of the operating mechanisms. This will provide the conceptual basis to offer a strong theoretical answer to the question of *why* the occurrence of flow is so prevalent, ultimately highlighting *how* the phenomenon is evolutionarily adaptive, as well as affording useful explanatory connections between flow and other psychological constructs, such as insight and implicit learning.

Outline

The argument in this chapter will proceed as follows: We begin with a presentation of Csikszentmihalyi's theory of flow, outlining the prevalent features of the phenomenological experience and the conditions by which the flow channel is optimally achieved. Close analysis here aims at a fundamental facet of the flow process, "skill-stretching." This specific system of learning, as qualitatively different from passive or inferential forms of learning, will serve as the basis for an alternative conceptualization of flow, framing the process as a cascade of insights affording one another in a self-perpetuating fashion. The phenomenon of insight implicated in this account of flow follows from the Gestalt framework of cognition, where insight is understood as an instance of fundamental restructuring (Köhler, 1924, 1947; Wertheimer, 1923). These intuitions, born out of the Gestalt psychology, will be further supported by current cognitive scientific theory, drawing connections to the work of Hogarth: Flow is framed as a process that allows for improved implicit learning, and thereby the cultivation of sound intuition. This conceptualization of flow seeks to best explain the phenomenological features of Csikszentmihalyi's analysis and, further, draws flow together with insight and implicit learning in a larger cognitive framework.

Csikszentmihalyi's Theory of Flow

Csikszentmihalyi's theory of flow provides an account of the phenomenological features characterizing the subjective experience of flow, as well as an analysis of the conditions by which the flow state is optimally achieved. Research on flow reliably documents a set of common features underlying the phenomenology of flow, including an intense or heightened concentration and attention on the activity at hand; a sense of distorted time; transcendence of the self; a reduction or loss of reflective self-consciousness; reduced or absent worry over failure; focus on the present moment; resilience against distraction; autotelic engagement in the activity itself; merging of action and awareness; and the feeling of being at one with the environment or activity—in other words, a deep sense of "at-oneness" with one's surroundings. Csikszentmihalyi expresses flow as an "almost automatic, effortless, yet highly focused state of consciousness" (1996, p. 110). Not only does the flow experience produce powerfully gratifying subjective experience, flow is also reported to yield optimal performance (Csikszentmihalyi, 1996). Flow is sometimes considered a state of optimal engagement, hyper-productivity, hyper-creativity, or hyper-motivation.

The conditions conducive to generating this altered state—creating the "flow channel"—involve the dynamic between the individual and his environment. There must be a dynamic match between the demands of the situation and the skills of the individual. When challenge outweighs skill, the individual develops anxiety and frustration; when skill outweighs challenge, he or she faces boredom. Simply matching the level of challenge to skill, however, is insufficient for producing flow. For example, a low level of challenge matched with a low level of skill produces apathy, which has been viewed by some as the "anti-flow" (Allison & Duncan, 1988). All of these phenomenological states—anxiety, boredom, apathy, and flow—can be understood as functions of how attention is being structured with respect to a given time or situation (Nakamura & Csikszentmihalyi, 2002). Not only must there be a match between challenge and skill, but the individual must also feel engaged or pushed to his limit. This is a point worth stressing: although Csikszentmihalyi describes a "match" or "balance" of challenge to skill, it should be emphasized that this does not prescribe that the problem or the demands at hand be completely within reach. On the contrary, the notion of challenge conveys a certain lack of ease, denoting a problem or a demand that is just beyond the current skill level of the agent.

Csikszentmihalyi, in his 1997 chapter "Finding Flow," reaffirms this central notion. He states that "flow also happens when a person's skills are fully involved in overcoming a challenge that is just about manageable, so it acts as a magnet for learning new skills and increasing challenges" (p. 47). Here emerges the notion of "skill-stretching"—a system of learning where the process of meeting and overcoming one challenge breeds a new and more developed skill set, in turn affording the ability to take on a still more difficult set of demands. This notion of "skill-stretching" is inherent to flow, and implies an important style or system of learning that qualitatively differs from more passive or incremental learning processes. The learning fostered during flow involves a growth principle (Shernoff et al., 2003). It is exactly this quality of learning that Csikszentmihalyi describes as the basis of the level of motivation observed in flow—motivation for and during the flow experience is, in large part, the enjoyment that comes as a result of confronting challenges (Csikszentmihalyi, 1996).

Another important factor to optimally engage the flow channel is feedback (Csikszentmihalyi, 1996). In other words, in order to remain constantly engaged and motivated within the flow state, the individual needs to have a clear sense of how well his skills are meeting the demands of the environment. This tight coupling between the individual and the environment is necessary for flow and is made possible via tight environmental feedback in response to the actions being performed. This feedback should be clearly indicative of the adjustments needed in order to maintain performance. Thus, a system that optimally induces and perpetuates the flow state is characterized by a dynamic match of challenge to skill, whereby a tight coupling between an individual's actions and his environment is achieved through a structure of tight feedback—both clear and timely in nature, and thus highly diagnostic of the total system's behavior. These conditions ultimately constitute an environment for the cultivation of skill-stretching.

An Alternative Conceptualization of Flow: The Insight Cascade

Csikszentmihalyi's descriptive analysis of the flow phenomenon appears to implicate a specific form of learning or system of engagement between agent and environment. He is correct that what is occurring during flow does not specify particular activity—a certain *what*—but rather a specific *how* (Csikszentmihalyi, 1996). This chapter aims to follow this notion in order to develop an alternative conceptualization of the immediate process of flow that emphasizes the tight dynamic coupling between environment and individual action, critically outlined by Csikszentmihalyi, as well as to explicate the concept of skill-stretching by appealing to well-established psychological phenomena existing in the framework of cognitive science.

The alternative conceptualization of the process of flow might be expressed as "an extended 'aha!'" The "aha!" moment refers to the overcoming of an impasse, specifically within an instance of insight problem-solving (IPS). This critical moment of grasping the solution to an impasse is perceived or felt as a moment of deep realization; the "aha!" moment is the phenomenological realization of the relevant course of action or approach to solving an insight problem (Sternberg & Davidson, 1995). This proposition invokes the notion of IPS because insight learning has been recognized, specifically within the Gestalt psychology framework, as qualitatively differing from other forms of learning. Insight learning is not the result of mere repetition or practice, but rather a moment of fundamental restructuring of the problem, based within the implicit procedural system of processing. The Gestalt understanding of insight appeals strongly to the concept of procedural transfer. To elucidate: whereby the solving of some types of non-insight problems is facilitated by content-similarity existing between the different problems, IPS benefits from the existence of procedural similarity between problems or scenarios. In other words, the way in which one construes and frames the pieces of a problem in relation to one another determines one's understanding of the problem itself, and in turn determines the ability to realize the impasse. Because insight is based in procedural processing, the method or procedure of grasping one solution to a problem can be transferred to another problem space. This might be understood as the transference of a mental set—the transference of the way in which one is primed to perceive or frame, and in turn potentially reframe, a scenario. Further implications of the Gestalt conceptualization of insight and procedural priming will be elaborated on in the next section.

With respect to the understanding of flow, conceptualizing the process as an extended "aha!" moment refers to a chain-like series of instances of IPS—an accelerated positive feedback loop, whereby the solving of each insight problem yields another insight problem to be solved. Flow might be understood as a cascade of transference of mental sets, each instantiation of insightful restructuring procedurally priming the agent to further engage insightfully with his or her dynamic surrounding. This moment-to-moment series of eureka effects fosters a string of insightful realizations—or an extended "aha!" As such, it is expected that the flow state yields a prolonged phenomenological feeling of the ongoing realizing of relevance in one's action with respect to the surrounding demands. Typically the flow state is perceived as smooth and continuous (hence the name), whereas impasse within an insight problem is experienced as a stoppage in performance. In flow, conditions that could emerge as impasse are quickly assimilated into the ongoing insight of the flow experience. Skills quickly stretch to meet these *potential* impasses, arriving at beneficial restructuring in a much more anticipatory and adaptive manner. Impasse is still present, but is experienced as a set of challenges or hurdles that are overcome, rather than roadblocks. In this manner, impasse is experienced as the challenge required to trigger and maintain flow, which can be seen as an *insight cascade*. Poet Mark Strand, for instance, describes his experience of flowing as "the powerful sense of doing exactly the right thing the only way it could be done" (Csikszentmihalyi, 1996, p.121).

Work surrounding the phenomenon of fluency has in fact attempted to bridge the phenomenology of processing and the act of processing itself. Fluency is defined as the subjective experience of ease or difficulty related to a mental process. Fluency refers not to the active cognitive process, but rather to the accompanying sensation of how easy or efficient the cognitive processing feels (Oppenheimer, 2008). Recent work, however, has suggested that the phenomenology of processing may correlate to the actual degree of ease of processing occurring at the neural level. In other words, fluency might serve to indicate one's quality of processing in the cognitive operation at hand. Topolinski and Reber (2010) specifically propose a fluency account of insight whereby the sudden change in processing that occurs when the solution to a problem pops into an individual's mind—the pivotal "aha!" moment—acts as the underlying causal mechanism of experiencing a light bulb going on inside one's head. This view integrates processing fluency with experiential fluency, whereby the latter is not merely a hedonic marker of the positive experience, but an essential concomitant of insightful processing.

The aforementioned work on fluency ties in strongly with the proposed reconceptualization of flow. Flow understood as an insight cascade refers to a series of instances of insightful processing, each marking a more complex or higher level of processing. These sudden bouts of increased processing are each accompanied by a subjective sensation of overcoming the impasse—the phenomenological breakthrough. In line with recent accounts, the increased fluency or ease in cognitive processing during IPS yields the concomitant positive affect marking the realization of successful relevant processing, as well as the rewarding feeling of overcoming difficulty and struggle. It follows that a cascade of insights would naturally yield an accompanying and ongoing stream of positive subjective affect, reinforcing a sense of meaning in one's processing—flow phenomenologically equates to an experience of extended fluency.

In sum, this proposed alternative conceptualization of flow heavily implies a very powerful form of learning and processing not only at the cognitive level, but also phenomenologically. Flow yields a high degree of skill-stretching, which occurs as the result of the dynamic interplay, or opponent-processing, between generation of insight problems and subsequent insight problem-solving. The flow state nurtures a dynamic system of interaction, whereby each instantiation of insightful restructuring procedurally primes the agent for subsequent insightful processing. It is through this series of transfers of mental sets that instances of IPS start to chain and afford one another in a self-perpetuating manner. Furthermore, this highly interactive and engaged form of learning and processing is naturally accompanied by a feeling of reward and ease—a prolonged sense of meaningful breakthrough, born out of the increase of fluency in one's processing. This conceptualization of flow homes in on the characteristic defining feature of flow that Mark Strand so aptly expressed in the preceding quotation—the potent sense of effortlessly engaging in exactly the right way with one's environment: "being in the zone." Hence this chapter will argue that flow ultimately cultivates an optimal form of implicit learning, directly contesting the usual interpretation of the sense of ease and effortlessness in processing as indicating highly implicitly automatized or plateaued learning.

This alternative conceptualization attempts to step beyond mere descriptive analysis, appealing to documented phenomena to interpret and explicate the immediate process of flowing. However, it is necessary to supplement this proposed alternative conceptualization of flow with a mechanistic explanation of how exactly a cascade of insights is instantiated and maintained in the brain, as well as an account of the increased efficiency in processing that underlies the phenomenological sense of experiential fluency. By describing what is actually occurring in the "aha!" moment, we can more concretely propose and argue the claim that flow constitutes optimal implicit learning. It is important to now take a closer look at the phenomenon of insight, specifically by addressing the two prevailing and opposed views within the insight literature. The aim is not only to argue in favor of the Gestalt framework as being more conceptually apt in explaining human cognition and insight processing, but also to highlight the limitations that the computational view presents when trying to frame this complex phenomenon. In turn, the chapter seeks to convey a better sense of the fundamental nature and structure of the insight processing that is proposed to take place during flow.

The insight literature has historically been divided into two schools of thought, each taking a different approach to explaining the phenomenon of insight and its fundamental nature. The first is the computational theory of mind, also referred to as the search-inference framework, or symbolic representation. The second is the Gestalt approach. The search-inference framework, initially proposed by Newell and Simon (1956, 1976), is still viewed today by many as the dominant formulation for insight (Barsalou, 1999; Dietrich & Markman, 2003). Nevertheless, this chapter emphasizes the opposing view—the Gestalt approach. Of the two theoretical camps, this latter framework is argued to be the most apt and precise appraisal of the phenomenon of insight, underlining its procedural, dynamic, flexible, and nonlinear nature.

These two camps rely upon two fundamentally different sets of premises. The computational theory of mind frames thinking as an action. More specifically, it runs on the idea that thinking creates a structure, like that found in a computer, whereby information is encoded into a set of propositions, and inferentially manipulated. Learning, in turn, is theorized to occur sequentially, improving via a series of incremental steps, following Thorndike's paradigm of incremental learning (Thorndike, 1932). It follows from this view that all forms of learning, including insight, are a process of simple feedback, sequential in nature, and are not qualitatively different from other forms of learning. By this account, flow is considered a form of engagement that does not differ in any fundamental way from mere sequential engagement or incremental learning. Dietrich's theory of flow draws upon this computational framework. By framing flow as an instance of *hypofrontality* (Dietrich, 2004), he argues that the flow state constitutes a temporary absence of explicit processing, resulting in an optimal engagement of the implicit system. Because he abides within the constraints of this representational framework, Dietrich claims that in flow, only behavior or actions that have been mastered can occur. His theory reduces flow to highly automatized implicit practiced behavior, which entails no degree of qualitative growth or complexification of the system.

Gestalt psychology, on the other hand, frames cognition as perception. The fundamental formula of this framework is that the whole is greater than the sum of the parts; the behavior of the whole is not determined solely by its individual elements, but rather from their interactions (Stephen & Dixon, 2009; Wertheimer, 1923). In the case of simple visual perception, the overarching perceptual form is thought to convey greater meaning than the sum of the individual, isolated constituent elements. More specifically, it is the organization of those individual elements that contributes substantial meaning. Insight operates within this framework, as a qualitatively different form of learning or thinking than that gained through incremental improvement. Gestalt psychologists characterize the phenomenon of insight as a fundamental restructuring of the cognitive system (Köhler, 1947). Insight affords a shift in perspective, which yields a novel representation of a particular situation or problem, through an understanding of the functional relationships between relevant component parts (Marková, 2005). Insight, according to Gestalt psychology, involves a relaxing or breaking of constraints, which allows the mind to override the imperatives of experience (Knoblich, Ohlsson, Haider, & Rhenius, 1999), such that one might reconfigure his or her mental space, and establish a fundamentally new set of constraints. Once one speaks of organization in terms of constraints, one is finding a point of convergence with the search-inference framework. In that framework, constraining the search space to avoid combinatorial explosion is central. A problem formulation that constrains the search in a felicitous manner is a good problem frame. Kaplan and Simon (1990), in fact, argued from the search-inference perspective that insight was such a reframing of a problem formulation. Support for this view was offered in recent findings by DeYoung, Flanders, and Peterson (2008). Investigating the question of what broad cognitive abilities support insight processing, it was found that divergent thinking and breaking frame were the indices that were uniquely associated with IPS. Further investigation yielded support for their hypothesis that the ability to break frame represents a different and separate form of cognitive ability than divergent thinking. It follows that one's ability to break frame independently predicts and facilitates his or her capacity for insight. As such, breaking frame is argued to be essential to the requisite problem-reformulation implicated in IPS. The act of breaking frame temporarily creates a new Gestalt by entering into a more abstract, holistic processing style, which in turn enables a new perspective from which to reconfigure the new set of constraints.

This process is termed *restructuring* or *reframing*, and is exemplified by the S-curve learning paradigm. S-curve shaped learning refers to the graphical representation of the changing rate of learning, which fundamentally differs from the incremental learning of Thorndike (1932) (Figure 24.1).

In the latter, learning is posited to increase automatically and incrementally over time, and is graphically represented by a steadily increasing curve where performance correlates positively with time or trials of learning. S-curve learning graphically maintains the shape of an "S," where the curve is marked by a slow initial increment, followed by a sudden steep positive acceleration, and ending in a plateau. S-curve learning exemplifies a form of learning marked by a pivotal point of grasping the scenario or solution to learning. S-curve or insight learning presupposes a certain level of realization within the cognitive agent. The graphic shift

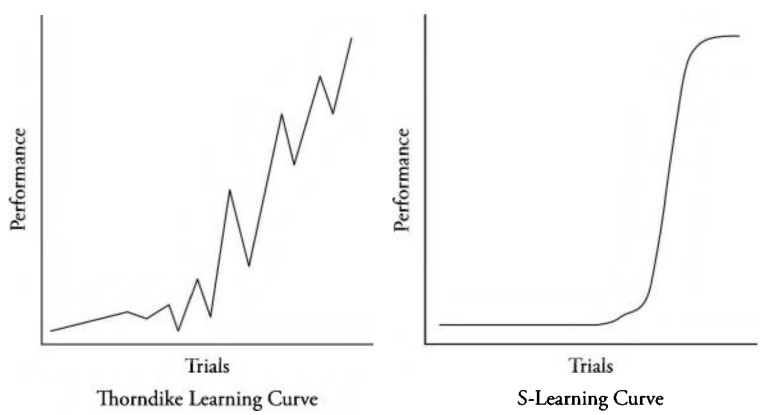

Figure 24.1. Graphical representations of learning paradigms: Incremental (Thorndike) vs. Insight (S-curve). Whereas incremental learning (left) is depicted as a steady increase in performance across trials, S-curve learning (right) is marked by a sudden and steep acceleration in performance. This pivotal moment in learning, as in the case of insight problem-solving (IPS), can be understood as the "aha!" moment of realization upon grasping the solution.

demonstrates the sudden leap toward a new mode of representation—a new way to make sense of one's surroundings. Insight here is an illustration of sudden improvement in performance, a qualitative shift in understanding that is maintained in the learner. Early Gestalt work, particularly by Köhler (1924, 1947), observed insightful behavior being marked by an abrupt yet smoothly directed process by which an objective is met (Marková, 2005). These changes in strategy were argued to reflect *emergence*—instances in which a dynamical system reorganizes itself (Köhler, 1947; Lewis 2005; Stephen & Dixon, 2009).

Support for the Gestalt framework of insight is evidenced by research conducted around the predictors of success on IPS tasks offering better understanding of the nature of insight processing. Schooler, McCleod, Brookes, and Melcher (1993), found that among various independent processes, the single best predictor of insight task performance—and not of non-insight task performance—was one's ability to engage in perceptual restructuring. These results provided further empirical support for the Gestalt theory of cognitive reframing during insight. Similarly, Baker-Sennett and Ceci (1996) measured one's independent ability to excel on a completion task, manipulating the number of prior cues provided. The fewer the cues needed before completion, the larger the leap signaled, and it was demonstrated that one's ability to make larger leaps was related to success on IPS. Once again, these empirical results mirror the intuitions of the Gestalt theorists, supporting the occurrence of abrupt cognitive leaps inherent in the S-curve insight model.

Support for this formalization of insight is also found within work investigating conditions of facilitation and hindrance to IPS. Macrae and Lewis (2002) measured the effects of an intervening task on the facial recognition abilities of three groups of individuals, where the task occurred between initial exposure to faces and a subsequent recall period. The two experimental groups' intervening tasks involved observing Navon letters.

The first group was required to focus on constituent letters, causing them to engage in a featural-level processing style, while the second group had to focus on the overarching letter, causing them to use a Gestalt processing style (Figure 24.2). The third group did not engage in any intervening task, thus acting as the control condition. Results displayed greatest facial recognition success among the second

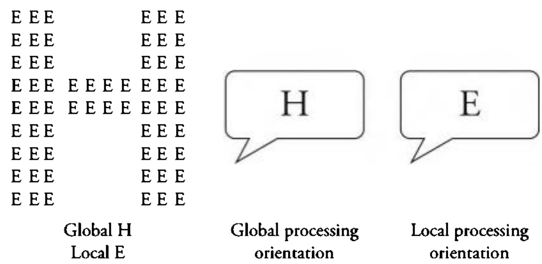

Figure 24.2. Navon letters: Induction of global vs. local processing styles. Navon letter task (left panel) can be used to flexibly induce different processing orientations. Focus on global letters (middle panel) vs. local letters (right panel) has been shown to, respectively, drive one's frame of thinking or processing style up to the Gestalt level vs. down to the featural level, which in turn has been shown to facilitate (vs. impair) holistic processing, such as facial recognition (Macrae & Lewis, 2002).

group, those having been driven up to the Gestalt level right before recall. This becomes particularly relevant because facial encoding and recognition are known to make use of holistic processing. Thus, being in a Gestalt frame of mind seems to facilitate holistic Gestalt processing. Dissociation is seen whereby driving an individual's cognitive processing upward not only significantly acts as facilitation, but driving it down to the featural level significantly hinders holistic Gestalt processing. This was reflected in the first group's low performance, with facial recall falling well below that of the control group. Finger (2002) showed that this impairment, however, was not permanent, but was quite flexibly undone. Using a similar experimental method to that of Macrae and Lewis, Finger was able to impair one group's facial recognition performance with a specific intervening task (specifically, driving the subjects' attention to the featural level via the component letter focus version of the preceding Navon letter tasks). A second group also engaged in this task, but the subjects were then asked to engage in a more Gestalt-oriented activity, such as listening to music, before performing the recall task. This second group performed much better than the first group on the recall task. These studies reaffirm the flexible dynamic nature of human cognition that the Gestalt psychologists predicted decades earlier, showing it to be highly responsive to the manner in which one is directing attention between scales. Furthermore, this same dissociation of facilitation and impairment, as exhibited earlier, is also shown to apply to IPS performance: Driving cognition down to the featural level or up to the

Gestalt level respectively impairs and enhances IPS (Förster, Friedman, & Liberman, 2004; Hunt & Carroll, 2008). Thus, it might be posited that this same flexible dynamic structures insight processing, where attention to features can break up inappropriate frames and afford reframing, while attention to Gestalts can generate the needed new framing.

Neuroimaging research shows patterns consistent with this theoretical model of insight. Insight processing is associated with marked right inferior gyrus activity, as well as increased electroencephalographic activity in the right hemisphere (Bowden & Jung-Beeman, 2003; Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Jung-Beeman et al., 2004). These findings appear to reflect a shift from primarily left-hemisphere processing to right-hemisphere processing, before returning to the left. This left-right-left pattern is assumed to reflect the process of cognitive reframing. This shift from the feature-level, sequential, logical, left-hemisphere system toward the right demonstrates a breaking of these constraints and the frame by which they were governed. The temporary right-lateralized processing putatively involves the coarse-grained Gestalt level, and being far less constrained, is aimed at seeking out multiple associations and meanings. Entering this more abstract mode enables a different approach toward subsequent left-hemispheric processing—this momentary Gestalt affords the ability to project structures of constraint that better fit the cognitive space. Recent work by Chi and Snyder (2011) lends further support to this observed neurological pattern of insight. Through the use of transcranial direct current stimulation (tDCS), it was found that inhibition of the left anterior temporal lobe (ATL) (L–) in combination with excitation of the right ATL (R+) caused a threefold facilitation in insight problem-solving ability, as compared to controls. Consistent with evidence for lateralization of frontal lobe functions, wherein the left hemisphere is associated with routine functioning and the right hemisphere with novel functioning (Goldberg, 1994), the authors theorized that the relative reduction of left hemispheric dominance and relative increase of right hemispheric dominance helped participants to break the tendency to examine a problem through routinized mental templates, and shift to examine a problem through a more novel representation. The L–/R+ stimulation effects support the Gestalt notion that insight is a breaking of constraints and a novel reframing of the problem space. Even more recently, Chi and Snyder (2012) used tDCS as an aid to solving the nine-dot problem whose *spontaneous* solution rate is statistically indistinguishable from zero. They were able to raise the spontaneous solution rate to around 40%. The Gestalt notion of insight processing, which fundamentally involves restructuring a set of constraints, also contains within it the idea of dynamically shifting multiple constraints simultaneously. In direct opposition to the inferential framework, the Gestalt view of insight processing is highly dynamical and nonlinear in nature and can thus be intervened on and improved upon.

The insight literature, as explicated within the framework of Gestalt psychology, offers a strong case for the dynamical, flexible, and insightful nature of the human mind. There are robust empirical grounds to argue that the nature of insight cannot be collapsed into a form of inferential sequential processing, as the computational theory of mind camp would claim. As such, it is not sufficient to conceptually reduce flow simply to highly automatized implicit behavior (Dietrich, 2004). Rather, the phenomena of insight and flow need to be supported by a mechanism nested within a dynamical framework.

This framework exists within the realm of *dynamical systems theory* (DST). The fields of psychology, cognitive science, and neuroscience have increasingly sought to explain and establish cognition as a complex dynamical engine of thought and behavior. More specifically, emerging research based in DST has generated empirically reliable and testable theories for the mechanisms of cognitive insight. A comprehensive look at these explanations of cognitive insight will ultimately be important in detailing the actual underlying cognitive process within the cascade of insights occurring during flow.

Self-Organized Criticality and Spontaneous Self-Organization

Cognitive insight can be understood as a process of emergent self-organization within an open system—specifically, the emergence of a new macroscopic cognitive structure. First, an overview of DST will be offered, briefly reviewing the notions of *emergence* and *self-organizing criticality* (SOC). A presentation of recent empirical research on insight within DST and SOC will serve to provide a concrete explanation of the actual underlying cognitive processes constituting the phenomenon of cognitive insight. Ultimately, this framework will help to properly substantiate a thorough, comprehensive, and concrete account of flow as an *insight cascade*.

The seminal work on DST and, especially, SOC is Bak, Tang, and Wiesenfeld's 1987 chapter in which they explain the key concepts of emergence and SOC through an investigation of the behavior of sand piles (Figure 24.3). Consider a surface with an infinite source of sand suspended above it, from which a stream descends in a constant manner, as in an hourglass. Over time a roughly conic pile forms; the micro-interactions between the individual grains of sand, as well as between grains and the surface, cause the sand to collect in a normal distribution under the sand stream. This conical shape *emerges*, without external direction, purely from the interactions of the grains and the surface. This emergent structure further constrains the placement of subsequent grains of sand in a self-organizing manner: As the conic pile rises, the structure becomes inherently unstable, and its ability to constrain the grains of sand declines.

The disorder (or *entropy*) of the system increases; this is initially reflected in the occurrence of micro-avalanches. Eventually, however, the growing instability of the system outpaces the ability of the micro-avalanches to shore up the pile, and the pile collapses in a major avalanche. This is a *critical period* for the pile, because there is the possibility that the structure can be permanently lost. However, there is also the possibility that the redistribution of the sand provides the base for a larger, more stable pile. Bak, Tang, and Wiesenfeld generalize this into a powerful explanatory model that offers useful theoretical and mathematical tools for understanding and explaining complex dynamic phenomena, including emergent properties. Hesse and Gross (2014) review the evidence and articulate the case for viewing the brain through this theoretical lens.

Spontaneous self-organization is an observable and naturally occurring property within a host of natural phenomena that abide by the principles of nonlinear dynamics. Among other examples, self-organization has been shown to underlie the emergent organizational behavior of fluid (Lorenz, 1963), lasers (Haken, 1983), single-cell organisms (Webster & Goodwin, 1996), and molecular networks (Sardanyes & Solé, 2006; Stephen, Dixon, & Isenhower, 2009). In line with the Gestalt intuitions, dynamic processes, as described by synergetics, have been observed to play a role in pattern recognition (Haken, 1980). As such, nonlinear dynamics have been posited as underlying major processes in the brain (Crick, 1979; Haken, 1980). Empirical findings in the realm of cognitive science lend strong support to this notion, whereby self-organization has served to explain locomotion (Kugler & Turvey, 1987; Swenson & Turvey, 1991), timing behavior (Kelso, 1995), as well as reaching (Mottet & Bootsma, 1999; Stephen, Dixon, & Isenhower, 2009). The growing body of recent complexity theory research has yielded strong grounds for theorists to propose the involvement of nonlinear dynamical processes in higher-order cognition (Stephen & Dixon, 2009; Stephen, Dixon, & Isenhower, 2009; Thelen & Smith, 1994; Van Orden, Holden, & Turvey, 2003, 2005). For instance, recent work on cortical neural networks and the propagation of neural activity showed critical neuronal avalanches to *spontaneously* arise in a self-organizing fashion when the cortical network was in a critical state (Beggs & Plenz, 2003, 2004)—an instantiation of the classic SOC sand pile phenomenon (Bak, Tang, & Wiesenfeld, 1987). Furthermore, neuronal avalanches have been claimed to correlate with optimal transmission and storage of information (Beggs, 2008; Beggs & Plenz, 2003, 2004; Haldeman & Beggs, 2005; Hsu & Beggs, 2006; Plenz & Thiagarajan, 2007), large network stability (Bertschinger & Natschläger, 2004), maximal sensitivity to sensory stimuli (Kinouchi & Copelli, 2006), and optimal computational capabilities (Bonachela et al., 2010; Legenstein & Maas, 2007). Given our review of the Gestalt approach to insight, it is plausible that insight is a complex dynamic phenomenon that could be well understood using these theoretical tools.

Figure 24.3. (See Color Insert) Self-organizing criticality (SOC): The sand pile model. Growing instability of a system (i.e., increased entropy due to addition of sand grains) will results in a critical period (or slope) where the system will spontaneously restructure itself (i.e., redistribution of sand pile); in other words, demonstrate the phenomenon of emergent and spontaneous self-organization.

One key example of this is the work of Stephen and Dixon, in a series of chapters on insight. Their fruitful application of DST and SOC to the phenomenon of insight clearly illustrates a strong connection between insight and flow. The actual process by which a complex open system engages in structural reorganization can be explained by synergetics, a systems theory that describes how macroscopic structures can naturally and spontaneously arise and evolve in a self-organized fashion from the interaction of microscopic subsystems (Haken, 1980). The process of self-organization is, as mentioned earlier, triggered by entropy overwhelming the system. More specifically, the event of entropy levels reaching system threshold causes the system to enter into a state of critical instability (Stephen, Dixon, & Isenhower, 2009). The approach toward critical instability causes the loosening and breaking of the existing constraints of the system, dissolving the configuration of previously coherent subcomponents, and allowing for these subsystems to freely interact. This micro-level interaction is capable of yielding different global system configurations or "modes" (Haken, 1980) at the macro level. And of these emergent modes, the most effective of the dissipative structures will be assumed as the new macroscopic organization of the total system, more capable of dispersing entropy. Thus, the phenomenon of self-organization can be understood as arising out of the *spontaneous* breaking and reforming of constraints within an open complex system (Stephen, Dixon, & Isenhower, 2009), to attain a more ordered state. It follows that this process of breaking and reforming of constraints can be predicted by an increase in entropy, followed by a decrease in entropy—a pattern or sequence of changes that in nonlinear dynamics is considered a "phase transition" (Stephen, Dixon, & Isenhower, 2009). A look at the recent work born out of the *dynamical systems theory of cognition* (DSTC) will serve to bridge the gap between dynamic lower-level processes and high-level cognitive structures (Stephen, Dixon, & Isenhower, 2009). Specifically, this theory frames the phenomenon of cognitive insight as an instance of emergent self-organization. Establishing the underlying cognitive process of insight will serve to solidify a concrete understanding of how flow operates as a cascade of self-perpetuating cognitive insights.

Dynamical Systems Theory of Cognition: The Mechanism of Insight and Flow

Dynamical theory fundamentally conceives that changes in behavior at the macro scale are generated from changes occurring at the micro scale. When applied to the realm of psychology, this conceptualization of cognition implies that the emergence of macroscopic cognitive structures might be generated from microscopic changes or fluctuations (Stephen, Dixon, & Isenhower, 2009). Stephen and Dixon (2009) propose this mechanistic framework as underlying the phenomenon of cognitive insight: insight is an instance of self-organization from which emerges a new macroscopic cognitive structure. This complex emergent processing is highly rooted within a tight dynamical system of interaction, coupling agent and action with his or her immediate surroundings.

Empirical support for the DSTC was exemplified by the gear-system paradigm (Stephen & Dixon, 2009; Stephen, Dixon, & Isenhower, 2009). This paradigm involved presenting a series of gear systems, one at a time, to participants on a computer screen. A gear system is composed of a set of interlocking gears, forming a pathway of gears from the initial gear to the final gear. Solving a gear-system problem meant correctly determining the turning direction of the final gear, given the initial gear turning direction, as indicated by an arrow. Participants received immediate accuracy feedback on their predictions upon completion of each gear-system problem before being presented with the next problem. The vast majority of individuals began solving via the strategy of *force-tracing*. Force-tracing involves physically moving one's fingers in a set of radial motions as a way of facilitating one's mental tracing of the path of motion that spans the gear-system. Force-tracing can be both measured and mathematically quantified. The gear-system paradigm is apt for the study of this self-organization framework because the task ultimately requires a change in representation. In other words, as the demands of the gear rotation tasks increase, the individual must shift strategies to maintain his performance level. This shift in strategy is marked by the *discovery of alternation*, a fundamentally different approach to solving the problems that no longer relies on finger-tracing motion. The alternation strategy emerges out of the discovery that the gear turning direction alternates between clockwise motion and counter-clockwise motion in sequence down the path. Thus, given the information of the initial gear turning direction and the length of the gear-system path, participants adopt this more efficient strategy by embodying the relational information between the component parts of the entire gear system (Dixon & Bangert, 2002). Pure insight problems have been argued to necessitate both an abrupt discontinuity in initial problem-solving approach and an essential restructuring of the problem representation in order to fulfill solution criteria (Chronicle, MacGregor, & Ormerod, 2004; Weisberg, 1996). The observed shift away from direct bodily interactions (force-tracing strategy) and toward relational information (alternation strategy) can be understood as an abrupt discontinuity of initial problem-solving approach, in combination with an instance of fundamental restructuring of the gear-system problem space. The emergence of the alternation strategy thus provides a concrete instance of pure insight problem-solving.

In accordance with the theory of emergent self-organization outlined earlier, it was predicted that a sharp increase in entropy, followed by a sharp decrease in entropy, would occur right before the discovery of the alternation strategy. This pattern of entropy behavior was found to reliably predict the phase transition from force-tracing strategy to alternation strategy in participants. Because this strategy was a more effective offloading mechanism of entropy, it verified an instance of self-organizational *spontaneous* emergence.

In the Gestalt language, the increase and decrease in entropy describes the act of temporarily breaking frame in order to provide for a restructuring of constraints. The necessary unconstrained, unmediated interaction among the more featural components constitutes the spontaneous bottom-up behavior that generates new interactional relations amidst the parts, which the more higher-up Gestalt processing can pick up on and constrain anew. The DSTC provides not only a comprehensive cognitive process underlying insight, which can be quantified and tested, but also robust empirical findings that demonstrate what the Gestalt theorists suggested all along, without having had the conceptual tools to formalize it (Epstein, 1988; Shaw & Turvey, 1981): Insight is a highly nonlinear, implicit, and procedural process that emerges in a spontaneous, self-organizing fashion. The DSTC homes in on the essential dynamical coupling and interactive relationship of cognition, action, and environment.

Network Theory

Network theory complements the DSTC work by Stephen and Dixon (2009), supplementing dynamical theory with an explicit structural mechanism for the proposed process of cognitive insight. More precisely, network theory understands insightful processing to be a reconfiguration of the total network, specifically adopting the configuration and behavior of a small-world network.

A network can be understood as a set of component nodes, between which a series of clusters and connections determine the overall configuration of the total network. These configuration properties can be expressed by a network's clustering coefficient and average path length values. A reconfiguration of the network is understood as a change in these nodes or links, a process that is capable of establishing a new set of relations within the network (Schilling, 2005). Not all networks share the same configuration properties. In fact, "small-world" networks embody distinct network behavior compared to other network structures, due to their unique set of configuration properties, residing structurally between a highly structured large-world network and a random network (Figure 24.4). The large-world network is characterized by a high clustering coefficient value and a high average path length value. Whereas the high clustering provides dense connectivity between similar nodes in the network, the large average path length makes it globally sparse and thus highly inefficient. By contrast, the random network is characterized by both a low clustering coefficient value and a low average path-length value. As a result, the random network is highly efficient, but lacks resiliency. Small-world network structural properties fall between these two aforementioned network extremes, and thus embody elements of both network configurations. Specifically, small-world network properties are marked by high clustering and low average path length. As such, small-world networks are uniquely balanced between efficiency and resiliency.

The specific property enabling this is the presence of a small set of random or atypical long-range links spanning the network, which act to connect more disparate nodes and clusters. The formation of long-range connections establishes a rewiring of the total network that results in a decrease in average path length significantly greater than the decrease in clustering. This is how the rewiring pattern yields a more efficient network overall, while maintaining a high degree of resiliency. In addition, this reconfiguration affects the ease of propagation of information, as measured by the network's diffusion rate. Due to the existence of unique long-range links in small-world networks, small-world networks demonstrate a faster rate of diffusion than large-world networks, nearly as fast as that of a random network (Watts, 1999). Importantly, the sudden drop in average path length yields the promotion and facilitation of further search and discovery of relationships between nodes and clusters previously not established within the network. The dramatic increase in search propagation and connection formation marks an intensified rate of diffusion whose

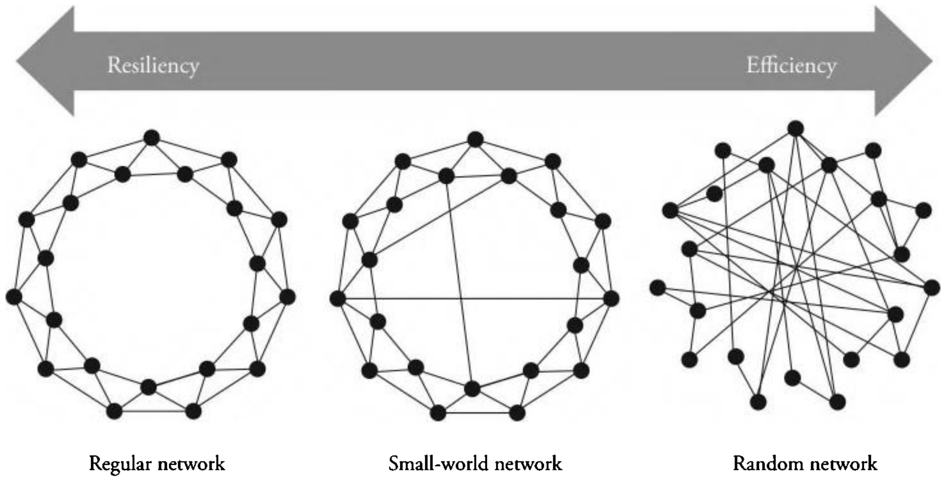

Figure 24.4. Network structure diagrams.

continued effect self-perpetuates in the absence of any continuous external prompt (Schilling, 2005). This self-perpetuation could serve as the basis for the momentum of the insight cascade proposed to be at work in flow.

Understanding network configurations and the effects of structural properties on information propagation and diffusion helps shed light on the developing understanding of cognitive networks that span and shape the brain. Cognitive networks are purported to exhibit small-world network configurations and behavior. First, cognitive networks embody a high degree of clustering. Because creating and maintaining connections between concepts is highly costly in terms of time and effort to the cognitive system (Simon, 1955), the system cannot afford to support many extraneous connections beyond those that are essential to the meaning and understanding of the cognitive network. As such, dense connectivity is maintained between related concepts, and sparse connectivity occurs between more disparate pieces of information. This kind of clustering creates great value for the system: it instills structure, order, and meaning within an individual's cognitive framework (Bartlett, 1932; Mayer & Greeno, 1972). Additionally, to be efficient and adaptive, cognitive networks need not use inefficient network searches, which may be produced as a consequence of sparse connectivity and resulting high average path length. The existence of an atypical link in the network allows for a wider set of nodes within a more immediate search range, minimizing the time, cost, and constraint of search for the system. This is particularly relevant to problem-solving when the solution necessitates searching outside the immediate domain of the problem space (Schilling, 2005). It follows that IPS that is highly characterized by the need to "look outside the box" should benefit from this configuration. Graph theory work has in fact been used to analyze known insight problems and represent their solution process in terms of simple network diagrams (Durso, Rea, & Dayton, 1994; Schilling, 2005). Connectivity properties consistently mimicked small-world network configuration behavior, most specifically the moment of insight as a characteristic drop in average path length. As such, the phenomenon of cognitive insight, according to network theory, is proposed to be an instance of atypical association significantly decreasing the network's average path length, and in turn creating a shortcut in one's cognitive network of representations. This macroscopic reconfiguration of the cognitive network is proposed as the explicit structural mechanism that establishes a new set of relations between network representations. As such, it is the mechanism that underlies the Gestalt notion of shifting frame—a shift in relative salience that governs the associations between network nodes and clusters. It is important to note that network reconfiguration at the macro level is a qualitative change in the structure and behavior of the total network that, notably, *has the potential of prompting a cascade of further atypical and insightful connections* (Schilling, 2005). Total network reconfiguration is not simply the reorganization of the network at the macro level; it is the instantiation of a mode of operation that procedurally affords and primes the system for further behavior. As such, the creation specifically of a small-world network provides the foundation for initial insightful restructuring, as well as the potential resulting cascade of procedurally afforded insights.

Finally, network theory further supplements the dynamic systems theory of cognitive insight with an account of the phenomenological properties of insight—namely, the characteristic sense of unexpected and sudden discovery. Network theory posits that the affective perceived moment of insightful realization is a function of both the degree of unexpectedness of the atypical connection forged, as well as the degree to which this connection shifts or reconfigures the overall network structure (Schilling, 2005). This account serves as a mechanistic explanation of fluency: the increased ease and efficiency in processing resulting from the atypical link formation underlies the experiential fluency felt in conjunction with the "aha!" experience of insightful processing. Not only does this theory highlight the phenomenon of insight as being grounded in a dynamical spontaneous self-organizing process that is qualitatively distinct from incremental learning, it also serves to provide an explanation for why an accompanying affective response is so consistently attributed to the experience of insight and how exactly this phenomenological experience of the moment of successful discovery manifests itself.

Flow, conceptualized as an insight cascade, can now be comprehensively expressed and understood in these concrete dynamical terms: Flow is a series of instances of cognitive insight, instantiated and perpetuated by the formation of long-range atypical network connections, serving to establish qualitatively novel macroscopic network configurations, thereby shifting the constraints of total system behavior. Furthermore, this self-perpetuating cascade of insightful processing diffuses spontaneously throughout the cognitive network, behaving as a self-organizing open complex system that is dynamically embedded in, and in exchange with, its immediate entropic surrounding. This naturally cascading phenomenon can be understood as arising out of a diffusion of procedural priming, a series of transferences of mental sets, which serves to procedurally provoke the system into a mode of operation that readily affords further insightful processing. In this way, SOC processing and small-world connection mutually afford one another, promoting the cultivation of insight cascades fluidly throughout the system. This conceptualization of the flow state highlights the intense dynamical coupling between agent, action, and the environment. This act of flowing engages the agent in a very powerful form of implicit learning (expanded upon in the following section) that is phenomenologically laden with a sense of meaning and reward, and, importantly, an experience of fluency and effortlessness.

Intuition

Another important phenomenological feature of both insight and flow is that they are experienced as non-deliberative and often ineffable (i.e., *spontaneous*) processes. Therefore in order to understand flow better, it is important to integrate an understanding of intuitive processing into the current model. Intuition is a concept that has been strongly developed in the work of Hogarth. He conceptualizes intuition as a result of implicit learning, based in the *tacit*, as opposed to *deliberate*, system, which he describes as effortless, reactive, and producing "approximate" responses. Hogarth specifically frames intuition as follows: "the essence of intuitive responses is that they are reached with little apparent effort and typically without conscious awareness. They involve little or no conscious deliberation" (2001, p. 14). This aligns with Reber's suggestion that knowledge and intuitive feelings might arise out of an implicit learning experience (Reber, 1989, 1993). This intuitive implicit system contrasts with the analytic deliberate system emphasized by the computational framework.

Hogarth points out two shortcomings of implicit processing. First, as implied earlier, implicit processing yields intuitions that are rarely precise. This is because implicit learning specifically suffers from the problem of over-fitting. Over-fitting occurs when correlational noise from the environment is interpreted as being causally relevant to the pattern of action. This informs Hogarth's notion of the ideal structure of an environment conducive to effective intuition acquisition. First, errors are diagnostic, and as such should have a large causal impact on performance. Second, the quality of feedback is very important. It should be speedy and accurate, without noise, delay, or bias. In this way, learning is facilitated and over-fitting is reduced, allowing for a learning system that tracks less correlational noise and more causal signal. Just as a scientific experiment is designed to distinguish cause from correlation by testing for disconfirmation, searching for a tight connection between the independent and dependent variables, and deconfounding variables, Hogarth proposes that the learning environment for implicit learning can be set up to do the same. The second shortcoming of the implicit learning system that Hogarth highlights is that implicit processing can only pick up on patterns in actualities existing in the environment, but is limited in its ability to yield patterns regarding potentialities. In other words, the implicit system cannot form patterns regarding possibilities of action not yet occurring in the environment—it cannot engage in counterfactual prediction. Overcoming these limitations in implicit processing is critical to the acquisition of good learning, but moreover is essential for adaptive processing.

Hogarth's work on the cultivation of intuition raises some important implications for processing and learning during flow. Importantly, it should be noted that the conditions of learning that Hogarth outlines mirror the conditions that Csikszentmihalyi implicates in flow. A system of learning that tightly couples actions and environment with timely feedback—thus providing high error diagnosticity—is a system conducive to cultivating flow and good intuitions. This suggests that flow is an evolutionary marker indicating when we are practicing good implicit learning (i.e. gaining intuition into real-world causal patterns, as opposed to correlational noise) and consequently promoting a form of highly relevant interaction with the environment. Furthermore, where implicit learning is limited to modeling actuality, the flow state promotes the exploration of possibilities, with the self-perpetuating diffusion of atypical links across the cognitive network prompting new network configurations. The flow state, as such, is a highly desirable state, as it overcomes the two deficits of implicit learning highlighted by Hogarth. Flow is a system of processing and cultivating causal pattern recognition in which cognition is stimulated to explore possibilities of action. These two elements are interdependent: exploring possibilities allows one to distinguish between actual causation and mere empirical generalization. In turn, zeroing-in on causation helps guide the insight away from being illusory or fantastical. Hence flow is so prevalent and beneficial because flow has a massively adaptive evolutionary function: It not only yields powerful implicit learning, but also provides feedback about how good these acquired intuitions and learning are.

Flow: Optimal Implicit Learning

Throughout this chapter, an argument for flow as optimal implicit learning has been proposed. Beyond overcoming the two limitations of implicit learning as proposed by Hogarth, flow will be specifically framed as a state that generates a form of scaffolded learning. This will be made clearer by invoking the work of Vygotsky. Vygotsky describes a *zone of proximal development* (ZPD) or *proximal learning* (Vygotsky, 1978). He differentiates the kind of development or learning instantiated during independent problem-solving from the kind of development that is gained through problem-solving under external guidance. The ZPD is described as being the kind of learning that a parent affords to a child: Because a parent can provide corrective feedback during learning, children are able to meet demands beyond those they could tackle on their own. Thus, the ZPD is the foundation for a learning system in which one does one's best learning. As such, proximal learning strongly implicates the phenomenon of skill stretching. It follows that when a child takes on the role of the guiding parent—when a child internalizes his or her teacher—he or she is capable of engaging in the ZPD without this external aid. As such, a cognitive system is capable of developing its own cognition by entering itself into the ZPD. In other words, this process of internalization allows the cognitive system to self-scaffold its process of learning.

We propose that in the flow state, the insight-cascade process is acting to pull one into the ZPD, a situation where demand is just beyond skill. One's own insight experience is taking on the role of the internalized teacher, helping one to reach and scaffold the learning process. In addition, the tight system of timely and highly diagnostic feedback at play between the actor and his environment further affords a level of guidance that helps maintain the structure of self-scaffolded learning. Flow, conceptualized as a self-organized dynamical insight cascade, can be understood as a self-perpetuating feedback loop of insightful processing occurring within the ZPD. The flow channel is a specific instance of the ZPD. The flow phenomenon, in DSTC terms, is an attractor for the ZPD; it is an emergent, self-organizing process that keeps cognition in an internalized state of optimal learning (Figure 24.5).

We have argued that the flow state is, as Hogarth claims, optimal for implicitly learning complex patterns in the environment and distinguishing them from correlational ones while exploring possibilities of action and learning. Further, it is also the optimal state for learning in general because it causes one to enter the ZPD. Flow marks optimal insight, an intuitive learning of complex causal patterns,

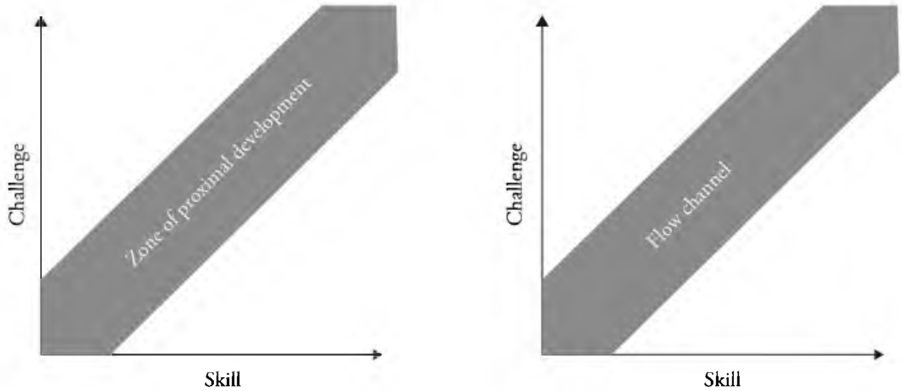

Figure 24.5. The overlap between the flow construct and the zone of proximal development.

supported by the open self-organizing system of cognition.

Conclusion

This chapter has offered a comprehensive account of the phenomenon of flow, within a cognitive scientific framework, to provide accounts for the underlying cognitive process and structural mechanism that mediate flow, and to explain why flow is a universal psychological occurrence. This conceptualization of flow extends beyond the description offered by Csikszentmihalyi and provides an explanation for the phenomenological vividness attributed to the flow experience.

The alternative conceptualization of flow appeals to the Gestalt notion of insight, based within a dynamical framework, expressed as a form of engagement that qualitatively differs from the incremental learning of computational inferential models. Specifically, flow is expressed as a self-perpetuating insight cascade—an extended "aha!" This understanding of flow suggests a dynamic interplay between the generation of insight problems and subsequent insight problem-solving, such that each instantiation of insightful restructuring procedurally primes the agent for further insightful processing. This cascading effect is explained as a series of transfers of mental sets and thus exemplifies a markedly implicit and procedural form of engagement, and tight coupling between the agent and his or her surroundings.

Complexity theory provides an apt framework to conceptualize the highly implicit and insightful processing occurring during flow. Namely, it frames human cognition as a flexible and dynamic engine of thought and behavior that behaves as an open complex system and evolves as a self-organizing multi-stable system. Appealing to this framework, the DSTC thus explains the phenomenon of cognitive insight as an instance of self-organization from which emerges a new macroscopic cognitive structure. This view emphasizes self-organization, and thus the process of insight, involving the *spontaneous* breaking and reforming of constraints, or in other words, a requisite micro-level interaction that yields the new emergent macro-structures in order to re-establish order in the system. The DSTC bridges the gap between lower-level processes and higher-order cognition, and mirrors the Gestalt understanding of insightful restructuring. Network theory supplements the DSTC by providing the structural mechanism underlying insight, as an instance of atypical association. This creation of a small-world network that results in a macroscopic reconfiguration is the mechanism for shifting frame. Flow thus implicates the formation of small-world networks in the brain, where each atypical insightful wiring prompts the network to search for more atypical associations, thus engaging in a self-perpetuating cascade of insightful connections.

Understanding flow in terms of enhanced insightful processing highlights the skill-stretching nature of the phenomenon. In addition to enabling the agent to self-scaffold into the ZPD, the flow channel is an environment for learning that fosters the cultivation of good intuition, distinguishing correlational noise from causal signal, and promotes the exploration of possibilities in action. As such, flow is an optimal state to yield development of the system. This understanding of flow helps explain why it is not only such a prevalent phenomenon, but also one that is regarded as intrinsically desirable and valued, while yielding substantial benefits.

The phenomenology of flow, as initially outlined by Csikszentmihalyi, can now be more richly explained. Flow, conceptualized as an insight cascade, is a highly dynamic and complex phenomenon that creates a stage whereupon the individual can more deeply engage and learn, yet in an effortless manner. The qualitative shift in processing during flow marks a critical increase in processing fluency, matched by the accompanying experiential fluency—the phenomenological breakthrough—so reliably reported with the "aha!" experience. This powerfully gratifying experience that accompanies flowing is an evolutionary marker that indicates heightened relevance in processing—the deep sense of doing precisely the right thing at the right time in the right way, or in other words, being in the zone.

Finally, flow is a prototypical example of the power of spontaneous thought to enhance and develop core cognitive abilities. It is an evolutionary marker for a form of self-organized processing that reconfigures brain networks in a way that increases the fluency of processing, while improving problem-solving and implicit learning. It is neither a deliberative form of processing nor an automatic form of processing. Flow unfolds effortlessly, but fills awareness with optimal experience that is highly adaptive and creative in nature. It is perhaps the best form of spontaneous thought.

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CHAPTER

25 Internal Orientation in Aesthetic Experience

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Abstract

There is considerable evidence to suggest that aesthetic experiences engage a distributed set of structures in the brain, and likely emerge from the interactions of multiple neural systems. In addition, aside from an external (i.e., object-focused) orientation, aesthetic experiences also involve an internal (i.e., person-focused) orientation. This internal orientation appears to have two dissociable neural components: one component involves the processing of visceral feeling states (i.e., interoception) and primarily engages the insula, whereas the other involves the processing of self-referential, autobiographical, and narrative information, and is represented by activation in the default mode network. Evidence supporting this neural dissociation has provided insights into processes that can lead to deep and moving aesthetic experiences.

Key Words: aesthetics, self-referential, interoception, narrative, default mode network

By their very nature, aesthetic judgments—broadly defined as *evaluative appraisals of objects*—include an external orientation. For example, whether we are evaluating the attractiveness of faces (Chatterjee, Thomas, Smith, & Aguirre, 2009; Vartanian, Lam, Fisher, Granic, & Goel, 2013), assessing the desirability of consumer goods (Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010; Van der Laan, De Ridder, Viergever, & Smeets, 2012), or pondering the beauty of works of art (Ishizu & Zeki, 2011; Nadal, Munar, Capó, Roselló, & Cela-Conde, 2008), our attention is always directed toward an object. However, phenomenologically, we are also aware that our aesthetic experiences extend beyond object-focused judgments alone, and include an important internal aspect as well. Typically, we gain awareness of this inner aspect when we are deeply moved by a work of art, a natural scene, or even an idea. Such experiences serve to deepen our interactions with the world, and embed our aesthetic experiences within our rich emotional and narrative lives.

My aim in this chapter is to draw on findings from the nascent field of neuroaesthetics to explore the dissociable components of this internal orientation of aesthetic experiences. Specifically, research in neuroaesthetics has shown that the internal orientation of aesthetic experiences is not a unitary construct, but rather has two dissociable neural and psychological aspects: emotional and autobiographical/narrative. Furthermore, this distinction has important implications for the structure of aesthetic experiences. To make a case for this distinction, I will begin by reviewing some of the basic findings from meta-analytic studies of the neuroaesthetics literature, before discussing a newly proposed neurological model for the emergence of aesthetic experiences (Chatterjee & Vartanian, 2014, 2016). I will then discuss a select set of studies that have a particular bearing on internal orientations in aesthetic experiences, and will end by highlighting the relevance of the findings for our understanding of the structure of aesthetic experiences.

Aesthetic Judgment: Distributed Structures in the Brain

Perhaps the first important finding to emerge from neuroimaging studies of aesthetic experiences is that they engage a distributed set of structures in the brain (see Pearce et al., 2016). To demonstrate this point, I will review the results of three recent meta-analyses of the neuroimaging literature on aesthetic judgment, each of which has parsed the data in a different way, and at the same time has offered unique insights into the process. Vartanian and Skov (2015) conducted a meta-analysis of studies that focused on a particular class of stimuli—paintings. Specifically, for their meta-analysis, they included data from 15 functional magnetic resonance imaging (fMRI) studies that involved viewing of paintings, regardless of task instructions; for example, they included studies of passive viewing, active judgment, unrestricted viewing, and memory (recognition), among others. Their results demonstrated that viewing paintings activated a distributed set of structures in the brain, each likely contributing a specific component to the overall experience of viewing artworks. Perhaps not surprisingly, viewing paintings activated regions in the visual cortex, including the lingual gyrus and the middle occipital gyrus. These activations can be attributed to the processing of various early, intermediate, and late visual features of the stimuli embedded within paintings, including orientation, shape, color, grouping, and categorization (see Chatterjee, 2003; Greenlee & Tse, 2008; Wandell, Dumoulin, & Brewer, 2009). Although not located in the occipital lobes, the inferior temporal cortex has a well-established role in the visual representation of form and color (Gross, 1992), and likely contributes to these processes while viewing paintings as well. Vartanian and Skov (2015) also observed activation in the precuneus, likely due to its involvement in the visuospatial exploration of pictorial stimuli (Cupchik, Vartanian, Crawley, & Mikulis, 2009; Fairhall & Ishai, 2008).

The meta-analysis also revealed activation in the fusiform gyrus and the parahippocampal place area (PPA). The fusiform gyrus is involved in object perception and recognition, and its activation likely represents the detection of objects within paintings (e.g., faces) (Grill-Spector & Sayres, 2008; Kanwisher & Yovel, 2009). In turn, the PPA is involved in the perception and recognition of places (Epstein & Kanwisher, 1998), which explains its involvement while viewing paintings rich in representations of scenes (e.g., landscapes). Also activated was the anterior temporal lobe (i.e., superior temporal gyrus), a region within the temporal lobes involved not just in semantic memory—including our knowledge of objects—but also in higher-order conceptual integration of information in relation to objects (e.g., how does a knife function?) (Bonner & Price, 2013; Patterson, Nestor, & Rogers, 2007; Peelen & Caramazza, 2012). Its activation while viewing paintings suggests that the perception of paintings might trigger higher-order semantic analysis of the represented objects beyond mere recognition.

The results also revealed two additional and theoretically interesting sets of activations. First, viewing paintings activated the anterior insula bilaterally, along with the putamen. The insula is a structure in the brain's core affective system, and is strongly associated with the visceral perception and the experience of (typically negative) emotions (Barrett, Mesquita, Ochsner, & Gross, 2007; Craig, 2010). In turn, the putamen is a structure in the basal ganglia, reliably activated by the anticipation of rewards (Liu, Hairston, Schrier, & Fan, 2011). Its activation while viewing paintings could signal their perceived rewarding properties. In addition, however, the results also revealed activation in the posterior cingulate cortex bilaterally. This region has emerged as a key component of the default mode network (DMN) involved in mind-wandering (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007), and its involvement here suggests that viewing paintings—across a variety of task instructions—might trigger internalized cognitions.

In another meta-analysis of this literature, Boccia et al. (2016) included data from 14 fMRI studies that had required participants to make aesthetic judgments about artworks. The focus of their meta-analysis was in some sense narrower than Vartanian and Skov's (2014) meta-analysis because of its focus on aesthetic judgment specifically. However, it also included data not considered by Vartanian and Skov (2015) (e.g., studies involving viewing sculptures). Consistent with Vartanian and Skov (2015), Boccia et al.'s (2016) results demonstrated that, overall, aesthetic judgments about artworks activated a distributed set of regions in the brain bilaterally, including the bilateral inferior occipital gyri, lingual and parahippocampal gyri, inferior frontal gyri, anterior cingulate cortex, amygdala, and insula. Unilaterally, the middle frontal gyrus, fusiform gyrus, and precuneus were activated in the right hemisphere, and the medial frontal gyrus, precentral gyrus, and middle occipital gyrus in the left hemisphere. The overlap between regions observed in Vartanian and Skov

(2014) and Boccia et al. (2016) is readily apparent, suggesting again that exposure to visual art (mostly occurring in the context of aesthetic judgment) engages structures in the brain involved in perception, emotion, and valuation.

However, the novel contribution of Boccia et al. (2016) involved further analysis of the data broken down by *categories* of paintings, namely portraits, scenes, abstract paintings, and body sculptures. This enabled the authors to isolate regions in the ventral visual stream that were differentially sensitive to the specific content of artworks. The results revealed that aesthetic judgment of portraits activated the fusiform face area (FFA), the inferior occipital gyrus, as well as the amygdala. In turn, for scenes, the activated regions included clusters in the PPA, the retrosplenial cortex, and the lingual gyrus. Abstract paintings activated the posterior cingulate cortex bilaterally, whereas body sculptures activated bilateral fusiform body areas, supplementary motor areas, the inferior frontal gyri, the hippocampi and insula, the lingual and inferior occipital gyri, inferior frontal gyrus, and superior parietal lobule in the right hemisphere. These category-specific activations revealed that in the course of the aesthetic judgment of artworks, the brain is sensitive to the specific content of the stimuli. For example, and predictably, whereas portraits are more likely to activate the FFA, scenes are more likely to activate the PPA. However, of particular interest here, the posterior cingulate cortex, a part of the DMN also activated in Vartanian and Skov's (2014) meta-analysis, was associated with viewing abstract artworks specifically. It is possible that due to their reduced perceptual constraints, viewing abstract paintings might be a particularly potent trigger for an internal orientation in thinking, compared to viewing paintings that are rich in representational content, which tend to direct thinking toward object recognition and identification (see Cupchik et al., 2009). This possibility is consistent with the idea that non-representational art has the ability to facilitate mind-wandering, in part because it lacks representational content that anchors perception to object recognition and identification.

The idea that the content of paintings can have an effect on mind-wandering was examined by Wang, Mo, Vartanian, Cant, and Cupchik (2015), who presented their subjects with traditional Chinese landscape paintings and realistic oil landscape paintings, and asked them to rate each painting on a number of different dimensions, including mind-wandering (Experiment 1). Critically, unlike realistic oil landscape paintings that aim to convey nature as precisely as possible, traditional Chinese landscape paintings aim to convey an experiential sense of "being in nature" rather than "seeing nature" (Law, 2011) (Figure 25.1). A prominent technique in this type of painting is referred to as "drawing-blank," which involves applying pressure to the brush in such a way that it leaves white streaks (i.e., blank spaces) on the canvass, meant to encourage deeper interaction with the artwork. As hypothesized, traditional Chinese landscape paintings were found to evoke more mind-wandering than realistic oil landscape paintings, suggesting that when cues for object recognition are reduced, mind-wandering is facilitated. In addition, aesthetic judgment of portraits also activated the amygdala, another important region in the brain's core emotion network (Barrett et al., 2007). This is consistent with the well-established

Figure 25.1. (See Color Insert) Examples of traditional Chinese and realistic old landscape paintings. Adapted with permission from Wang et al. (2015).

ability of faces to convey affective information, which in turn might trigger reciprocal empathic responses in the viewer (see Chatterjee & Vartanian, 2014, 2016).

Finally, Brown, Goa, Tisdelle, Eickhoff, & Liotti (2011) conducted a meta-analysis of 93 fMRI and positron emission tomography (PET) studies of positive-valence appraisal across sensory modalities. They intentionally focused on different sensory modalities because they were motivated to find core universal processes underlying aesthetic evaluation across the senses. As such, they included studies that involved the appraisal of the valence of perceived objects in the visual, auditory, gustatory, and olfactory domains. In addition, within each modality they included a wide range of stimuli. For example, within vision they selected studies that involved evaluations of pictures, artworks, images of food, erotic images, and images of loved ones (such as infants and romantic partners). Their results demonstrated that although a set of regions was sensitive to aesthetic evaluation, the region activated most reliably across *all* modalities was the right anterior insula (Barrett et al., 2007; Craig, 2010). Based on this finding, Brown et al. (2011) argued that at its core, aesthetic judgment consists of the appraisal of the valence of perceived objects. In addition, they also hypothesized that the neural system deployed for this purpose likely originally evolved for the appraisal of objects of survival advantage (e.g., food), and was later co-opted for the experience of objects that satisfy social needs, such as artworks (see also Feist, 2007).

In summary, the results of the three meta-analyses discussed here reveal that aesthetic judgments activate a distributed network of structures in the brain, each of which appears to contribute to a specific sub-process supporting the behavior. Not only was the anterior insula shown to be activated in studies of positive-valence appraisal (Brown et al., 2011), but it was also activated in studies involving exposure to paintings regardless of task demands (Vartanian & Skov, 2014) as well as studies of aesthetic judgment (Boccia et al., 2016). This suggests that viewing and rating stimuli such as artworks have the ability to generate an affective response in the viewer, perhaps automatically. The involvement of the insula could represent the importance of visceral feeling states (i.e., interoception) (Craig, 2001) in aesthetic experiences.

In addition, the results of Vartanian and Skov (2014) revealed activation in the bilateral posterior cingulate in response to viewing paintings. This is consistent with the suggestion that exposure to art can trigger an internal mental orientation. Interestingly, when the data were broken down and analyzed in category-specific ways, it was the aesthetic judgment of abstract artworks that was shown to activate the posterior cingulate cortex bilaterally (Boccia et al., 2016). This suggests that specific categories of art might be stronger triggers of the DMN than others. Next, I will turn to how these structures come together to support aesthetic experiences.

Aesthetic Experiences: Three Interacting Systems

Thus far I have reviewed some meta-analytic findings from the field of neuroaesthetics to demonstrate that aesthetic evaluations and exposure to artworks engage a distributed set of structures in the brain. Chatterjee and Vartanian (2014, 2016) have recently argued that this distributed set of brain structures can be broadly organized within three neural systems: emotion-valuation, sensory-motor, and meaning-knowledge (Figure 25.2). According to this view, aesthetic experiences are an emergent property of the interaction of these systems in the brain. A brief review of Chatterjee and Vartanian's (2014, 2016) tripartite system will be presented next.

With respect to the emotion-valuation system, numerous studies have shown that the aesthetic evaluation of a broad category of cultural artifacts (e.g., paintings, architecture, sculptures, music) activates the same neural systems that are activated while evaluating primary reinforcers (e.g., food,

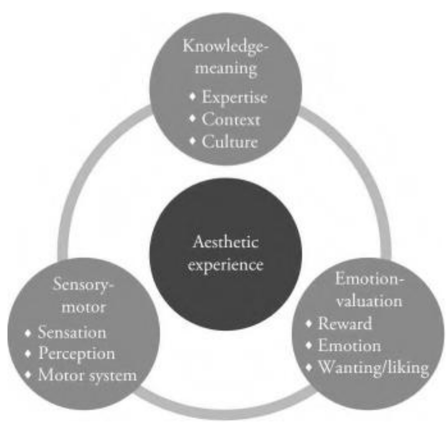

Figure 25.2. (See Color Insert) The aesthetic triad. According to this framework, aesthetic experiences are an emergent property of the interaction of the sensory-motor, emotion-valuation, and knowledge-meaning neural systems. Reprinted, with permission, from *Trends in Cognitive Sciences* 18 ©2014 by Cell Press.

drink), including the nucleus accumbens, the dorsal striatum, and the orbitofrontal cortex (OFC) (Kampe, Frith, Dolan, & Frith, 2001; O'Doherty et al., 2003; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007). In fact, a system involving the OFC and striatal neurons may underlie the valuation of rewards irrespective of the modality giving rise to the rewarding stimuli (Montague & Berns, 2002). This observation has given rise to the notion of a "common currency" for choice that transcends domains. In this sense, the involvement of these regions in aesthetic judgment likely represents a specific example of their more general role in evaluative judgments involving an affective component.

With respect to the sensory-motor system, it should come as no surprise that the aesthetic evaluation of objects engages regions of the brain involved in sensation and perception. More interesting, perhaps, is the observation that aesthetic experiences can also involve the motor system that taps into the extended mirror neuron system. This system is engaged when people infer the intent of artistic gestures, or observe the consequences of actions (Cattaneo & Rizzolatti, 2009; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). This subtle motor engagement represents an embodied element of our empathetic responses to (visual) art. Drawing on the literature that has implicated the mirror neuron system in aesthetic interactions with artworks, Freedberg and Gallese (2007) have argued that our understanding of aesthetic experiences would be incomplete without seriously taking into consideration the role of the mirror neuron system in the process. This line of thinking is further corroborated by cutting-edge and innovative research involving the collection of physiological data from museum-goers in the course of interacting with artworks in actual museum settings (Tröndle & Tschacher, 2012; Tschacher et al., 2012). Indeed, this research has shown that the perception of artworks has a profound effect on the physiology of the viewers, providing additional data for the argument that there is a notable embodied element in aesthetic experiences.

Finally, the meaning-knowledge system encompasses all the top-down and contextual factors that are known to influence aesthetic experiences. Here I will focus on two such factors. The first is expertise, typically measured in the form of formal training in a relevant domain in the arts. For example, in the domain of architecture, it has been shown that architects and non-architects differ in their affective responses when assessing the aesthetic value of buildings (Kirk, Skov, Christensen, & Nygaard, 2009). In addition, there are eye-movement data to suggest that experts view aesthetic products (e.g., paintings and other design objects) differently than non-experts, displaying greater sensitivity to their structural and compositional properties than non-experts (Locher, 2014; Nodine, Locher, & Krupinski, 1993). Second, our experience of artworks extends beyond their perceptual features, and involves attributions of factors such as authenticity (Newman & Bloom, 2012) and source of origin (e.g., from a museum vs. computer-generated; Kirk, Skov, Hulme, Christensen, & Zeki, 2009). Indeed, knowledge regarding authenticity also affects the neural response to art. For example, Huang, Bridge, Kemp, and Parker (2011) presented participants with portraits that were labeled as either authentic Rembrandts or fakes. Authentic paintings evoked greater OFC activity, whereas fakes evoked greater neural activity in the frontopolar cortex and the right precuneus. Indeed, recent years have witnessed a greater emphasis on the role of the meaning-knowledge system in aesthetic experiences (Bullot & Reber, 2013).

Importantly, not all aesthetic experiences necessarily draw equally from each of the three systems. In addition, although aesthetic experiences can encompass explicit aesthetic judgments, they are not limited to them. Specifically, aesthetic emotions, as byproducts of how we interact with objects, can lead to aesthetic experiences without the necessity of explicit judgment (see Leder, Belke, Oeberst, & Augustin, 2004). As will be shown in the following, this model can accommodate the emergence of internal orientations early or later in the course of interaction with visual stimuli, including artworks.

Internal Orientation: Two Components

The field of empirical aesthetics has recently been criticized on the grounds that historically, many experiments conducted therein have focused on a combination of seemingly artificial stimuli (e.g., random polygons) and subtle emotions (e.g., arousal), rather than moving and profound encounters involving real artworks (Silvia, 2012). This criticism is valid, and in recent years the field has embraced the use of methodological innovations that enable one to collect data in naturalistic settings while people are engaged with artworks outside of rigid laboratory settings. Even within the narrow confines of neuroimaging settings, efforts have been made to better understand people's deeper experiences within aesthetic contexts. Perhaps not surprisingly, the shift toward the elicitation of depth in aesthetic encounters has led to novel discoveries that had not surfaced in earlier studies that were primarily focused on object-oriented aesthetic judgments. Here I will review a select set of studies that I believe have made important contributions to our understanding of internal orientations in aesthetic experiences, in the process highlighting the dissociable contributions of the insula and the DMN to this experience.

Using a passive viewing paradigm, Cupchik et al. (2009) presented their participants with representational paintings under two conditions. In the *aesthetic condition* they were instructed to "approach the paintings in a subjective and engaged manner, experiencing the mood of the work and the feelings it evokes, and to focus on its colours, tones, composition, and shapes" (p. 86). In contrast, in the *pragmatic condition* they were instructed to "apply an everyday informational criterion for viewing the paintings, and to approach the images in an objective and detached manner to obtain information about the content of the painting and visual narrative" (p. 86). The pragmatic condition was meant to represent the way in which people typically perceive objects in their everyday lives (i.e., with the goal of object identification), whereas the aesthetic condition was meant to capture interactions with artwork in explicitly aesthetic contexts (e.g., museum settings), involving subjective reactions to their stylistic and structural properties. In addition, the researchers opted to use representational paintings specifically because they are well suited for affective evocation as well as object recognition—the primary foci of their study. In turn, the baseline blocks consisted of non-representational paintings. Although they lacked representational content, the baseline paintings incorporated variations in color, shape, and form, thereby enabling a comparison of each experimental condition with the baseline condition (to isolate areas involved in viewing representational content under varying task instructions).

When the aesthetic condition was contrasted with the baseline condition, activations were observed in the bilateral insula. In turn, when the pragmatic condition was contrasted with the baseline condition, activations were observed in the right fusiform gyrus (BA 37). In addition, significant activations were detected in the bilateral occipital gyri in both the aesthetic and pragmatic conditions compared to baseline. The direct comparison of aesthetic and pragmatic conditions revealed greater activation in the left lateral prefrontal cortex (PFC) (BA 10) in the aesthetic condition. The results suggest that engaging in an aesthetic orientation that explicitly emphasizes a focus on the mood and the feelings that artworks evoke in the observer activates the insula, consistent with this region's role in the experience of emotion. Importantly, research involving other media (e.g., sculptures) has corroborated the involvement of the insula in aesthetic evaluation (e.g., Di Dio, Macaluso, & Rizzolatti, 2007), consistent with the results of Brown et al.'s (2011) meta-analysis that isolated this region's involvement in valence-based appraisals.

In turn, the activation observed in the left lateral PFC (BA 10) when the aesthetic condition was contrasted directly with the pragmatic condition highlights top-down control in directing perception toward aesthetic orientation. This interpretation is consistent with two functions associated with BA 10. First, the lateral PFC (BA 10) has been shown to play a role in the top-down control of cognition (Ridderinkhof, Ullsperger, Crone, & Niewenhuis, 2004) and the maintenance of a main goal while performing concurrent sub-goals (Koechlin et al., 1999). In addition, lateral PFC has also been shown to be involved in higher-order self-referential processing and the evaluation of internally generated information (Burgess, Dumontheil, & Gilbert, 2007; Christoff, Ream, Geddes, & Gabrieli, 2003; Northoff et al., 2006). In summary, the results of Cupchik et al. (2009) suggest that whereas the aesthetic orientation that people typically assume when viewing artworks activates the insula, the active *assumption* of that orientation likely requires the engagement of the lateral PFC (BA 10).

Another study that was deigned explicitly to probe the neural response to *moving* art was conducted by Vessel, Starr, and Rubin (2012), who presented a diverse set of paintings to participants in the fMRI scanner, accompanied by the instruction to "give your gut-level response, based on how much you find the painting beautiful, compelling, or powerful . . .. Respond on the basis of how much this image 'moves' you. What is most important is for you to indicate what works you find powerful, pleasing, or profound" (p. 3). Procedurally, the ratings were conducted using a 1–4 scale that asked participants "how strongly does this painting move you?" Their analyses revealed suppressed deactivation of regions that constitute the DMN, including the medial prefrontal cortex and the posterior cingulate cortex, only when participants viewed paintings that they rated as most moving (i.e., level 4) but not otherwise. Equally important, they did *not* observe a linear increase in activation in the DMN as a function of increasing ratings (i.e., from 1 to 4). Their results suggested that only our *most moving* aesthetic experiences involve the integration of sensory and emotional reactions linked with personal relevance—a process known to engage the DMN.

That there should be something special about our most moving aesthetic experiences is consistent with several contemporary theoretical models of aesthetic experience, including recently proposed dual-process models according to which artworks can be processed aesthetically using automatic or controlled processes, with the relative contribution of the two systems determining the depth of one's aesthetic experience (e.g., Graf & Landwehr, 2015). Specifically, processing performed immediately upon encountering an aesthetic object is likely to be bottom-up and stimulus-driven, giving rise to aesthetic evaluations of pleasure or displeasure. In turn, more elaborate top-down processing can emerge, giving rise to fluency-based aesthetic evaluations (e.g., interest, boredom, confusion). In many ways, this dual-process model is consistent with information-processing models that also predict that more elementary stimulus-driven functions performed on artworks are likely to occur early following exposure, whereas deeper and more elaborate processing is likely to occur later in the information-processing sequence of operations (Chatterjee, 2003; Leder et al., 2004).

Testing these models requires high temporal resolution studies of brain activity following exposure to art. Neuroimaging methods that allow examining the temporal aspects of aesthetic evaluation, such as magnetoencephalography (MEG), enable the assessment of neural responses with a temporal fidelity not possible with fMRI. Munar et al. (2012) used MEG to study brain activity when participants rated a diverse array of visual images as "beautiful" or "not beautiful" (i.e., binary response). Their results demonstrated that activity in the right lateral OFC within 300–400 milliseconds following the presentation of the stimulus was greater for images rated as "not beautiful" than as "beautiful." This indicates that aesthetic judgments of beauty that do not require elaborate processing are associated with brain activity occurring rapidly in the brain. In turn, Cela-Conde et al. (2013) used MEG to study the functional connectivity dynamics underlying aesthetic appreciation. The researchers focused on early and delayed temporal epochs following the presentation of artworks—one within 250 milliseconds and one between 1,000 and 1,500 milliseconds, respectively—and found dissociable patterns of neural activity and connectivity in relation to early and delayed phases. Importantly, activity in the DMN corresponded mainly to the delayed phase. The authors argued that whereas the early phase of aesthetic evaluation involves rapid judgment of a stimulus as "beautiful" or "not beautiful," it is the delayed phase that engages a deeper level of processing in terms of *why* we find a stimulus beautiful. This interpretation is consistent with predictions derived from contemporary theoretical models of aesthetic experience, according to which one would indeed expect activation in the DMN to come online later, rather than earlier, in the course of processing artworks.

However, here it is important to emphasize that internal orientations in the course of aesthetic experience need not necessarily be delayed responses. For example, using electroencephalographic (EEG) evidence, Noguchi and Murota (2013) have recently shown that sensory (bottom-up) and contextual (top-down) integration can occur within 200–300 milliseconds of seeing an artwork. In addition, the majority of the studies that were included in Vartanian and Skov's (2014) meta-analysis of viewing paintings had stimulus presentation durations in the fMRI not exceeding a few seconds. Nevertheless, the analysis revealed activation in the bilateral posterior cingulate cortex. This suggests that the three neural systems can interact early or late in the service of forming an aesthetic judgment, rather than necessarily exerting their effects sequentially (see Vartanian & Chatterjee, 2014, 2016).

Summary and Implications

In this chapter I have argued that the internal (i.e., person-focused) orientation in aesthetic experience likely involves two dissociable components: one component is represented by activation in the insula, and likely involves the processing of visceral feeling states (i.e., interoception) in the service of aesthetic experiences. The second component is represented by activation in the DMN, and likely involves the processing of self-referential, autobiographical, and narrative information in the service of aesthetic experiences. These two components—emotive and narrative—appear to capture the breadth of what is understood by internal orientations in aesthetic experiences. This neural dissociation has enriched our understanding of the structure of aesthetic experiences, and has provided insights into processes that can lead to deep and moving aesthetic experiences—an area of contemporary focus in empirical and theoretical aesthetics (see Cupchik, 2016). Further exploration of the contributions of not only these regions, but also the large-scale salience and default-mode networks, would appear to be a particularly promising avenue for future research (see Bressler & Menon, 2010).

For example, investigators have begun to probe the neural and psychological *after-effects* of aesthetic experiences. These effects are important because they could help explain how and why aesthetic episodes—including exposure to moving art—can have lingering effects on our cognition following the termination of the aesthetic interaction. For example, Wang et al. (2015) investigated the calming effect induced by viewing traditional Chinese landscape paintings on cognitive control—measured by performance on the flanker task administered immediately following exposure to the artworks (Experiment 2). As noted earlier, they demonstrated that subjectively, traditional Chinese landscape paintings induce greater levels of relaxation and mind-wandering, coupled with lower levels of object-oriented absorption and recognition in viewers, compared to realistic oil landscape paintings (Experiment 1). In turn, traditional Chinese landscape paintings placed greater demands on the brain's attention and working memory networks during the flanker task than did switching from realistic oil landscape paintings. Future studies could build on this line of research by exploring the differential after-effects of emotive versus narrative internal orientations on cognition. If this dissociation proves reliable in future experiments, it could inform our models of the structure of aesthetic experiences.

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CHAPTER

26 Neuropsychopharmacology of Flexible and Creative Thinking

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Abstract

Many factors affect performance on tasks associated with creativity. Stress is one of the more established of these factors impacting performance, most likely mediated by effects on neurotransmitter systems. This chapter discusses the literature on the effects of stress, the noradrenergic system, the dopaminergic system, and other pharmacological factors on creativity. This chapter will also discuss the effects of norepinephrine and dopamine on other related aspects of cognition, such as working memory and set shifting. The effects on divergent and convergent task performance will also be discussed, as well as the need for greater understanding of the optimization of creativity performance.

Key Words: creativity, convergent, divergent, stress, norepinephrine, dopamine, working memory, set shifting

In order to understand the neural mechanisms involved in creativity, it is important to also understand the conditions that affect optimal performance on creativity tasks. For this purpose, an understanding of the neuropsychopharmacology of creativity is critical. Furthermore, better understanding of the neuropsychopharmacology of creativity may also allow a greater opportunity for intervention in particular settings. Most research in this area thus far has focused on the catecholaminergic systems—the dopaminergic system and the noradrenergic system—but evidence is beginning to be explored for other systems as well. A greater volume of literature exists for the pharmacological effects on other executive functions highly interrelated with creativity, such as set-shifting and working memory. However, some evidence suggests that the distinctions between creativity and these other executive functions may also be quite critical, as will be discussed in the following.

The Noradrenergic System

The noradrenergic system has a range of behavioral effects. The noradrenergic system is critical in arousal (Coull, Frith, Dolan, Frackowiak, & Grasby, 1997; Coull, Jones, Egan, Frith, & Maze 2004; Smith & Nutt, 1996). The prefrontal cortex, important in a range of types of cognitive flexibility (Duncan, Burgess, & Emslie, 1995; Eslinger & Grattan, 1993; Karnath & Wallesch, 1992; Robbins, 2007; Vikki, 1992), projects fibers to the locus coeruleus in primates (Arnsten & Goldman-Rakic, 1984), which contains the majority of noradrenergic neurons that project throughout the central nervous system (Barnes & Pompeiano, 1991) (Figure 26.1). Cognitive flexibility as assessed by verbal problem-solving tasks, such as anagrams and the compound remote associates task (Bowden & Jung-Beeman, 2003), involves a search through a wide conceptual space in order to identify a solution ("unconstrained flexibility"), and is often utilized in creativity-related research. Generally, performance

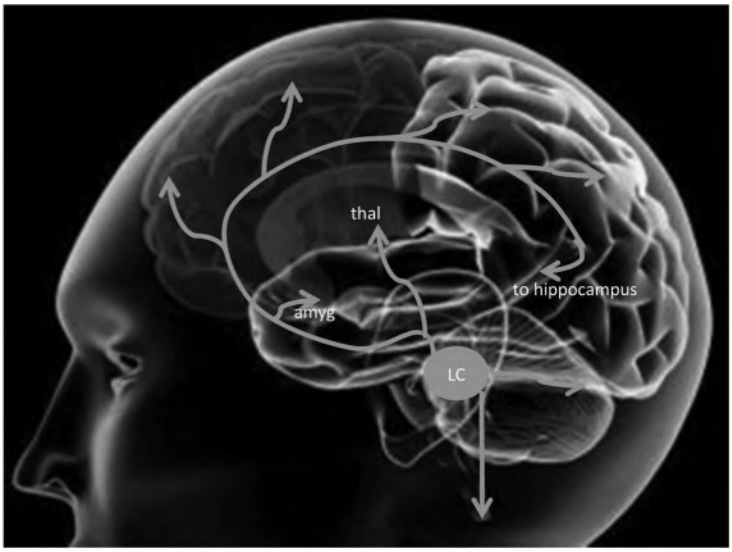

Figure 26.1. (See Color Insert) Noradrenergic pathways. The locus coeruleus (LC) projects posteriorly to the cerebellum and up to the thalamus (thal) and amygdala (amyg), as well as throughout the neocortex along a pericingular tract, also terminating posteriorly at the hippocampus (Heimer, 1995). The descending fibers to the spinal cord are also shown. Not shown is the lateral tegmental noradrenergic system, which also projects to the amygdala and down to the spinal cord. Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284–304). New York: Oxford University Press.

on such tasks improves with decreased noradrenergic activity (Alexander, Hillier, Smith, Tivarus, & Beversdorf, 2007; Beversdorf, Hughes, Steinberg, Lewis, & Heilman, 1999; Beversdorf, White, Cheever, Hughes, & Bornstein, 2002).

Other cognitive flexibility tasks, such as the Wisconsin Cart Sorting Test (Heaton, 1981), involve set-shifting between a limited range of options ("constrained flexibility"), and may not be modulated by the noradrenergic system in the same manner, but instead may potentially benefit from increased noradrenergic activity (Aston-Jones & Cohen, 2005; Usher, Cohen, Servan-Schreiber, Rajkowski, & Aston-Jones, 1999). Decreased noradrenergic activity appears to benefit tasks such as solving anagrams when subjects are struggling or challenged by stressors (Alexander et al., 2007; Campbell, Tivarus, M. E., Hillier, A., Beversdorf 2008), whereas increased set switching on a two-alternative forced choice task is associated with increased noradrenergic tone in non-human primates (Aston-Jones & Cohen, 2005; Usher et al., 1999).

"Constrained" flexibility can be further subdivided into intradimensional and extradimensional set-shifting (Robbins, 2007). Intradimensional shifts require shifting to responses to novel sets of stimuli from within the same sensory domain (such as shifting from choosing between two odors to responding to two novel odors), whereas extradimensional shifts require shifting to stimuli from a different sensory domain (such as shifting from choosing between two odors to responding to two textures). The dopaminergic system appears to affect intradimensional set-shifting (Robbins, 2007), while the noradrenergic system, specifically by action on the $\alpha 1$ receptor, appears to modulate performance on extradimensional set-shifting (Lapiz & Morilak, 2006; Robbins, 2007). The β-adrenergic receptors in the noradrenergic system, though, appear to modulate "unconstrained" flexibility (Alexander et al., 2007; Beversdorf et al., 1999, 2002). A systematic exploration of the effects of the noradrenergic system on intradimensional and extradimensional set-shifting as well as creative problem-solving is needed to better characterize these contrasting effects. Exploration of such comparisons has been initiated in an animal model, revealing no effects of β-adrenergic antagonists on reversal learning, intradimensional set-shifting, or extradimensional set-shifting. However, significant benefit occurs for the requirement for the rodent to shift to a novel solution in order to obtain reward (Hecht, Will, Schachtman, Welby, & Beversdorf, 2014).

Previous work in humans has explored the effects of the β-adrenergic blocker propranolol, a drug that specifically blocks β-adrenergic receptors throughout the brain as well as in the periphery, without affecting other noradrenergic receptors, on convergent tasks among "unconstrained cognitive flexibility" tasks involving problem-solving, where the end product of the task involving cognitive flexibility is the production of a single correct solution to a problem. Examples include finding the single correct response on the compound remote associates task, or the correct word that solves an anagram (Alexander et al., 2007; Campbell et al., 2008). However, effects are not known on divergent tasks among the "unconstrained cognitive flexibility" tasks, where subjects are required to produce multiple alternative responses. Noradrenergic agents are also known to have a range of other cognitive effects, including effects on motor learning (Foster, Good, Fowlkes, & Sawaki, 2006), response inhibition (Chamberlain, Müller, Blackwell, Robbins, & Sahakian, 2006b), working memory, and emotional memory (Chamberlain et al., 2006a).

The noradrenergic effect on emotional memory deserves particular comment, due to a potentially important clinical role. An enhancement of memory due to emotional arousal may contribute to the development of intrusive memories in clinical conditions such as post-traumatic stress disorder (Ehlers et al., 2002; Ehlers, Hackmann, & Michael, 2004; Smith & Beversdorf, 2008), and centrally acting β-adrenergic receptor antagonists are known to reduce this memory enhancement effect (Cahill, Prins, Weber, & McGaugh, 1994; van Stegeren, Everaerd, Cahill, McGaugh, & Gooren, 1998). Research has explored the role of propranolol in the development of post-traumatic stress disorder, by interfering with reconsolidation (Pitman et al., 2002; Vaiva et al., 2003). α1 antagonists have similarly revealed benefits in patients with post-traumatic stress disorder (Arnsten, 2007). More recently, propranolol has been used to block the return of fear when combined with exposure therapy in phobias (Kroes et al., 2015). The relationship between creativity and the emotional effects of the noradrenergic system are in need of further exploration.

In the periphery, α2 adrenergic agonists inhibit the release of norepinephrine presynaptically, which suggests that they would have a similar effect as the postsynaptic β-adrenergic antagonists. However, α2 agonists have distinct cognitive effects. High-dose clonidine, an α2 agonist, has been shown to improve immediate spatial memory in aged monkeys (Arnsten, Cai, & Goldman-Ra, 1988; Arnsten & Leslie, 1991), an effect also found in younger monkeys (Franowicz & Arnsten, 1999), and believed to be mediated by action at the prefrontal cortex (Li, Mao, Wang, & Mei, 1999). Lower doses of clonidine, those that are typically utilized clinically in humans, demonstrate varying results at varying doses, including impaired visual working memory, impulsive responses on planning tasks, and varying effects on spatial working memory (Coull, Middleton, Robbins, & Sahakian, 1995; Jäkälä et al., 1999). Pharmacological stimulation of the postsynaptic α2A subtype of adrenoreceptors decreases noise and results in beneficial effects for attention deficit disorder patients (Brennan & Arnsten, 2008). However, α2 agonists do not appear to have the same effect on creative verbal problem-solving as occurs with β-adrenergic antagonists (Choi, Novak, Hillier, Votolato, & Beversdorf, 2006).

The cognitive effects of stress are mediated by pharmacological systems, and as such, discussion of stress and pharmacological effects are intertwined. Stress is an important factor long known to impair performance on tasks requiring creativity in healthy individuals (Martindale & Greenough, 1973). Stress is known to increase the activity of the noradrenergic system (Kvetnansky, Pacak, Sabban, Kopin, & Goldstein, 1998; Ward et al., 1983), as well as the hypothalamic pituitary adrenal (HPA) axis. Drugs that block the noradrenergic system in the brain, specifically via action on β-adrenergic receptors, have long been used to mitigate stress-induced impairment in performance on tasks including public speaking or test taking in anxiety-prone individuals (Faigel, 1991; Lader, 1988; Laverdue & Boulenger, 1991). Exploration of these mechanisms will allow a greater understanding of the processing of information involved in creativity. Furthermore, research involving healthy adolescents with a history of stress-induced cognitive impairment during exams has demonstrated that treatment with the β-adrenergic antagonist propranolol significantly improved scores on the Scholastic Aptitude Test (SAT) (Faigel, 1991). However, the effects of stress and the noradrenergic system on cognition are not limited to patients with known stress-induced cognitive impairment. As noted earlier, stress has long been known to impair performance on tasks requiring creativity in healthy individuals (Martindale & Greenough, 1973). Therefore, the role of action on the β-adrenergic receptors during "unconstrained" cognitive flexibility has received recent attention in creativity research in healthy individuals, along with the effects of stress. Administration of a well-characterized social evaluative stressor involving public speaking and mental arithmetic, the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993), resulted in impaired performance on creative verbal problem-solving requiring flexibility of access to lexical, semantic, and associative networks in individuals without any history of anxiety-related disorders (Alexander et al., 2007). This impairment was abolished by the administration of propranolol (Alexander et al., 2007). This effect on individuals without any history of an anxiety-related disorder suggests that the effects of stress and the noradrenergic system represent a fundamental aspect regulating cognitive performance, not a phenomenon limited to specific patient populations. However, it should be noted that the effect of propranolol in this study does not exclusively implicate the noradrenergic system, since propranolol has also been shown to block the corticosterone-induced impairment of working memory (Roozendaal, McReynolds, & McGaugh, 2004). Furthermore, the administration of cortisol is associated with a number of effects, including impaired memory (de Quervain, Roozendaal, Nitsch, McGaugh, & Hock, 2000; Het, Ramlow, Wolf, 2005), and enhanced response inhibition (Shields, Bonner, & Moons, 2015). In fact, action on the prefrontal cortex corticotropin-releasing factor receptor 1 has been recently identified as the target involved in stress-induced executive dysfunction, including reversal learning and temporal order memory (Uribe-Mariño et al., 2016). Therefore, future work must systematically disentangle the roles of the adrenergic system and the HPA axis in the effect of stress on cognitive processes associated with creativity.

As described in the preceding, the locus coeruleus projects to the majority of the central nervous system, sending efferents throughout the brain (Barnes & Pompeiano, 1991) (Figure 26.1), thus supporting an effect on a distributed function such as creativity. Effects of the noradrenergic system outside the setting of stress, however, are more dependent on the situation. For example, performance on an anagram task is better after administration of the centrally and peripherally acting β-adrenergic antagonist propranolol than after the noradrenergic agonist ephedrine (Beversdorf et al., 1999; Heilman, Nadeau, & Beversdorf, 2003). Performance on the anagram task is also better after the administration of propranolol than after the peripheral-only β-adrenergic antagonist nadolol (Beversdorf et al., 2002), suggesting that this effect of propranolol is mediated centrally, rather than as a result of peripheral feedback. Central mechanisms are consistent with the effect of norepinephrine on the signal-to-noise ratio of neuronal activity within the cerebral cortex (Hasselmo, Linster, Patil, Ma, & Cecik, 1997), as well as the correlation between the electronic coupling, or coherent firing of interconnected noradrenergic neurons in the monkey cortex and proportions of goal-directed versus exploratory behavior (Usher et al., 1999). However, in both anagram studies without stressors, while performance on propranolol was better than on ephedrine or nadolol, it did not differ significantly from placebo (Beversdorf et al., 1999, 2002). Subsequent research examined how task difficulty might relate to the drug's effect (Campbell et al., 2008). A drug proposed to benefit a broad search of a network might be expected to yield a greater benefit when problems are more challenging, requiring greater access to the "noise" in the signal-to-noise ratio in order to solve the problem, as is discussed further later in this chapter. In this exploration, propranolol was found to be beneficial for a range of verbal problem-solving tasks requiring network flexibility when the subject was struggling, but did not confer benefit (and in some cases even impaired performance) when the subject was solving problems with ease (Campbell et al., 2008). The benefit was seen for the subjects who had the greatest difficulty solving the problems, and for the most difficult problems across all subjects (Campbell et al., 2008). Also, consistent with this, performance on creativity tasks has been found to be better in the setting of "leaky sensory gating," as indicated by the P50 ERP (Zabelina, O'Leary, Pornpattananangkul, Nusslock, & Beeman, 2015), which is of particular interest given recent evidence from neuroimaging studies that demonstrate increased gain in the precision of cortical representations associated with both markers of baseline catecholamine levels and administration of the norepinephrine transporter blocker atomoxetine (Warren et al., 2016). Propranolol can also benefit performance on verbal problem-solving for the easiest problems in situations where there is upregulated activity of the noradrenergic system due to cocaine withdrawal (Kelley, Yeager, Pepper, & Beversdorf, 2005; Kelley, Yeager, Pepper, Bornstein, & Beversdorf, 2007) and psychosocial stress (Alexander et al., 2007), or where there is a physiological or anatomical alteration of the language network, resulting in loss of flexibility due to conditions such as autism spectrum disorder (ASD) (language network: Beversdorf et al., 2007a; convergent task effects: Beversdorf, Carpenter, Miller, Cios, & Hillier, 2008; Zamzow, Ferguson, Ragsdale, Lewis, & Beversdorf, 2017; divergent task effects: Beversdorf et al., 2011), and benefits are also seen for naming in Broca's aphasia due to stroke (Beversdorf et al., 2007b). More recently, these benefits in ASD with propranolol have also been observed in the social domain (Zamzow et al., 2014; Zamzow et al., 2016).

The variation in the effect of noradrenergic drugs between patient groups, as observed in cocaine withdrawal, ASD, and aphasia, may also be important in the use of adrenergic drugs in attention deficit disorder. Early theories proposed that arousal and optimal performance might be best described by an inverted U-shaped curve (Yerkes & Dodson, 1908), suggesting such a relationship for the noradrenergic system. While markedly increased arousal or noradrenergic tone might result in hyper-arousal and inability to perform a task in most individuals, a person with attention deficit disorder might be, at baseline, at a suboptimal, underaroused, point on the inverted U-shaped curve associated with low noradrenergic tone and may require stimulants to perform optimally. Animal data suggest that there is an optimal point of tonic activity of the locus coeruleus that tends to support the emergence of phasic activity, associated with focused or selective attention (Aston-Jones, Rajkowski, & Cohen, 1999; Aston-Jones & Cohen, 2005). Noradrenergic transmission is known to be genetically weaker in some patients with attention deficit disorder (Arnsten, 2007). The effects of drugs on creativity in this population warrant further study. Preliminary evidence suggests that the effect of stimulants on creativity is limited (Farah, Haimm, Sankoorikal, Smith, & Chatterjee, 2009).

The relationship between noradrenergic tone and performance on creative verbal problem-solving tasks can also be observed in the performance impacts of alterations in noradrenergic tone induced by changes in posture (Lipnicki & Byrne, 2005), sleep phase (Stickgold, Hobson, Fosse, & Fosse, 2001), and vagal nerve stimulation (Ghacibeh, Shenker, Shenal, Uthman, & Heilman, 2006). Rapid eye movement (REM) sleep, a state associated with decreased noradrenergic activity, enhances integration of weakly associated information for creative problem-solving (Cai, Mednick, Harrison, Kanady, & Mednick 2009; Stickgold et al., 2001) and is associated with high levels of spontaneous thought akin to those experienced in waking restful states (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013). These effects appear to be specific to the noradrenergic system and not due to general anti-anxiety effects, since such cognitive effects do not appear to occur with non-adrenergic anxiolytics (Silver, Hughes, Bornstein, & Beversdorf, 2004).

Evidence from models derived from activity in brain slice preparations support an effect of norepinephrine on the signal-to-noise ratio of neuronal activity within the cerebral cortex (Hasselmo et al., 1997). Presumably, propranolol increases access to "noise," which in this case would be represented by increased associational input that might be adaptive for solving more difficult problems where the most immediate response is not optimal (Alexander et al., 2007). In one population characterized by decreased flexibility of network access (Beversdorf et al., 2007a), a potential neuroimaging marker has been observed. Decreased functional connectivity as measured by functional magnetic resonance imaging (fMRI) (i.e., a decrease in the synchrony of activation between activated brain regions) is observed for long distance cortico-cortical connections during language and executive function tasks in ASD (Just, Cherkassky, Keller, & Minshew, 2004; Just, Cherkassky, Keller, Kana, & Minshew, 2007), as well as in other conditions believed to be related to the under-connectivity between distant cortical regions in ASD (Belmonte et al., 2004). Recent evidence suggests that propranolol increases functional connectivity in ASD, lending some support to the proposed mechanism of action of propranolol on network access (Narayanan et al., 2010). It is not clear whether the noradrenergic system is dysregulated in ASD (Martchek, Thevarkunnel, Bauman, Blatt, & Kemper, 2006; Minderaa, Anderson, Volkmar, Akkerhuis, & Cohen, 1994). However, others have proposed that the positive behavioral effects of febrile illness in ASD (Curran et al., 2007) may be related to the normalization of a developmentally dysregulated noradrenergic system in ASD (Mehler & Purpura, 2009). Regardless of the baseline activity of the noradrenergic system in ASD, the network rigidity in ASD (Beversdorf et al., 2007a), as well as the suggested effect or propranolol on flexible access in sematic space (Campbell et al., 2008), raises the possibility of the potential for benefit from noradrenergic agents in ASD. Furthermore, uncontrolled studies tracking response in a series of cases have suggested a benefit in both social and language domains in ASD with β-adrenergic antagonists (Ratey et al., 1987), in addition to the benefits observed in the single-dose psychopharmacological challenge studies described in the preceding. The effect of propranolol on task performance has not yet been incorporated in imaging studies, as the previous imaging study assessed functional connectivity with fMRI (fcMRI) during a task where all subjects performed at ceiling (Narayanan et al., 2010). Effects on resting state connectivity, particularly on the default mode network, depend on the subnetwork examined (Hegarty II et al., 2017).

Less is known about the specific cognitive effects of β1 and β2 adrenergic receptors. However, in one animal study, endogenous β1 selective activation impaired working memory (Ramos et al., 2005). A subsequent study demonstrated that β2 selective agonists enhance working memory in aging animals (Ramos, Colgan, Nou, & Arnsten, 2008), suggesting opposing effects between β1 and β2 receptors on working memory, and possibly explaining the lack of effect of the non-specific β-antagonist propranolol on working memory in previous research (Arnsten & Goldman-Rakic, 1985; Li & Mei, 1994). Further research will be necessary to better understand the specific cognitive effects due to action at selective subtypes of β-adrenergic (β1 and β2) receptors.

The Dopaminergic System

The dopaminergic system has a range of cognitive effects, including aspects of executive function closely related to creativity, in addition to its well-known effects on the motor system. Research in animal models has demonstrated varying effects of dopaminergic agents on set-shifting tasks, differing according to which receptor subtype each agent impacts (Floresco et al., 2005). Among set-shifting tasks, this effect appears to be specific to intradimensional set shifting (Robbins, 2007). Whereas agonists for both D1 and D2 receptors did not affect set shifting, D2 antagonists impaired set shifting in rodents (Floresco, Ghods-Sharifi, Vexelman, Magyar., 2006; Stefani & Moghaddam, 2005), an effect also observed in humans (Mehta, Manes, Magnolfi, Sahakian, & Robbins, 2004). In further support of a role of the dopaminergic system in executive function, the ability to maintain and flexibly alter cognitive representations in response to environmental demands is known to be impaired in Parkinson's disease (Cools, 2006). Computational models propose that phasic stimulation of D2 receptors in the striatum drives flexible adaptation of cognitive representations, which are maintained by the prefrontal cortex (Cohen, Braver, & Brown, 2002), which contrasts with the effect on priming, which appears to be mediated by D1 receptors (Roesch-Ely et al., 2006; Pederzolli et al., 2008). Receptor specificity of effects on creativity is not known. It should be noted that the interaction between dopaminergic agonists and Parkinson's disease and their effect on cognition are complex for set-shifting as well as working memory. Early in Parkinson's disease, greater dopaminergic depletion in the dorsal striatum leads to impaired adaptation in responses and updating in working memory, which is improved by L-dopa, while working memory itself benefits less from the administration of L-dopa. However, L-dopa also can excessively enhance reward biases due to effects on the relatively intact ventral striatum (Cools, 2006). These other cognitive effects of the dopaminergic system are discussed further later in the chapter.

Regarding effects on other related executive functions, in healthy subjects those with lower working memory capacity tend to benefit from increased prefrontal function with dopaminergic stimulation (Gibbs & D'Esposito, 2005; Kimberg, D'Esposito, & Farah, 1997). This is likely related to the fact that dopamine synthesis capacity in the striatum is related to working memory capacity, such that those with the least working memory capacity also have less dopamine, and therefore benefit from dopaminegic stimulation (Cools, Gibbs, Miyakawa, Jagust, & D'Esposito, 2008), suggesting an inverted U-shaped relationship between performance and dopaminergic function. In animal models this effect on working memory appears to be mediated by action at the D1 receptor (Arnsten, Cai, Murphy, & Goldman-Rakic, 1994; Sawaguchi & Goldman-Rakic, 1991; Williams & Goldman-Rakic, 1995). Dopamine also appears to be critical for a range of other aspects of cognition involving frontal-subcortical circuits, including the temporal coupling of deliberation and execution during decision-making, as dopamine replacement reverses the delay specific to decision-related hesitations, independent of motor slowing, in situations requiring decision-making in uncertainty in patients with Parkinson's disease (Pessiglione et al., 2005).

Another critical role of dopamine has recently become apparent with the development of pathological gambling in the setting of treatment with dopaminergic agonists (Dodd et al., 2005; Gallagher, O'Sullivan, Evans, Lees, & Schrag, 2007). This has contributed to a greater understanding of the roles of dopamine in decision-making, revealing that dopamine neurons encode the difference between expected and received rewards, and interact with other neurotransmitter systems to regulate such decision making (Nakamura, Matsumoto, & Hikosaka, 2008), likely related to the enhanced reward bias from effects on the relatively intact ventral striatum described in the preceding (Cools, 2006). The relationship between this effect of dopamine and creativity is also in need of further exploration.

Early interest in the role of the dopaminergic system in creativity came from research examining the effects on the semantic network in priming studies, since the ability to search within the semantic network is a critical component of both semantic priming and verbal creativity tasks. In 1996, Kischka and colleagues demonstrated in a priming experiment in healthy individuals that word recognition occured more rapidly when presented 700 milliseconds after exposure to another directly related or indirectly related word. However, after administration of L-dopa, the precursor for dopamine, only words presented after directly related words were recognized quickly. A role of the dopaminergic system in the restriction of the semantic network in priming was proposed. Spreading activation of either a directly or indirectly related word facilitated word recognition without L-dopa, but only the directly related word facilitated word recognition with L-dopa (Kischka et al., 1996). This effect appears to be sensitive to the time between the initial and target stimuli, likely a reflection of the effects of the timing of spreading activation. Subsequent research by Angwin et al. (2004) demonstrated that L-dopa affected both direct and indirect priming with an interstimulus interval of 500 milliseconds, but had no affect at 250 milliseconds. This finding would seem consistent with what might be expected with an effect on a widely distributed network (Alexander et al., 2007; Campbell et al., 2008). However, since L-dopa is a dopamine precursor, it remained unclear as to which specific dopamine receptors might be responsible for the priming effect. Studies in healthy volunteers (Roesch-Ely et al., 2006) as well as patients with Parkinson's disease (Pederzolli et al., 2008) suggest that the priming effect is mediated by action on the D1 receptor.

In order to begin to examine how dopaminergic agents might affect semantic networks, the effect of L-dopa on functional connectivity during fMRI was examined using a non-priming language task: a word categorization task. An isolated increase in connectivity was observed with L-dopa between the left fusiform gyrus and the receptive language areas, with no other region pairs affected (Tivarus, Hillier, Schmalbrock, & Beversdorf, 2008). Since the left fusiform gyrus is considered the visual word form receptive area (Beversdorf et al., 1997), this would appear to fit with the effects on priming, as the interaction between this fusiform area (critical for visual word form recognition) and Wernicke's area (critical for processing word meaning) would be essential for priming effects. However, since the predominant target among cortical areas for dopaminergic projecting fibers is the frontal lobe

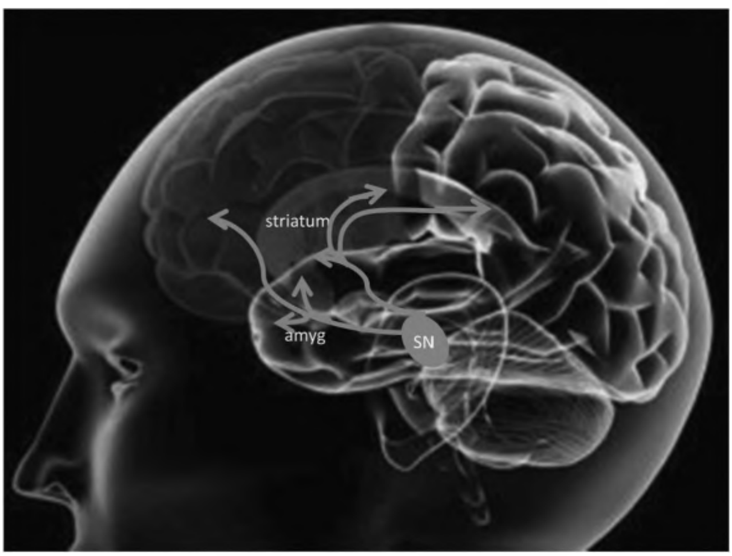

Figure 26.2. (See Color Insert) Dopaminergic pathways. Projections from the substantia nigra (SN) to the striatum are demonstrated, as are projections from the ventral tegmental area (VTA) to the amygdala (amyg), ventral striatum, and frontal cortex (Heimer, 1995). Not shown are the tuberoinfundibular and posterior hypothalamic dopaminergic systems. Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284–304). New York: Oxford University Press.

(Hall et al., 1994; Lidow, Goldman-Rakic, Gallager, & Rakic, 1991) (Figure 26.2), such an effect of L-dopa on these posterior regions seems unexpected. Subsequent evidence using independent component analysis of fMRI data during language tasks suggests that the posterior effects of L-dopa may be mediated indirectly by the fronto-thalamic connections from the areas containing the frontal projections of the dopaminergic fibers (Kim, Goel, Tivarus, Hillier, & Beversdorf, 2010). Subsequent fMRI studies examining the effect of L-dopa during priming revealed changes in region-of-interest (ROI) activation with drug in the dorsal prefrontal cortex, medially and laterally, anterior cingulate, left frontal operculum, and left middle temporal gyrus (Copland, McMahon, Silburn, & de Zubicaray, 2009), which also may suggest an indirect frontal-posterior interaction.

However, in consideration of the research based on administration of L-dopa, it must be noted that L-dopa is also a precursor to norepinephrine. Further study has been initiated in hopes of disentangling the potential effects of the dopaminergic and noradrenergic systems on priming and creativity in problem-solving, both of which are known to be sensitive to the action of catecholaminergic agents (dopamine and norepinephrine) on semantic networks (Campbell et al., 2008; Kischka et al., 1996). Dopaminergic agonists were found to have no effect on creativity in verbal problem-solving (Smyth & Beversdorf, 2007), and noradrenergic agents did not appear to affect priming in the manner observed with dopaminergic agents (Cios, Miller, Hillier, A., Tivarus, & Beversdorf, 2009). This appears to suggest a role for the dopaminergic system (but not the noradrenergic system) on automatic searches of the semantic network, such as in word recognition (Cios et al., 2009; Kischka et al., 1996), and a role for the noradrenergic system (but not the dopaminergic system) on controlled searches of the semantic network, such as during verbal problem-solving (Campbell et al., 2008; Smyth & Beversdorf, 2007).

Despite these findings, other recent research has suggested a more direct relationship between the dopaminergic system and creativity. Studies examining rate of eye-blink, proposed to be a marker of dopaminergic activity (Groman et al., 2014), demonstrated an inverted U-shaped relationship between eye-blink rate and creativity as assessed by an alternate uses task (AUT) and the remote associates task (RAT) (Chermahini & Hommel, 2010). Genetic studies demonstrate a relationship between D2 receptor polymorphisms and a composite creativity score, as well as performance on verbal creativity, as assessed by object use fluency and sentence fluency from three words (Reuter, Roth, Holve, & Hennig, 2006). Catechol-O-methyltransferase (COMT) gene polymorphisms, critical for the metabolism of both norepinephrine and dopamine, have been shown to affect performance on insight-based problem-solving tasks (Jiang, Shang, & Su, 2015). Additionally, gray matter volume in dopaminergic subcortical regions as well as the right dorsolateral prefrontal cortex were found to be positively associated with divergent thinking performance (fluency for unusual uses and unimaginable things) with voxel-based morphometry using MRI (Takeuchi et al., 2010), and a negative association was observed in the relationship between thalamic D2 receptor densities and performance on verbal, figural, and numerical fluency tasks with receptor binding studies using positron emission tomography (PET) (de Manzano, Cervenka, Karabanov, Farde, & Ullén, 2010). A report of a single case describing changes in artistic behavior with dopaminergic agonists in Parkinson's disease has also been cited as evidence for a relationship between the dopaminergic system and creativity (Kulisevsky, Pagonabarraga, & Martinez-Corral, 2009). However, the potential for this pathology having effects on interest in (as well as obsession with) artistic output, as well as potential effects on style in such cases, is hard to disentangle from other aspects of creativity (Chatterjee et al., 2006). Enhanced performance on several creativity-associated tasks, though, has recently been reported under dopaminergic therapy in Parkinson's disease (Faust-Socher, Kenett, Cohen, Hassin-Baer, & Inzelberg, 2014). While this array of indirect supportive data for a role for the dopaminergic system in creativity is of interest, the distinction between the roles of the noradrenergic and dopaminergic systems in creativity is in need of further study.

Other Systems

Neurons in the nucleus basalis, medial septal nucleus, and the diagonal band of Broca in the basal forebrain are the main sources of cholinergic projection throughout the neocortex and hippocampus (Selden, Gitelman, Salamon-Murayama, Parrish, & Mesulam, 1998) (Figure 26.3). The cholinergic system is another neurotransmitter system involved in modulating the signal-to-noise ratio within the cortex by suppressing background intrinsic cortical activity (Hasselmo & Bower, 1992), thus modulating the efficiency of cortical processing of sensory or associational information (Sarter & Bruno, 1997). Acetylcholine is particularly important for

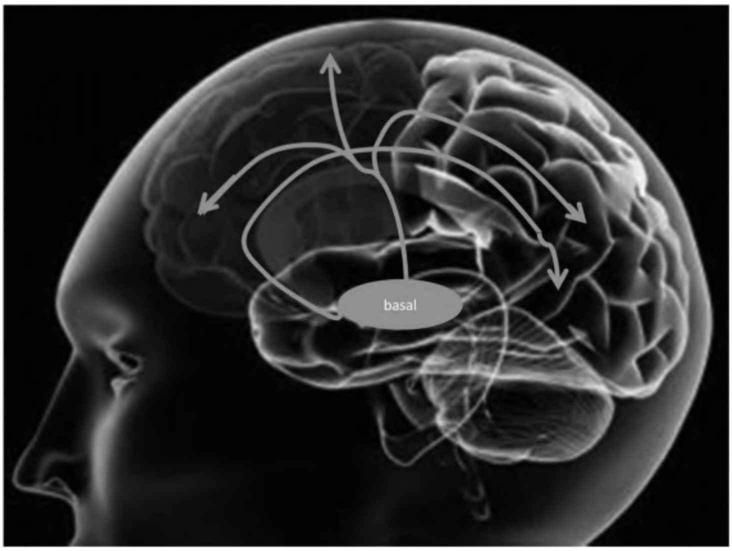

Figure 26.3. (See Color Insert) Cholinergic pathways. Cortical projections from the basal forebrain are demonstrated to the cingulate and pericingulate cortex, as well as the mesial frontal cortex along a mesial pericingular tract, and laterally through the external capsule and claustrum to the capsular region and lateral neocortex (Selden et al., 1998). Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284-304). New York: Oxford University Press.

attentional performance (Sarter & Bruno, 2001). Studies in rodents demonstrate that acetylcholine is critical for both top-down and bottom-up processing of stimuli, mediated by action on the prefrontal cortex (Gill, Sarter, & Givens, 2000; Newman & McGaughy, 2008).

Cholinergic dysfunction has been used as a model for Alzheimer's disease (Whitehouse et al., 1982) due to the significant degeneration of the cholinergic neurons in these patients. Among the two main subtypes of acetylcholine receptors, muscarinic receptors have been clearly demonstrated to interfere with encoding of new information, with less of an effect on previously stored information (Hasselmo & Wyble, 1997). Blockade of nicotinic receptors has also revealed significant effects on memory in an age-dependent manner (Newhouse, Potter, Corwin, & Lenox, 1992, 1994). However, despite clear effects on signal-to-noise ratio in the cortex, as well as memory effects, neither muscarinic nor nicotinic blockade resulted in effects on the type of unconstrained cognitive flexibility modulated by the noradrenergic system (Smyth & Beversdorf, in preparation).

Our understanding of the role of individual neurotransmitter systems in cognition has significantly progressed in recent years. However, these systems do not act in isolation. Complex interactions occur between them, which are only beginning to be understood. For example, action at D2 dopaminergic receptors and at NMDA glutamate receptors appear to interact in their effects on set-shifting (Floresco, Magyar, Ghods-Sharifi, Vexelman, & Tse, 2005; Floresco, Ghods-Sharifi, Vexelman, & Magyar, 2006; Stefani & Moghaddam, 2005). Also, as described earlier, the dopaminergic system appears to preferentially affect intradimensional set-shifting (Robbins, 2007), while the noradrenergic system, specifically by action on the $\alpha 1$ adrenergic receptor, appears to preferentially modulate performance on extradimensional set-shifting (Lapiz & Morilak, 2006; Robbins, 2007). Noradrenergic innervation of dopaminergic neurons, by action on $\alpha 1$ adrenergic receptors, is known to directly inhibit the activity of the dopaminergic neurons (Paladini & Williams, 2004). In addition, the effects of drugs on cognition also depend on location of action when isolated brain regions are studied (Cools & Robbins, 2004). Finally, the mechanism by which the regulatory neurotransmitters act is beginning to be more fully understood, with potential targets for intervention at these second messenger systems, which are the downstream intracellular pathways that are triggered by the binding of the neurotransmitter at the extracellular receptor (Arnsten, 2007, 2009). These factors will all need to be accounted for in future studies of creativity.

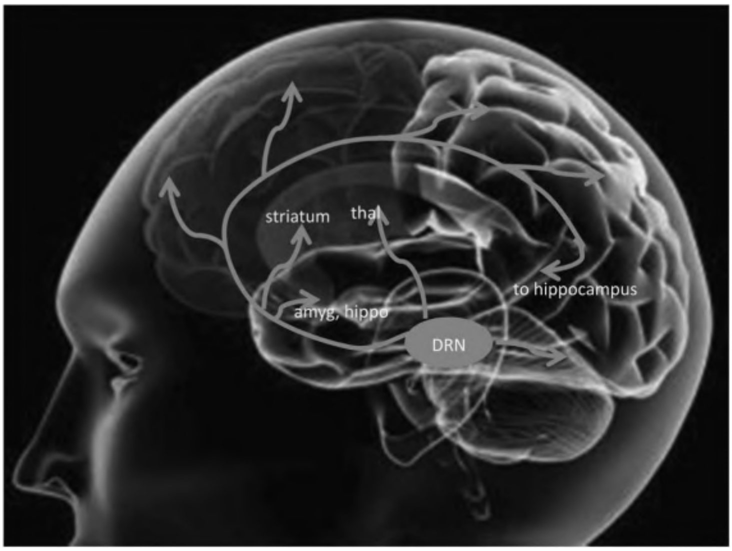

Figure 26.4. (See Color Insert) Serotonergic pathways. The dorsal raphe nuclei (DRN) project posteriorly to the cerebellum and intracerebellar nuclei, and up to the thalamus (thal), with projections also to the amygdala (amyg), hippocampus (hippo), hypothalamus, olfactory and entorhinal cortices, then to the ventral striatum, as well as throughout the neocortex along a pericingular tract, also terminating posteriorly at the hippocampus (Heimer, 1995). Not shown are the caudal raphe nuclei, which also project to the cerebellum and intracerebellar nuclei, and down to the spinal cord. Reproduced by permission from Beversdorf, D. Q. (2013). Neuropsychopharmacology and cognition. In A. Chatterjee & B. Coslett (Eds.), *The roots of cognitive neuroscience: Behavioral neurology and neuropsychology* (pp. 284–304). New York: Oxford University Press.

The serotonergic system, with neurons in the dorsal raphe nucleus projecting throughout the forebrain and neocortex (Figure 26.4), has long been known for its effects on mood and various psychiatric conditions, and is also responsive to stress (Malyszko, Urano, Takada, & Takada, 1994). However, recent research is revealing that the serotonergic system and its interaction with other neurotransmitter systems serve important cognitive roles as well. Recent evidence suggests that the balance between the serotonergic and dopaminergic systems appears to be critical for the processing of reward and punishment (Krantz, Kasper, & Lanzenberger, 2010). The firing of midbrain dopamine neurons shows a firing pattern that reflects the magnitude and probability of rewards (Roesch, Calu, & Schoenbaum, 2007; Schultz, 2007). While tryptophan depletion enhances punishment prediction but does not affect reward prediction (Cools, Robinson, & Sahakian, 2008), serotonergic neurons appear to signal reward value (Nakamura et al., 2008). Furthermore, prefrontal serotonin depletion affects reversal learning, but not set-shifting (Clarke et al., 2005). A potential role in creativity is also suggested for the serotonergic system. Performance on figural and numeric creativity tasks has been associated with polymorphisms of the tryptophan hydroxylase gene TPH1 (Reuter, Roth, Holve, & Hennig, 2006), and both the number solved and the prevalence of use of insight on the compound remote associates task was positively associated with high positive mood (Subramaniam, Kounios, Parrish, & Jung-Beeman, 2008), also suggesting a role of the serotonergic system.

Future Directions

As our understanding of neurotransmitter interactions, localized effects, and other types of neurotransmitters and neuropeptides grows, it also will need to be integrated with our advances in understanding of epigenetic regulatory factors, in order to fully understand how complex phenomena such as creativity are carried out in the brain. Furthermore, the recently reported effects of transcranial direct-current stimulation on creativity task performance (Colombo, Bartesaghi, Simonelli, & Anton, 2015; Green et al., 2017; Milano et al., 2016) may relate to critical underlying regional neuropharmacological mechanisms.

In addition to the patient populations described earlier, where certain aspects of creative performance may be affected, recent evidence has demonstrated relationships between genetic markers for schizophrenia, bipolar disorder, and professional affiliations associated with creativity in a large population study (Andreasen, 2005, 2008; Power et al., 2015).

Better understanding of modulatory effects on the performance on creativity tasks may result in clinical benefits for patients with a wide variety of clinical syndromes. This understanding also may allow for the possibility of optimization of performance, for example, how to overcome effects on cognition induced by stressful situations where creativity may be impaired. Finally, non-pharmacological approaches that are likely related to pharmacological systems will have increasing importance, as several studies have shown positive effects of meditation on performance on creativity tasks (Ding, Tang, Tang, & Posner, 2014).

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PART VI

Sleep, Dreaming, and Memory

CHAPTER

27

Dreaming Is an Intensified Form of Mind-Wandering, Based in an Augmented Portion of the Default Network

G. William Domhoff

Abstract

This chapter argues that dreaming is an intensified form of mind-wandering that makes use of embodied simulation. It further hypothesizes that the neural network that enables dreaming is very likely an augmented portion of the default network. This network is activated whenever there is (1) a mature and intact neural substrate that can support the cognitive process of dreaming; (2) an adequate level of cortical activation; (3) an occlusion of external stimuli; (4) a cognitively mature imagination system (a necessity indicated by the virtual lack of dreaming in preschoolers and its relative paucity until ages 8–9); and (5) the loss of conscious self-control, which may be neurologically mediated in the final step in a complex process by the decoupling of the dorsal attentional network from the anterior portions of the default network. If this testable theory proves to be correct, then dreaming may be the quintessential cognitive simulation.

Key Words: dreaming, dream, mind-wandering, cognition, default network

Introduction

The serendipitous discovery of a strong correlation between dreaming and rapid eye movements (REM) in 1953 provided the context for the gradual realization that dreaming could be best understood as a form of internally mediated thought (Aserinsky, 1996; Aserinsky & Kleitman, 1953, 1955). The further discovery a few years later that these eyes movements were part of one stage of sleep (REM sleep), within a very regular sleep cycle, reinforced the notion that dreaming was one event within a sleep-wake cycle that is largely independent of ordinary environmental stimuli (Dement & Kleitman, 1957a, 1957b).

Moreover, subsequent research also revealed that dreaming is not solely linked to REM sleep, or even to sleep. Awakenings from REM sleep are more likely to lead to long and vivid dream reports, but long and vivid reports can be recalled from non-rapid eye movement (NREM) 2 awakenings as well, especially late in the sleep period, or after spontaneous NREM morning awakenings (Cicogna, Natale, Occhionero, & Bosinelli, 1998; Herman, Ellman, & Roffwarg, 1978; Pivik & Foulkes, 1968) There is also solid evidence that dreaming can occur during sleep onset and briefly during periods of mind-wandering (Foulkes, 1985; Foulkes & Schmidt, 1983; Foulkes & Vogel, 1965). The most important implication of these varied findings is that dreaming depends on an adequate level of brain activation in the absence of external distractions, not on the neurophysiology of a particular sleep stage (Antrobus, 1986; Antrobus, Kondo, & Reinsel, 1995; Foulkes, 1985; Wamsley et al., 2007; Zimmerman, 1970).

Soon after the basics of the sleep cycle were established, sleep and dream researchers learned that they could not trigger dreams or very often and reliably influence them with either pre-sleep stimuli, such as fear-arousing or sensual movies, or with concurrent stimuli administered during REM, such as sounds or the whispering of the names of significant people in the dreamers' lives (Berger, 1963; Dement, 1965; Dement & Wolpert, 1958; Foulkes, 1966, 1996; Rechtschaffen, 1978). For example, only 5% of 179 awakenings showed any sign of incorporation in a large-scale study comparing the influence of neutral and affect-arousing pre-sleep films on the REM reports of 24 adult participants (Foulkes & Rechtschaffen, 1964); similar results were obtained in a study of boys between ages 7 and 11 (Foulkes, Pivik, Steadman, Spear, & Symonds, 1967). Moreover, the impact of external stimuli on dreams may be exaggerated because the criteria for incorporation are very loose in some of these studies, including alleged metaphoric expressions of the stimulus (see Arkin & Antrobus, 1991, for a critical review).

Pre-sleep suggestions to dream about a specific topic also proved to be nearly futile, and the few meager results were tempered by the impossibility of confirming affirmative reports by participants who might be overly eager to please researchers (Domhoff, 1985, pp. 84–88; see also Griffin & Foulkes, 1977, for a well-controlled study with null results). However, one well-controlled study did find that participants often dreamed about topics they had been asked to try not to think about; an innovative control was added in that the participants did not know they would be asked about their dreams until they opened a sealed envelope when they awakened the next day (Wegner, Wenzlaff, & Kozak, 2004).

Even during-sleep suggestions related to the dreamer's current concerns have very little impact. For example, in one study, seven male participants each slept in the lab on three experimental nights to see if their REM dream reports would incorporate recorded words, some of which related to their current concerns, as determined by pre-sleep questioning, and some of which did not (Hoelscher, Klinger, & Barta, 1981, p. 89). Although 56 of 59 REM awakenings yielded dream reports, independent judges agreed that there were only 13 incorporations, 10 of which involved repeated words related to one of the participants' personal concerns. However, it was also judged that five of the concerns and all three of the non-concerns appeared in dreams in which these stimuli were not suggested, which reduced the number of likely incorporated suggestions to five (Hoelscher et al., 1981, p. 90).

Based on a consideration of the laboratory dream research literature over a period of nearly 40 years, a dream researcher who conducted several studies that tried to influence dream content later concluded: "Probably the most general conclusion to be reached from a wide variety of disparate stimuli employed and analyses undertaken is that dreams are relatively autonomous, or 'isolated,' mental phenomena, in that they are not readily susceptible to either induction or modification by immediate pre-sleep manipulation, at least those within the realm of possibility in ethical human experimentation" (Foulkes, 1996, p. 614). On the few occasions when stimuli seem to be incorporated, "the narrative seems to determine the fate of the stimulus, rather than the stimulus determining the fate of the narrative," which again shows the stimulus-independent nature of dreaming (Foulkes & Domhoff, 2014, p. 168).

Nor do significant events of the previous day very often have an effect on dream content. In three careful studies of this issue, two in the laboratory, one based on dreams written down at home in the morning, blind judges could not match the participants' pre-sleep verbal reports of their activities or major concerns of the day with dream reports from night awakenings from REM periods or morning reports at home (Roussy, 1998; Roussy et al., 2000; Roussy et al., 1996). Thus, the generally unsuccessful search for specific stimuli, significant daily events, or even current concerns that can influence the dreams of the subsequent night has demonstrated that dreaming is a form of internally mediated thought that occurs when the mind is not being directed by internal or external stimuli, which makes it similar in nature to mind-wandering and daydreaming (Antrobus, Singer, Goldstein, & Fortgang, 1970; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007; Singer, 1966).

More recently, the equally serendipitous discovery of the default network and its relationship to mind-wandering opened a new chapter in dream research because several dream researchers soon noticed that the default network shared regions with the network that is activated in REM sleep (e.g., Domhoff, 2011; Hartmann, 2011; Pace-Schott, 2011). When the mind-wandering supported by the default network is conceptualized in terms of simulation, which is defined as "a particular kind or subset of thinking that involves imaginatively placing oneself in a hypothetical scenario and exploring possible outcomes," then the potential link to dreaming is clear (Schacter, Addis, & Buckner, 2008, p. 42). Mind-wandering and dreaming both involve thinking that is turned inward to personal concerns and often jumps from topic to topic (Smallwood & Schooler, 2006, 2015).

Evidence from dream studies further suggests that dreams are "embodied" simulations, in which there is not only mental imagery and narrative flow, but also an activation of secondary sensorimotor and visual areas that have to do with perceptions and actions. They are also embodied in the further sense that the imagery involved in simulation is subjectively "felt" as the experienced body in action (Bergen, 2012; Gibbs, 2006; Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009). Dreaming may even be the quintessential embodied simulation because it often includes a vivid sensory environment and intense interpersonal interactions, and sometimes unfolds over a period of 15–30 minutes. From this perspective, dreams are dramatizations that have parallels with theatrical plays. The dreamer and the other characters are usually engaged in one or another activity (e.g., looking, walking) or a social interaction (e.g., criticizing, hugging), and sometimes express thoughts or emotions. The sense of being a participant in (or observer of) an event is a defining feature of dreaming. In all these regards, dreaming has nothing to do with hallucinations, psychotic states, or drug states, nor with the other kinds of mental experiences that can occur during sleep or upon awakening (e.g., night terrors and sleep paralysis) (e.g., Arkin, 1981; Boselli, Parrino, Smerieri, & Terzano, 1998; Broughton, 1968; Cheyne & Pennycook, 2013; Fisher, Kahn, Edwards, & Davis, 1973; Santomauro & French, 2009).

Combining what is known from laboratory dream studies and neurocognitive studies, it seems likely that the neural network for dreaming becomes operative whenever there is (1) a mature and intact default network that can support the cognitive process of dreaming, a qualification that allows for the impact of lesions on the functioning of this network; (2) an adequate level of cortical activation, which is provided by subcortical ascending pathways and crucial regions in the hypothalamus; (3) an occlusion of external stimuli, which likely happens in the posterior thalamus, but may include some gating in primary sensorimotor areas; (4) a cognitively mature imagination system, a necessity indicated by the relative lack of dreaming in preschoolers and its infrequency until ages 9–11; and (5) the loss of conscious self-control, which may be neurologically mediated as the final step in a complex process by the decoupling of the dorsal attentional network from the anterior portions of the default network.

Although dreams are often thought of as disjointed and highly bizarre, several laboratory studies showed that they are far more coherent and faithful to waking life than is usually recognized by psychologists and neuroscientists not familiar with the literature on dreams. For example, the largest study of adult REM dream content in the sleep laboratory, based on 635 dream reports collected "for a variety of experimental purposes" in a series of investigations over a period of seven years between 1960 and 1967, concluded that "dreaming consciousness" is a "remarkably faithful replica of waking life" (Snyder, 1970, p. 133).

Nor are there many differences between dream reports collected in sleep labs and those collected in non-lab settings, except in the case of several aggression indicators, as best shown in studies that used the same participants in both settings (Domhoff & Schneider, 1999; Hall, 1966b; Strauch & Meier, 1996; Weisz & Foulkes, 1970; Zepelin, 1972). So-called "typical dreams," such as flying, losing teeth, or appearing inappropriately dressed in public, which many people report they have experienced, are actually extremely rare, less than 1% of dreams in each instance in both lab and non-lab studies (Barrett, 1991; Domhoff, 1996; Snyder, 1970; Strauch & Meier, 1996). "Recurrent dreams" are less than 2% of all dreams, and the appearance of everyday issues such as politics, economics, and religion is also very infrequent (Desjardins & Zadra, 2006; Domhoff & Schneider, 2008; Hall, 1951; Hartmann, 2000).

In the most detailed lab study of unusual and anomalous characteristics of dream reports, the investigators concluded that their results "emphasize the rarity of the bizarre in dreams" because major distortions of actual waking experiences reach a high of only 16.7% of all the activities and social interactions, and of only 6.2% and 7.8% for all characters and physical surroundings (Dorus, Dorus, & Rechtschaffen, 1971, p. 367). The figures for the most improbable category of event (those never experienced by the dreamer in waking life) were 4.9% of all physical surroundings, 1.3% of all characters, and 6.8% of all activities and social interactions. Similar findings were reported in other lab and non-lab studies (Hall, 1966a; Revonsuo & Salmivalli, 1995; Snyder, 1970; Strauch & Meier, 1996).

Moreover, other studies suggest that there may be only small differences between dream reports and drifting waking thought in terms of bizarreness. For example, a study comparing REM reports to streams of waking thought recorded in a darkened room found that there were more abrupt topic changes or scene changes ("discontinuities") in the waking sample than in REM reports, which makes the use of scene changes a problematic indicator of more frequent bizarreness in dreaming. In addition, there were as many "improbable combinations," such as unusual juxtapositions of objects, in waking as in REM. The REM dream reports only were higher on "improbable identities," such as metamorphoses and blended characters (Reinsel, Antrobus, & Wollman, 1992, p. 173).

Frequent topic changes also are found in laboratory studies of mind-wandering, even when participants are asked to focus on a visual discrimination task on a computer screen (Mason et al., 2007). Inattention while carrying out these and other cognitive tests in the laboratory leads to impairments in executive-system abilities, which may have parallels with any impairments in thinking during dreaming. The authors of one review of the literature characterize the findings as evidence for a "restless mind" (Smallwood & Schooler, 2006). The same authors describe mind-wandering as "a state of decoupled information processing, which occurs because of a shift of attention from the immediate environment," a statement that might apply to dreaming as well (Smallwood & Schooler, 2006, p. 956).

It is also notable that 29 college students (13 men, 16 women), who were signaled randomly over a period of seven days by means of a pager, judged that one-third of all their thoughts were "spontaneous," meaning that those thoughts were not directed and had arisen unexpectedly (Klinger, 1999, 2009; Klinger & Cox, 1987–1988). Demonstrating that spontaneous thoughts can be highly unusual, 21% of the reports analyzed in one of these analyses had aspects that were physically impossible, and many thoughts were judged as disconnected. In addition, 9% of the 1,425 thought samples had "more than a trace" of dreamlike thought and another 16% had a "trace" of such thought (Klinger & Cox, 1987–1988, p. 124). Importantly, there were also wide individual differences in how much thinking was reported to be deliberate or spontaneous in these studies. For two-thirds of the participants, the majority of their thoughts were deliberate and intentional, but for the other one-third the majority of their thoughts were spontaneous (Klinger, 1999, 2009).

The findings in field studies of mind-wandering dovetail with the inadvertent discovery of brief episodes of dreaming during periods of drifting waking thought during practice sessions in the sleep lab, which were meant to prepare participants to focus on their most recent thoughts during sleep awakenings (Foulkes, 1985, pp. 71–72). Participants reclined in a moderately lighted room, with instructions to relax but stay awake, and with their wakefulness monitored by EEG and EMG recordings. They then responded to random verbal requests from the experimenters to report "the very last thing going through your mind just before I called you" (Foulkes, 1985, p. 71). To the researchers' surprise, they learned that 24% of sampled thoughts reported by 16 women college students were described as visual and dramatic, and were experienced as dreams (Foulkes & Scott, 1973).

In a replication study with 10 men and 10 women, who were asked to report their thoughts after 12 random calls in sessions of 45–60 minutes, 19% of the probes led to reports in which the participants "experienced multimodal sensory imagination that was dramatic in form and which, for the moment at least, was experienced as reality rather than imagination" (Foulkes, 1985, p. 72; Foulkes & Fleisher, 1975, for the first report of the replication study). The investigators further learned that 20% of the probes demonstrated involvement in "what might be called *mindwandering* (the subject is not controlling his thoughts, but he is aware he is in the laboratory . . .)." No instances of objective or self-reported sleep were recorded during this study (Foulkes & Fleisher, 1975, p. 70). The original findings were replicated for a second time as a preliminary part of a study of dream reports from sleep-onset, REM sleep, and NREM sleep, but the results were not formally published (Foulkes, 1985, p. 89, footnote 39, and pp. 70–77 for a summary of all three studies).

Systematic quantitative studies of dream content reveal that there is considerable psychological meaning in dream content in terms of correspondences with waking demographic and psychological variables, such as nationality, gender, age, and major personal waking concerns (Domhoff, 1996, 2003; Pesant & Zadra, 2006; Zadra & Domhoff, 2016). This point is also demonstrated by the consistency of dream content over months, years, or decades in studies of all or parts of about 25 different dream series, which were kept by a wide range of individuals for their own reasons without any intention of later providing them to dream researchers. These dream series are an archival form of data that can be classified as a non-reactive measure because they are not influenced by the demand characteristics implicit in any experimental setting or the expectancies of experimenters and participants when they enter into an experimental study (Orne, 1962; Rosenthal & Ambady, 1995; Rosenthal & Rosnow, 1969; Webb, Campbell, Schwartz, Sechrest, & Grove, 1981). Nor are the results from studying dream series influenced by autocorrelation (i.e., the lack of independence among a series of responses from a single individual), as shown by a study of content findings from four different dream series using the Wald-Walkowitz (1940) runs test to test for randomness. Overall, 125 runs tests were carried out, which resulted in six statistically significant results, five at the .05 level and one at the .01 level. The percentages of statistically significant differences that were found—4.8% at the .05 level and 0.8% at the .01 level—are close to what would be expected by chance (Domhoff & Schneider, 2015).

Detailed content analyses of about a dozen dream series, which led to a series of inferences that could be accepted or rejected by the dreamer and other respondents, demonstrate that there is continuity between many of the conceptions and personal concerns expressed by individuals in dreaming and waking thought, with the frequency of the appearance of a person or activity shown to be a reliable index of the intensity of a personal concern. The best-established continuities for individuals involve the main people in a dreamer's life and the nature of the social interactions with them. There also is solid evidence for continuity with many of the dreamer's main interests and activities (Bulkeley, 2012, 2014; Domhoff, 1996, 2003). However, this general finding must be qualified in certain ways.

First, the continuity is not with day-to-day events or the activities of any given day, but with personal concerns, as best shown in three closely related studies of this issue discussed earlier in the chapter (Roussy, 1998; Roussy et al., 2000; Roussy et al., 1996). Second, the continuity usually is with both thought and behavior, but sometimes it is only with waking thought. Third, there are dream elements that are not continuous with waking conceptions and concerns. It is these discontinuous aspects of dream content that may be the products of figurative thinking (as yet unsupported for dreaming) or impaired cognitive functioning (as yet unspecified and not studied). It may be that 20%–30% of dream reports are "adventure dreams," with no obvious connections to the dreamer's waking personal concerns (Domhoff, Meyer-Gomes, & Schredl, 2005–2006; Foulkes, 1999, p. 136).

The general findings on consistency and continuity suggest that there may be another level of meaning in dreaming, namely, a degree of lawfulness in at least some of its aspects. This conclusion is based on a comparison of the relationships found in waking social networks with the social networks found in five dream series, ranging in size from 208 to 423 dream reports, three from women, two from men. The study found that the "same properties apply to dream social networks" (Schweickert, 2007, p. 279); that is, waking social networks and networks of dream characters are both "small world" networks in that they are characterized by a combination of features, such as short paths to other people via shared connections, a tendency for two people who are known by another person to know each other, and a tendency for the people who appear frequently to appear together (Han, Schweickert, Xi, & Viau-Quesnela, 2015). In addition, both waking and dreaming social networks share a strong tendency for a few characters to be more central to the overall network than others and for a large number of characters to be connected in a large general component, although the size of the general component varied greatly for the five dream series that were studied (Han, Schweickert, Xi, & Viau-Quesnela, 2015).

The findings with the first five dreamers were replicated and extended through a comparison of the waking social network and the network of dream characters in a series of 4,254 dream reports written over a 41-year period by a middle-aged woman. The results were compared with the findings from the dreamer's waking social network, which was constructed from a questionnaire in which she rated how well each possible pair of people actually knew each other in waking life and how emotionally close they were on a 1 (low) to 5 (high) scale (Han, 2014, p. 36). She also rated her own emotional closeness to each person on the same 5-point scale. In all, there were 120 characters that appeared in her dreams that were known personally by the dreamer—9 immediate family members, 55 other relatives, 28 friends, 9 boyfriends, 14 coworkers, and 5 miscellaneous characters.

The dream and waking social networks were similar in several important ways, starting with the fact that the "density" of the networks, defined as the percentage of all possible connections that actually appeared, was .16 in the waking network and .14 in the dreaming network (Han, 2014, p. 47). A centrality measure based on how connected a person is to other well-connected people revealed a high correlation between the dream and waking-life networks.

However, her network of dream characters more often brought together immediate family members, other relatives, and friends than was the case in waking life, although this difference did not hold true for her coworkers (Han, 2014, pp. 48–49). Very importantly, the people who were emotionally close to the dreamer in waking life tended to appear in dreams together, even though they were not in the same social networks in waking life (Han, 2014, p. 50).

There are also unexpected findings on the dreams of children and adolescents based on longitudinal and cross-sectional laboratory studies of many dozens of participants. Preschool and young elementary school children awakened in the sleep lab report dreams after only 15%–20% of REM awakenings, and their dream reports differ in complexity and content from those of adults, even though their verbal skills are excellent and there is every indication that they were comfortable in the laboratory setting (Foulkes, 1982; Foulkes, Hollifield, Sullivan, Bradley, & Terry, 1990). Moreover, children's dream reports are not adultlike in frequency, length, and form until ages 9–11, and the content is not regularly connected to everyday emotional preoccupations and interests until ages 11–13 (Foulkes, 1982, 1999; Foulkes, Hollifield, Sullivan, Bradley, & Terry, 1990). In addition to the cross-sectional replication of the original longitudinal results for children ages 5–8 by the same investigator (Foulkes et al., 1990), the results for children ages 9–15 were later replicated in a six-year longitudinal study (Strauch, 2004, 2005; Strauch & Lederbogen, 1999).

Although the results with children were totally unexpected, they are consistent with several different sets of findings concerning preschool children's cognitive abilities. To begin with, only half of children's statements about an event are narratives by age 3, albeit limited ones, but by age five or six many children can tell a story, usually a personal one, that contains a beginning, middle, and end (Reese, 2013, pp. 197–198; Taylor, 2013, p. 803). In addition, there is continuing narrative development after ages 5–6; in one study, children age 7 included only three of the eight basic elements that are part of a well-developed narrative, but by age 11 they included six of the eight. Similarly, children's ability to engage in "pretend dramatic play is typically delayed until age four in five in preschool environments" (Nelson, 2007, p. 170). Before that age they seem to lack the ability to simulate versions of past and future events, which is considered essential to imagination, defined as the "capacity to mentally transcend time, place, and/or circumstance to think about what might have been, plan and anticipate the future, create fictional worlds, and consider remote and close alternatives to actual experiences" (Taylor, 2013, p. 791).

Then, too, personal (autobiographical, auotonoetic) memories only gradually develop and become organized into an autobiographical self around age 6 (Bauer, 2013, pp. 521–522; Gopnik, 2009, Chapter 5; Tulving, 2005); that is, personal episodic memories for specific events slowly evolve into a more personal type of memory that has feeling components and a sense of subjective experiencing or re-experiencing, in which the memories are "infused with a sense of personal involvement" (Bauer, 2013, p. 521). Studies that included specific questions about conscious thoughts found that preschool children, in contrast to those ages 6–7 and older, do not seem to have much awareness of a spontaneous inner mental life (Eisbach, 2013b, for a review and synthesis).

Between ages 3 and 6, preschool children understand many aspects of thinking quite well, but "they don't understand that your thoughts can be internally generated," or that "thoughts can simply follow the logic of your internal experiences instead of being triggered from the outside" (Gopnik, 2009, p. 152). Apparently due to this inability to consciously experience their own thinking, preschool children "don't experience their lives as a single timeline stretching back into the past and forward into future," or "feel immersed in a constant stream of changing thoughts and feelings" (Gopnik, 2009, p. 153). As a result, it is not until around age 6 that children have "the basics of autobiographical memory," along with an inner mental life and "a roughly adult understanding of consciousness" (Gopnik, 2009, p. 156). Moreover, only 44% of children understand mind-wandering at ages 6–7, compared to 86% by ages 10–11 (Eisbach, 2013a, Table 2). Linking back to the capacity for imagination, it may be that imagination plays a role in children's gradual conscious understanding of mental flow, including mind-wandering (Eisbach, 2013b, pp. 370–372).

Finally, the ability to produce mental imagery seems to be lacking in preschool children, which seems to be yet another reason why preschool children seldom dream. This conclusion is derived from numerous different types of detailed studies of visual mental imagery that are too complex to be summarized within the confines of this chapter (Frick, Hansen, & Newcombe, 2013, pp. 386–387, 395; Frick, Möhring, & Newcombe, 2014, pp. 536–538; Gopnik, 2009, p. 152; Kosslyn, Margolis, Barrett, Goldknopfan, & Daly, 1990, p. 995). However, it is important to stress that deficiencies in the "ability to transform mental representations" may have more general implications in terms of preschoolers' cognitive capacities because they may be important in "understanding other people's mental states and even physical events" (Frick, Möhring, & Newcombe, 2014, p. 539).

The absence of visual imagery in people who are born blind, or lose their sight before ages 5–7, also lends support to the hypothesis that the ability to generate mental imagery is not fully developed until after age 6 or 7 (Kerr, 1993; Kirtley, 1975). This is best demonstrated by the fact that people who become blind after age 7 "continue to be able while awake to conjure up [visual] mental images of persons, objects, and events, and they continue to dream in [visual] imagery" (Foulkes, 1999, p. 15). Since this generalization includes visual dream images of people they met after they became blind, it seems likely that they have retained a developmentally acquired system of visual imagery that is independent of their visual perceptual capabilities (Kerr, 1993, pp. 30–35).

It is noteworthy that narrative, imaginative, and mental imagery abilities were found to be lacking in waking tests that were carried out in conjunction with the longitudinal and cross-sectional dream studies (Foulkes, 1982; Foulkes et al., 1990). For example, children ages 5–7 were able to produce only simple narrative scenes without chronology or sequence, but at age 8 they were able to generate a narrative with continuity in two temporal units, along with evidence of causality (Foulkes et al., 1990, pp. 456, 461). A greater ability to produce complex imaginative narratives in response to the story prompts correlated with the participants' overall rate of dream recall when age was held constant and also at age 8, when the correlation with the total score on the imaginative narrative test was .45 (Foulkes et al., 1990, p. 458). Nor did the mental imagery tests used in the cross-sectional study show the ability to create mental imagery at age 5; the investigators concluded that "the possibility of kinematic imaging emerges somewhere between 5 and 8 years of age, rather than being generally well-developed in 5-year-olds" (Foulkes, Sullivan, Hollifield, & Bradley, 1989, p. 450). Furthermore, the one good and consistent predictor of the frequency of dream reporting in children ages 5–8 is visual spatial skills, as best measured by the Block Design test of the Wechsler Intelligence Scale for Children and the Embedded Figures Test (Foulkes, 1982; Foulkes et al., 1990).

Taken together, the gradual development of narrative skills, imagination, mental imagery, and an autobiographical self may help to explain why preschool children seldom dream and why the dream reports of children ages 5–7 often lack a sense of sequence, complexity, and kinetic imagery. However, the fact that the default network is not very well developed until ages 10–11 may be a factor as well, a possibility that is considered as part of the ensuing discussion of the role of the default network in supporting dreaming.

The Default Network and Dreaming

The possibility that the default network, or an augmented portion of it, is the basis for dreaming has been demonstrated by comparing the consensus results from default network studies with the findings from six REM imaging studies; this meta-analysis showed that many regions of the default network are activated during REM, in conjunction with the lingual gyrus and other areas in the secondary visual cortex, which are thought to support mental imagery, along with the caudate nucleus, which supports the initiation of skilled actions (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013). However, the fact remains that the sample size for the REM meta-analysis is relatively small, which leads to the hope that future neuroimaging studies of dreaming will lead to a larger pool of studies from which to draw.

The inclusion of networks for mental imagery within the default network is crucial because vivid mental imagery is one of the striking characteristics of dreams (Moulton & Kosslyn, 2011, p. 98). In addition, there are overlaps between the default network and the social brain, with one comprehensive synthesis concluding that parts of the social brain are the "social-affective part" of the default network (Amft, Bzdok, Laird, Fox, & Schilbach, 2015). Then, too, the wide range of thoughts related to the past, present, and future that can arise during drifting waking thought and dreaming may be possible because there is a "striking overlap between the cortical network that mediates contextual associative thinking" and the default network (Bar, 2011, p. 17, including his Figure 2.3). In addition, the inclusion of language areas in the temporal lobes within the default network is consistent with the frequency and specificity of language use in dreams (Foulkes et al., 1993; Meier, 1993).

There is one particularly notable absence from the REM network when it is compared with the waking default network: the posterior cingulate cortex. Although there is a "posterior cingulate cortex/lingual gyrus" cluster in the results from the meta-analysis, the bulk of the cluster is in the lingual gyrus, and the posterior cingulate cortex parts of the cluster are more lateral in the brain than the typical activations in the waking default network, which tend to be along the midline/medial aspect. There is also a significant cluster of mid-posterior cingulate cortex deactivation during REM. The absence of the posterior cingulate cortex may indicate that the environment is not being monitored for potential threats (Pace-Schott, 2007, p. 139). Then, too, the absence of the posterior cingulate cortex, which seems to be involved in retrieving past episodic memories, may help explain the rarity of episodic memories in dream reports (Baylor & Cavallero, 2001; Fosse, Hobson, & Stickgold, 2003).

There are two distinct subsystems within the default network, which are connected by two hubs, the dorsal medial prefrontal cortex and the posterior cingulate cortex. The first of the two subsystems, the "dorsal medial prefrontal cortex system," which includes the dorsal medial prefrontal cortex, the temporoparietal junction, the lateral temporal cortex, and the temporal pole of the temporal lobe, is preferentially activated by instructions to think about the person's present situation or present mental state ("present self"). The second subsystem, called the medial temporal lobe system, which includes the ventral medial prefrontal cortex, posterior inferior parietal lobule, retrosplenial cortex, parahippocampal cortex, and hippocampal formation, is preferentially activated by thinking about personal situations and decisions in the future ("future self") (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010, pp. 554, 559). These results were supported and augmented in a later meta-analytic study (Andrews-Hanna, Smallwood, & Spreng, 2014).

The imaging studies that established the relationship between the default network and dreaming concentrated their attention on REM because of its strong relationship with dreaming. However, REM is an imperfect proxy for the putative neural network for dreaming because of the evidence that dreaming also can occur during the sleep-onset process, NREM 2, and in brief episodes during long periods of mind-wandering. Several studies of the transition to sleep show that the default network is still active at sleep onset and into NREM 2, before slow-wave sleep occurs (e.g., Horovitz, 2008; Horovitz et al., 2009; Larson-Prior et al., 2009). Importantly, the largest and most detailed fMRI study of the neurophysiology of the sleep-onset process not only confirmed and extended the earlier findings, but also showed the same decoupling of the anterior default network from the dorsal attentional network that is found in waking mind-wandering studies that are discussed later in this chapter (Sämann et al., 2011).

None of these studies involves awakenings, but their findings concerning the continuing functional connectivity of the default network fit with several studies demonstrating varying amounts of dreaming at different points in the sleep-onset process (Foulkes, Spear, & Symonds, 1966; Foulkes & Vogel, 1965; Hayashi, Katoh, & Hori, 1999; Hori, Hayashi, & Morikawa, 1994). Although there are more "fleeting progressions of visual imagery or dissociated images and thoughts" during sleep onset than during REM periods, the "typical" report during the sleep-onset period is a dream that is "no less well organized than its REM-period counterpart" (Foulkes & Vogel, 1965, p. 238). Once participants no longer subjectively felt they were awake and in control of their thoughts, most of their reports could not be distinguished from REM dream reports, even though they were not always formally asleep based on the standard criteria for sleep (Foulkes & Vogel, 1965, p. 239). However, there were wide individual differences in the frequency with which they dreamed in the different stages of the sleep-onset process. For example, five participants dreamed during the first two stages, both of which include alpha patterns, and four participants dreamed only during the last two stages, which are dominated by theta waves (Foulkes & Vogel, 1965, p. 237).

Similarly, most reports from NREM 2 are dreams, not rambling thoughts. Two studies showed that the auditory awakening thresholds are "approximately equal" for REM and NREM 2, and both were lower than for slow-wave sleep (Rechtschaffen, Hauri, & Zeitlin, 1966; Zimmerman, 1970). Moreover, even the NREM 2 reports that were not dreams provide evidence for the functioning of the default network because they seem similar to "that large portion of our waking thought which wanders in seemingly disorganized, drifting, non-directed fashion whenever we are not attending to external stimuli or actively working out a problem or a daydream" (Rechtschaffen, Verdone, & Wheaton, 1963, p. 411). In addition, all-night MEG sleep recordings from four participants found that some of the same regions active during REM sleep are also differentially active in NREM 2; the researchers speculated that the dorsal medial prefrontal cortex may be the "geographic center" for dreaming in both REM and NREM 2 (Ioannides, Kostopoulos, Liu, & Fenwick, 2009, pp. 455, 465).

Based on the findings on the considerable similarity of dreams during sleep onset, NREM 2 sleep, REM sleep, and brief episodes of dreaming during mind-wandering, along with the evidence for the involvement of the default network in all these instances, it seems likely that the main issue in understanding dreaming is the degree to which the default network is the ascendant brain network.

The Transition into Mind-Wandering and Dreaming

The transition into mind-wandering and dreaming is a complex process that at the outset involves the relative deactivation of the frontoparietal network and the sensory networks with which it has strong connections. The importance of the frontoparietal network in this process is evidenced by its connectivity correlation of .70 with the default network, which reflects their close working relationship (Lee et al., 2012). The nature of their interaction is demonstrated in an experimental study that used transcranial magnetic stimulation (TMS) to alter the relationship between them, as demonstrated through changes in brain activation examined with the simultaneous use of fMRI (Chen, Oathes, Chang, Bradley, & Zhou, 2013). Excitatory TMS to the anterior portion of the frontoparietal network decreased its connectivity to the default network. On the other hand, inhibitory stimulation of the anterior portion of the frontoparietal network by TMS increased the activation level of the default network (Chen, Oathes, Chang, Bradley, & Zhou, 2013).

When the default network becomes more active in relation to the frontoparietal network, the drift into more intense mind-wandering and dreaming very likely involves a gradual deactivation in the dorsal attentional network, which works closely with the frontoparietal network in maintaining a focused alertness. The reciprocal relationship between focused attention and drifting waking thought is reflected in the –.74 correlation between the dorsal attentional network and the default network, and the –.20 correlation between the default network and the ventral attentional network, which is involved in modulating the relationships among the frontoparietal network, the dorsal attentional network, and the default network (Lee et al., 2012).

The relationship between the default network and the dorsal attentional network was one important dimension of a combined EEG/fMRI study of shifts in mental states, which showed that it is the posterior part of the default network that decouples from the dorsal attentional network; this decoupling led to the "strongest" inverse relationship between the two networks, which was between the anterior portions of the default network and the dorsal attentional network (Chang, Liu, Chen, Liu, & Duyn, 2013, p. 230). At the same time as the posterior portions of the default network and the dorsal attentional network are decoupling, the anterior regions of the default network become more connected and activated, which very likely leads to intensified mind-wandering and dreaming.

In addition, the decoupling of the anterior portions of the default network from the dorsal attentional network is accompanied by a similar disconnection from the thalamic region in the salience network, a network that is essential in preparing the body for action in response to both internal and external alerting signals (Menon & Uddin, 2010; Seeley et al., 2007). Still, the salience network, with hubs in the anterior cingulate cortex and right insula, can bring the brain to instant attention by sending signals to the frontoparietal and dorsal attentional networks, which in turn deactivate the default network (Chang et al., 2013; Chen et al., 2013; Di & Biswal, 2015; Parvizi, Rangarajan, Shirer, Desai, & Grecius, 2013). The importance of the salience network in regaining focused attention also is revealed by the fact that patients with traumatic brain injuries cannot shift away from the default network as rapidly as other people (Bonnelle et al., 2012).

Based on the way in which the frontoparietal network becomes relatively decoupled from the default network, along with the decoupling of the anterior portions of the default network from the dorsal attentional network and the salience network, it seems plausible to hypothesize that the anterior portions of the default network are at the center of the "neural network for dreaming" delineated in the meta-analysis that compared six REM imaging studies with the canonical default network (Fox et al., 2013). This hypothesis is strengthened by the work on the "dorsal medial prefrontal cortex system" because it includes the dorsal medial prefrontal cortex, the temporoparietal junction, and the lateral temporal cortex (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010). This area is at the heart of the waking self-system, which has been studied extensively with neuroimaging methodologies (e.g., Amft, Bzdok, Laird, Fox, & Schilbach, 2015; D'Argembeau et al., 2012; Di & Biswal, 2014; Heatherton, 2010; Jenkins & Mitchell, 2011). This fact may explain why the dreamer is usually at the center of dream scenarios, which very often express (to repeat a point made earlier) personal conceptions and concerns according to systematic studies of dream content (Domhoff, 1996, 2003, 2011; Domhoff & Fox, 2015).

The Development of the Default Network

If the default network is indeed the central component in the neural network for dreaming, then its very gradual development between infancy and preadolescence may help to explain the low levels of dreaming in young children and the relative simplicity of their dream content. Although the default network can be detected in infants, it is not very well developed in the preschool years, perhaps reflecting the localized regional structure of many brain networks at that age (Amso & Casey, 2006; Gao et al., 2009). In addition, the myelination so essential to major increases in the speed with which neuronal connections operate is not yet complete in many areas. Notably, myelination is not functionally complete until ages 5–7 in the parietal lobes, which contain important regions of the default network (Janowsky & Carper, 1996).

The developmental changes in the default network have been studied in a cross-sectional study of 66 American participants ages 7–9, 54 participants ages 10–15, and 91 who were 19–31. The research showed gradual changes in terms of increased within-network connectivity and integration, along with increased segregation from other networks. This adds up to a dramatically different picture by ages 10–11, when most of the major hubs in the network are finally connected (Fair et al., 2008; Fair et al., 2009). These findings have been replicated in a cross-sectional study of 447 Brazilian participants ages 7–15 that come from a wider socioeconomic spectrum (Sato et al., 2014).

The results from these two studies have been replicated, extended, and refined in a longitudinal study of both the default and frontoparietal networks in 45 participants (24 girls, 21 boys) aged 10–13. The investigators first of all found that "by age 10, the basic functional architecture of the default mode network is in place," and more generally that the "participants' functional networks resembled those found in mature adults in previous work" (Sherman et al., 2014, pp. 151, 154). The fact that the default network is in many ways similar between ages 10 and 13 is consistent with the finding in both lab and non-lab studies that the frequency of dream recall and the content of dream reports become more adultlike during preadolescence (Foulkes, 1982; Strauch, 2005; Strauch & Meier, 1996). However, a correlation does not demonstrate causation, and in addition, this one is only impressionistic and qualitative. But it may be striking enough to encourage future imaging studies of preadolescents and adolescents that include the collection of dream reports from the same participants.

At the same time that the default network becomes more adultlike, significant changes are also happening at the cognitive level in the central executive network (which is supported by the frontoparietal network). Specifically, it is changing at ages 10–11 from a unitary network to the "related yet separable" network that characterizes the adult executive network. This is shown in a study of 135 children ages 8 years 3 months to 10 years 3 months, who were tested on working memory, inhibition, and attention-shifting measures twice over a two-year period (Brydges, Fox, Reid, & Anderson, 2014). It therefore appears that adultlike dreaming is a cognitive achievement based on the development of the central executive network and the imagination/mind-wandering network (supported by the default network). Their separate integrative developments are accompanied by the achievement of a closer working relationship between them during preadolescence.

Evidence from Neurological Studies

Patients in neurological studies add a vital subjective dimension to the evidence for the role of an augmented portion of the default network in dreaming through verbal reports on the presence, absence, or distortion of their usual dreaming following focal brain lesions. It is their testimony that ultimately shows whether or not this network has to be functional for normal dreaming to occur. Among several findings that could be discussed, three are of basic importance because they show what areas of the brain are not necessary for dreaming, what areas are essential to dreaming, and what areas have the same function in dreaming as they do in waking life.

The most important systematic findings on what areas of the brain are not necessary for dreaming, all of which fall outside the default network, emerged from a neuropsychological study of 361 newly admitted neurological patients in the late 1980s (Solms, 1997). In this study, each patient was questioned during the intake interview about any possible changes in the frequency and nature of their dreaming. The findings from interviews and questionnaires were compared with findings from neurological tests and CT scans. There was a primary emphasis on patients with focal brain lesions so that hypotheses about the role of specific regions of the brain in dreaming could be tested. In the case of the 200 patients that reported no changes in their dreaming, they had lesions in regions that are essential to sensation, locomotion, and higher-order executive functions: the primary visual cortex, the primary sensorimotor cortices, and the dorsolateral prefrontal cortex (Solms, 1997, pp. 153–154, 219–223, 237).

Conversely, several studies of the temporary or permanent loss of dreaming, or of a large reduction in the frequency of dreaming, involve lesions in three different brain areas, all of which are part of the default network and are active during REM sleep: the ventromedial regions in the frontal lobe; areas in the parietal lobe; and the temporoparietal junction (Solms, 1997, Table 2.2, pp. 11–15, and Chapter 4). The importance of the ventromedial region in dreaming was first established for REM-era dream researchers by two different studies of over a dozen lobotomized schizophrenics in a hospital sleep laboratory, which showed that all but one of them did not dream, but continued to sleep normally (Jus, Jus, Gautier, et al., 1973; Jus, Jus, Villeneuve, et al., 1973). In addition to the two laboratory studies, the large-scale clinical study of 361 new neurological cases found eight cases of non-dreaming patients who suffered neurological damage in "precisely the same region" that was the focus of lobotomies—"a circumscribed lesion just anterior to the frontal horn of the ventricle, in the lower medial quadrant of the frontal lobe" (Solms, 1997, p. 145).

Forty-seven cases examined with CT scans in this clinical neurology study showed that injuries to either parietal lobe can sometimes, but not always, lead to the loss of dreaming; this finding is consistent with several cases in the historical literature (Solms, 1997, pp. 141–145). This large-scale study also found a few cases suggesting that lesions localized to the temporoparietal junction might be sufficient to lead to the loss of dreaming, but the researcher concluded that this possibility should "be treated with caution" due to the small number of cases (Solms, 1997, p. 143). Later, however, this possibility was supported by two studies of individual patients (Bischof & Basset, 2004; Poza & Marti-Masso, 2006).

Neurological patients who report changes in the visual imagery in their dreams, such as the complete loss of visual imagery or the inability to represent movement, are important because their lesions in specific areas of the secondary and tertiary visual cortices provide specific evidence that the neural network for dreaming shares regions with the same neural substrate that subserves waking mental imagery. The most solid and convincing evidence for this point comes from sleep laboratory studies of two patients, one with Turner's syndrome, which sometimes affects areas that generate visual imagery, and the other with a lesion in the right hemisphere. The lack of any visual imagery in the patient with Turner's syndrome and the presence of only static visual imagery in the other patient were verified by their inability to carry out mental imagery tasks on standard cognitive tests (Kerr & Foulkes, 1981; Kerr, Foulkes, & Jurkovic, 1978). Their lack of visual imagery in dreaming was then revealed through REM sleep awakenings. These two laboratory studies lend credence to several cases in the clinical neurology study showing changes in visual aspects of dreaming consistent with their brain lesions, and to cases going back to the 1880s of patients who reported specific impairments in the visual aspects of their dreaming that corresponded with similar impairments in their waking vision (Solms, 1997, Chapters 2 and 3).

When this clinical evidence is combined with the results of imaging studies, the case for the default network as the central component in the neural network for dreaming is greatly strengthened. But more studies clearly need to be carried out before these important findings can be viewed as fully established.

Are Dreams Useful Non-adaptations?

The many replicated lab and non-lab findings concerning the process of dreaming, such as the periodic regularity of REM dreaming and the fact of dreaming at sleep onset, during late-night NREM, and even occasionally in drifting waking thought, along with the lack of dreaming in young children and the consistency of dream content over years and decades in individual cases, do not fit with the idea that dreaming has any adaptive function (e.g., Antrobus, 1993; Blagrove, 2000; Domhoff, 2003, Chapter 6; Foulkes, 1993). However, the issue of adaptation may be approachable from a new angle if the default network proves to have adaptive value due to the new associations and ideas it provides via mind-wandering and daydreaming, a possibility that is still being debated (e.g., Baird et al., 2012; Kane & McVay, 2012; Mooneyham & Schooler, 2013; Smallwood & Andrews-Hanna, 2013; Takeuchi et al., 2012).

More specifically, it might be that new ideas can emerge shortly after spontaneous morning awakenings, whether people were dreaming or not, because the default network is likely more activated than the regions of the prefrontal cortex that support executive functions. According to this hypothesis, the alleged benefits of sleep on post-awakening creativity and scores on creativity tests are more likely a result of the activation of the default network and the drifting waking thoughts that it supports. If mind-wandering does turn out to have adaptive value, then the rare occasions when new ideas emerge from dreams would be an example of how "non-adaptations" can be useful to individuals and cultures. In other words, it may be that there has been selection for mind-wandering and daydreaming because they make it possible to rethink the past and plan for the future, but it is unlikely that dreaming is more than the accidental activation of an augmented portion of the default network.

Even if dreams are simply dramatic byproducts that simulate a person's conceptions and concerns, the fact remains that they have been put to use by people in many different times and places as crucial aspects of religious and healing ceremonies, which means that they have an emergent cultural function due to human inventiveness. Thus, the psychological meaning that can be extracted from many dream reports and the cultural usefulness of dreams must be distinguished from each other and from the issue of adaptive function in order to develop an adequate theory of dreams

Acknowledgments

This chapter draws upon arguments and findings that are more fully developed in my *The Emergence of Dreaming: Mind-Wandering, Embodied Simulation, and The Default Network* (Oxford University Press, 2018). My thanks to Kalina Christoff and Kieran Fox for their very helpful additions and corrections to the original version of this chapter.

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CHAPTER

28

Neural Correlates of Self-Generated Imagery and Cognition Throughout the Sleep Cycle

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Abstract

Humans have been aware for thousands of years that sleep comes in many forms, accompanied by different kinds of mental content. This chapter reviews the first-person report literature on the frequency and type of content experienced in various stages of sleep, showing that different sleep stages are dissociable at the subjective level. It then relates these subjective differences to the growing literature differentiating the various sleep stages at the neurophysiological level, including evidence from electrophysiology, neurochemistry, and functional neuroimaging. The authors suggest that there is emerging evidence for relationships between sleep stage, neurophysiological activity, and subjective experiences. Specifically, they emphasize that functional neuroimaging work suggests a parallel between activation and deactivation of default network and visual network brain areas and the varying frequency and intensity of imagery and dream mentation across sleep stages; additionally, frontoparietal control network activity across sleep stages may parallel levels of cognitive control and meta-awareness.

Key Words: sleep, dream, default network, frontoparietal control network, neurophysiology, electrophysiology, neurochemistry, neuroimaging

Introduction: The Multiplicity of Sleep

Awareness of the subjective multiplicity of sleep goes back thousands of years—at least as far as the ancient Indian philosophical texts known as the *Upanishads*, composed around the sixth century BCE (Deutsch & Dalvi, 2004; Hume, 1921; Prabhavananda, Manchester, & Isherwood, 1984; Sharma, 2012). Ancient Indian philosophers clearly recognized a distinction between dreamless sleep, dreaming, and even "lucid" dreaming—being aware that one is dreaming while dreaming (Prabhavananda Manchester, & Isherwood, 1984; Sharma, 2012). In the West, Aristotle made strikingly prescient observations for his time: he recognized both dreamless and dreaming sleep; described what we today call sleep-onset hypnagogic imagery; correctly hypothesized that dreaming represents the activity of our perceptual faculties in the absence of external inputs; and even recognized the possibility of lucid dreaming (Aristoteles & Gallop, 1996; Barbera, 2008). And at least one thousand years ago, Tibetan Buddhist practitioners had developed sophisticated cognitive practices geared toward increasing metacognitive awareness during dreamless sleep and dreaming (Gillespie, 1988; Wangyal, 1998). These traditions began a fruitful mapping of quantitative and qualitative psychological (ψ) differences throughout the sleep cycle.

Western science began to finally put these observations on a firmer footing in the mid-twentieth century, with the discovery that surface-recorded brain electrical potentials could dissociate between several sleep stages (Aserinsky & Kleitman, 1953, 1955; Dement & Kleitman, 1957a, 1957b; Monroe, Rechtschaffen, Foulkes, & Jensen, 1965). This research, the first to definitively identify neurobiological (Φ) markers related to particular cognitive states (ψ) during sleep, led to the well-known classification of sleep into rapid eye movement (REM) and non-rapid eye movement (NREM) stages (Rechtschaffen & Kales, 1968), with four major stages generally recognized by contemporary researchers (NREM 1, 2, 3–4, and REM).

These stages have not been equally recognized or researched over the past few decades. REM and NREM (the latter of which had not been carefully differentiated into substages, and was generally known as "slow wave sleep," [SWS]) were intensively investigated from the beginning of modern sleep and dream science in the 1950s. It was rapidly recognized that these stages were characterized by differences in subjective experience—most notably, by the high frequency of dream reports following awakening from REM, but the relative paucity of such reports following awakenings from NREM (reviewed by Nielsen, 1999, 2000).

A pair of more marginal and difficult to investigate stages were largely ignored until relatively recently: NREM 1 (sleep onset) and so-called "lucid dreaming," in which one is aware of the fact that one is dreaming *while* dreaming (LaBerge, Nagel, Dement, & Zarcone Jr., 1981). Detailed investigation of the electrophysiological substages and phenomenological content of NREM 1, although inaugurated in the 1960s (Foulkes, Spear, & Symonds, 1966; Foulkes & Vogel, 1965; Vogel, Foulkes, & Trosman, 1966), was not conducted in earnest until the 1990s (Hayashi, Katoh, & Hori, 1999; Hori, Hayashi, & Morikawa, 1994; Tanaka, Hayashi, & Hori, 1996, 1997). Lucid REM sleep dreaming (LREM) still remains controversial to many researchers; pioneering but tenuous polysomnographic research from the 1980s (Fenwick et al., 1984; LaBerge, 1980; LaBerge, Levitan, & Dement, 1986; LaBerge, Nagel, Dement, & Zarcone, 1981) has continued to be replicated and extended, however (Holzinger, LaBerge, & Levitan, 2006; LaBerge & Levitan, 1995; Voss, Holzmann, Tuin, & Hobson, 2009), as well as investigated with more sophisticated methods, such as combined electroencephalography and functional magnetic resonance imaging (EEG-fMRI) (Dresler et al., 2011; Dresler et al., 2012) and transcranial direct current stimulation (Stumbrys, Erlacher, & Schredl, 2013).

In this chapter, we aim to briefly review what is known about the differentiability of sleep stages according to various neurophysiological methods and markers, and to relate these neurophysiological differences to variations in subjective experience across the sleep cycle as indicated by first-person reports.

Sleep Mentation as Self-Generated Thought

We and others have argued at length elsewhere that mentation during sleep, particularly dreaming per se, can be viewed as an intensified form of waking self-generated thought or mind-wandering (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Domhoff, 2011; Domhoff & Fox, 2015; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013); see also Domhoff, Chapter 27 in this volume). The basis for this claim is twofold: both the subjective experience of dreaming and its neurophysiological correlates (as indexed by REM sleep) parallel those of waking mind-wandering and related forms of self-generated thought.

Waking self-generated thought is typically characterized by auditory and visual imagery, ubiquitous affect, a strong focus on current concerns and social interactions, and varying degrees of narrative structure (Andrews-Hanna, Smallwood, & Spreng, 2014; Fox et al., 2013; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015); see also Stawarczyk, Chapter 16 in this volume). The same statements can be made about REM sleep mentation, with the qualification that these characteristics in fact tend to be heightened or exaggerated in dreaming: The audiovisual world is fully present and immersive, emotions are often more intense and perhaps more ubiquitous, social characters are more numerous and interactions with them more elaborate, and narrative structure is extended over time and in more complex ways (Domhoff & Fox, 2015; Fox et al., 2013; Windt, 2010).

A similar parallel is observed at the neurophysiological level. Waking self-generated thought, as compared to active focus on a task or external stimulus, is associated with a relatively consistent pattern of brain activations centered on the default network and extending into medial occipital areas involved in visual imagery, as well as some executive brain regions tied to the frontoparietal control network (Fox et al., 2015). When our group meta-analyzed functional neuroimaging studies of REM sleep, during which dreaming occurs approximately 80% of the time (Hobson, Pace-Schott, & Stickgold, 2000), we found that many of the same brain areas implicated in waking self-generated thought were even more strongly recruited during REM sleep, including the medial prefrontal cortex, numerous medial temporal lobe structures, and medial occipital areas (Fox et al., 2013). Additionally, by slightly relaxing statistical thresholds, further overlap in the inferior parietal lobule, another key default network region, was revealed (Domhoff & Fox, 2015).

Overall, these results suggested to us that dreaming, and its most common neurophysiological correlate, REM sleep, show an overall intensification or amplification of both the subjective qualities and neural recruitment associated with waking self-generated cognition (cf. Fig. 3 in Fox et al., 2013, as well as Domhoff, Chapter 27 in this volume). Due to the fact that the NREM sleep stages are also characterized by variable levels of cognitive activity and dream experience, determining their general neural correlates presents an attractive target for research: A general understanding of these neural substrates would allow further examination of the hypothesis that self-generated thought has a common brain basis, independent of the particular conscious state in which it takes place. Reviewing the general neural correlates of the NREM sleep stages, and how they might fit into the spectrum of self-generated cognition across wake and dreaming, is therefore the main aim of this chapter.

Sleep Can Be Meaningfully Dissociated into Stages

The preceding overview only hints at the enormous body of work that has been conducted over the past 60 years within a paradigm whose core assumption is that sleep stages can be meaningfully dissociated and more or less independently investigated. Loomis and colleagues (Loomis, Harvey, & Hobart, 1935; Loomis, Harvey, & Hobart, 1937) were the first to provide detailed descriptions of distinct neurophysiological stages in normal human sleep, and much subsequent work has followed, corroborated, and expanded on these efforts. What are the criteria upon which these sleep stages are distinguished—and are they valid?

Nielsen (2014) rightly points out that the widespread use of standard sleep-stage scoring criteria (Rechtschaffen & Kales, 1968) has led to an artificially categorical view of sleep stages, accompanied by tacit assumptions of both mutual exclusivity and abrupt transitions. Even the narrow use of just a few electrophysiological markers cannot support such a view; and of the hundreds of potential physiological and neural markers that fluctuate throughout the sleep-wake cycle, only a select few are routinely employed to differentiate sleep stages (Nielsen, 2014). These facts should put us on guard against any facile reification of distinct sleep stages.

A key question therefore needs to be asked: Are sleep stages a fact of neurophysiology or an investigative convenience? The answer, we believe, is that they are somewhere in between. While keeping the preceding caveats firmly in mind and refraining from reifying classification schemes as actual entities, we agree with the conclusions of various comprehensive reviews of this issue (e.g., Hobson et al., 2000; Nielsen, 2000): persuasive evidence argues for the distinctiveness of sleep stages *in general*. Although the various major sleep stages share features in common, can oscillate back and forth unpredictably, and may hybridize and give rise to not easily classified transitional stages (Nielsen, 2014), meaningful (if tentative) statements can nonetheless be made about their characteristic patterns of phenomenology, electrophysiology, and neurochemistry (Hobson et al., 2000; Nielsen, 2000).

In the following sections we present these multiple lines of evidence in support of the utility and plausibility of distinctive (if not entirely mutually exclusive) sleep stages. We argue that these neurophysiological and phenomenological idiosyncrasies lead to the strong and testable hypothesis that patterns of brain activation, as measured by relatively non-invasive functional neuroimaging methods like fMRI and positron emission tomography (PET), should vary accordingly across the NREM and REM sleep stages. Moreover, the finding that REM sleep (with high chances of dreaming) shares many neural correlates with waking self-generated thought (Domhoff, 2011; Domhoff & Fox, 2015; Fox et al., 2013), coupled with the knowledge that self-generated thought frequency and vividness differ markedly across sleep stages (Hobson et al., 2000; Nielsen, 2000), leads to the even stronger hypothesis that specific brain areas involved in self-generated thought should show corresponding activation and deactivation throughout the sleep cycle in concert with subjectively experienced differences in content.

The body of this chapter provides an overview of all neuroimaging studies of sleep and dreaming in humans, in an effort to synthesize what has been learned from two decades of investigations of brain activations and deactivations throughout the sleep cycle. The aim is not to argue for strict one-to-one isomorphisms between mental states (ψ) and neuromarkers (Φ), but rather to summarize the current evidence for broad but intriguing correspondences between first- and third-person levels of description.

General Evidence for Psychological and Neurophysiological Differences Across Sleep Stages

Phenomenological Dissociation of Sleep Stages

The subjectively experienced ("phenomenological" for our purposes) differences in the experience of sleep stages have been noted for millennia (Aristoteles & Gallop, 1996)(Deutsch & Dalvi, 2004; Sharma, 2012; Thompson, 2014), but systematic research using large, representative samples has taken place mostly in the past few decades (Domhoff, 2003; Nielsen, 2000). Although many methodological difficulties (and almost as many theoretical deadlocks) have burdened this otherwise burgeoning field, some general conclusions can be cautiously drawn regarding differences in the frequency, quality, and content of mentation across sleep stages.

Nielsen (1999, 2000) has thoroughly summarized this literature, highlighting the critical distinction between *cognitive activity* in general (which can include thought-like mentation, isolated flashes of imagery, and so on) and truly immersive and hallucinatory *dreaming* proper (a particular subset of cognitive activity). Whereas cognitive activity is fairly prevalent throughout all sleep stages (at least 40% of awakenings from any given sleep stage will lead to a report of some kind of cognitive activity; Nielsen, 1999), dreaming proper is largely restricted to REM sleep and certain substages of NREM 1 sleep onset, and is comparatively rare during other NREM sleep stages (Table 28.1).

Table 28.1 Approximate Frequency of Subjective Reports of Cognitive Activity and Dreaming Across Sleep Stages

Sleep Stage	Cognitive Activity	Dreaming	Predominant EEG Rhythm
NREM 1 (sleep onset)	~40%	~35%	Alpha, theta
NREM 2	50%	~15%–25%	Theta, spindles (beta)
NREM 3–4 (SWS)	40-50%	~10%	Delta
REM	80%	80%	Theta, beta
LREM	100%	100%	Theta, beta, gamma

EEG: electroencephalography; LREM: lucid REM; NREM: non-rapid eye movement; REM: rapid eye movement; SO: sleep onset; SWS: slow-wave sleep.

Table based upon comprehensive reviews by Nielsen (1999, 2000) and Hobson et al. (2000).

Electrophysiological Dissociation of Sleep Stages

The first and best-known neurophysiological (Φ) division of sleep is based on scalp electrode recordings of pooled neuronal electrical potentials, presumed to represent primarily the summation of postsynaptic potentials throughout dendritic arbors and cell somata, and to a lesser extent, synchronous discharge (action potential firing) of populations of neurons (Buzsáki, Anastassiou, & Koch, 2012; Olejniczak, 2006).

The central findings regarding EEG correlates of sleep are summarized in Table 28.1 and Figure 28.1. Briefly, resting (eyes-closed) wakefulness is characterized by alpha rhythms (8–12 Hz); the transition to NREM 1 (sleep onset) is defined by the gradual disappearance of alpha and the appearance of theta (4–7 Hz) ripples and rolling eye movements. NREM 2 begins when high-frequency spindles (in the beta frequency; 12.5–30 Hz) and large-amplitude K-complexes appear frequently in the EEG. NREM 3–4, or SWS, is characterized instead by very slow delta band (0.5–4 Hz) activity, synchronized in large-amplitude waves. Finally, REM sleep involves a return to highly desynchronized and low-amplitude activity, predominantly in the theta and beta bands, similar to active wakefulness. Lucid REM sleep, in the few investigations so far conducted, involves an EEG pattern similar to REM sleep but with increased power in the gamma (>30 Hz) band (Voss et al., 2014; Voss et al., 2009). As these electrophysiological differences are well validated and expertly reviewed elsewhere (Antrobus, 1991; Silber et al., 2007; Williams, Karacan, & Hursch, 1974), they are not discussed further here.

Neurochemical Dissociation of Sleep Stages

The patterns of neurochemical activity throughout the sleep-wake cycle are exceedingly complex and consequently poorly understood. At least a dozen major neurotransmitters are involved in regulating NREM and REM, by virtue of either increased or decreased activity (compared to waking) during various sleep stages, but many secondary players with less clear roles are also involved (Gottesmann, 1999; Hobson et al., 2000; Kahn, Pace-Schott, & Hobson, 1997; Lena et al., 2005; Pace-Schott & Hobson, 2002; Stenberg, 2007). Moreover, changes in neurotransmitter levels are

Stage	Sub stages[1]	EEG Signature	EEG Signature Waveform
Wake	1	Alpha wave train	
	2	Alpha wave intermittent (>50%)	
NREM 1	3	Alpha wave intermittent (<50%)	
	4	EEG flattening (<20 μV)	
	5	Theta ripples	
	6	Vertex sharp wave (<200 μV)	
	7	> 1 Vertex sharp wave (<200 μV)	
	8	Incomplete spindle	
NREM 2	9	Complete Spindle	
NREM 3–4		Delta	
REM		Theta	

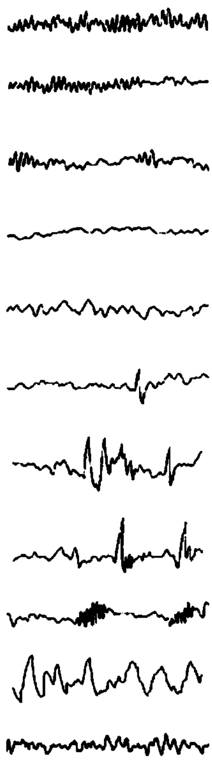

Figure 28.1. (See Color Insert) Main electrophysiological correlates of each sleep stage. NREM 1 substages are included, as is eyes-closed waking rest, for comparison. Note the easily differentiable EEG signature accompanying each sleep stage. Reproduced from Stenstrom, Fox, et al. (2012).

far from a uniform phenomenon throughout the brain: region-by-transmitter interactions have in some cases been experimentally demonstrated (e.g., for dopamine: Lena et al., 2005), and it seems likely that activity levels for other neurotransmitters will also vary, based not just on sleep stage, but also which region of the brain is being investigated. These complexities are further exacerbated by the existence of many receptor subtypes for each neurotransmitter, and the concomitant (and often unknown—at least for sleep) differences in downstream effects caused by the actions of a single neurotransmitter (Monti & Monti, 2007). A final and major difficulty is that implanting recording electrodes directly into the subcortical nuclei responsible for manufacturing and/or disseminating these neurotransmitters is the ideal method of investigation—an approach typically precluded in humans. Almost everything that is known about the neurochemistry of sleep has therefore been drawn from studies of animals with variable phylogenetic proximity to humans, such as rats, cats, rabbits, and monkeys (Gottesmann, 1999; Jones, 1991, 2005; Lena et al., 2005; Stenberg, 2007).

The enormous difficulty of studying the neurochemistry of sleep and dreaming have thus far precluded the formulation of a clear model of each neurotransmitter's relative activity throughout NREM and REM sleep stages, much less what the functional implications of such neurochemical heterogeneity might be. Nonetheless, decades of research have yielded some broad trends, which we summarize in Table 28.2.

Although a stage-by-stage model is premature given the current limits of our knowledge, broad trends can distinguish waking at least from REM and NREM sleep. Generally speaking, all major neurotransmitters show some level of tonic activity during waking; conversely, all of these neurotransmitters show a greater or lesser decrease of activity during various NREM stages of sleep (it should be noted, however, that much of this data is derived only from the later stages of "slow-wave" NREM sleep). Finally, REM sleep shows an intermediate pattern: most neurotransmitter activity is decreased

Table 28.2 Neurochemical Profiles of the Various Stages of Sleep as Compared to Waking

Neurotransmitter	State	
	REM (↑ Dreaming)	**NREM (↓ Dreaming)**
ACh	↑↑	↓
Asp	↓	↓↓
DA	↑↑	↓
GABA	?	?
Glu	↓↓	↓
HA	↓↓	↓
NE	↓↓	↓
5-HT	↓↓	↓

ACh: acetylcholine; Asp: aspartate; DA: dopamine: GABA: γ-amino butyric acid; Glu: glutamate; HA: histamine; NE: norepinephrine/noradrenaline; NREM: non-rapid-eye-movement sleep; REM: rapid-eye-movement sleep; 5-HT: serotonin; SWS: slow wave sleep.

Based on data from Gottesmann (1999); Hobson (2009); Lena et al. (2005); E. F. Pace-Schott & Hobson (2002).

relative to waking, but notably, acetylcholine and dopamine levels appear to be elevated (Table 28.2).

Functional Neuroimaging of Sleep and Dreaming: A Fourth Line of Evidence

Overview

The preceding sections have highlighted some of the key evidence supporting the hypothesis that stages of sleep are dissociable in terms of their (1) phenomenology, (2) electrophysiology, and more provisionally, (3) neurochemistry. These many heterogeneities across sleep stages lead to the strong and testable hypothesis that brain activations and deactivations, as detected with non-invasive functional neuroimaging modalities, might also show dissociable patterns throughout the sleep cycle. Functional neuroimaging therefore provides a fourth line of evidence that could either corroborate (or possibly contradict) the ample body of research suggesting phenomenological and neurophysiological dissociability. As noted earlier, the phenomenological variations in self-generated thought across sleep stages further suggest that differential activation patterns, if they exist, should exhibit some relationship with the numerous regions implicated in self-generated thought in waking (Fox et al., 2015) and REM sleep (Fox et al., 2013).

Despite a profusion of neuroimaging studies elucidating the neural basis of sleep and dreaming (Desseilles, Dang-Vu, Sterpenich, & Schwartz, 2011; Maquet, 2010; Pace-Schott, 2007), no comprehensive overview has been conducted in recent years. While distinctive patterns of observed brain activity appear to largely parallel the differential subjective content reported from laboratory awakenings across the various sleep stages, there has yet to be any systematic attempt to specifically relate these particular patterns of brain activity to differing first-person experiences. Recently, we conducted such a meta-analysis and review of subjective content for REM sleep and dreaming (Fox et al., 2013); here, we expand upon those results to include functional neuroimaging and subjective report data from all sleep stages, in a preliminary attempt to relate subjective experience, electrophysiology, neurochemistry, and brain blood-flow-related activity across each sleep stage.

Literature Review

In order to ensure that our review was comprehensive, we scoured Google Scholar, PubMed, and PsycInfo online databases for any study whose title or abstract included keywords such as "PET," "fMRI," and "neuroimaging," in combination with keywords such as "sleep," "dreaming," "NREM," or "REM." The reference list of each study found was also consulted, as was the bibliography of a major review of functional neuroimaging of sleep (Hobson et al., 2000). Our search yielded 58 functional neuroimaging (PET or fMRI) studies of REM and NREM sleep. We limit our discussion here to studies that employed a baseline of resting wakefulness (either pre- or post-sleep)—in order to minimize the confounding effects of various tasks and baseline conditions—and to studies that involved neurologically and psychiatrically healthy participants. We also avoid discussing studies that introduced extraneous factors (e.g., auditory stimulation during sleep) or pharmacological agents. A total of 16 studies were ultimately consulted (Table 28.3), many of which examined more than a single sleep stage.

Neural Correlates of NREM 1 Sleep

As discussed earlier, NREM 1 sleep is a highly heterogeneous sleep stage that can be divided into various substages with varying degrees of visual imagery and cognitive activity. These fine-scale subdivisions on short timescales (or the order of seconds or tens of seconds) mean that it is not possible for present functional neuroimaging technologies, with their generally poor temporal resolution, to adequately resolve NREM 1 substages.

Nonetheless, a handful of studies (Andrade et al., 2011; Kaufmann et al., 2006; Kjaer, Law, Wiltschiøtz, Paulson, & Madsen, 2002; Picchioni et al., 2008) have investigated the neural correlates of NREM 1 (broadly defined) with some intriguing preliminary results. For instance, the first PET study of NREM 1 found that, compared to a baseline of resting wakefulness, NREM 1 sleep showed greater activation in numerous visual areas, including the fusiform gyrus (BA 19), and the middle occipital gyrus bilaterally (BA 18/19) (Kjaer et al., 2002). Another study also found evidence for medial occipital activation in the cuneus (Kaufmann et al., 2006). Functional connectivity analyses, using the hippocampus as a seed region, have also found increased connectivity with various visual regions, including the fusiform gyrus and the middle and superior occipital gyri (Andrade et al., 2011). Most studies of NREM 1 to date therefore show evidence for increased activation of, or coupling with, widespread visual regions (although for an exception to this trend, see the results of Picchioni et al., 2008).

Table 28.3 Functional Neuroimaging Studies of Sleep Reviewed

Study	Modality	*N*	Stage(s) Investigated	Sleep Deprivation?
Maquet et al. (1996)	PET	11	REM	Y
Braun et al. (1997)	PET	37	SWS, REM	Y
Maquet et al. (1997)	PET	11	SWS	Y
Nofzinger et al. (1997)	PET	6	REM	N
Braun et al. (1998)	PET	10	REM	Y
Kajimura et al. (1999)	PET	18	SWS	Y
Finelli et al. (2000)	PET	8	REM	Y
Maquet et al. (2000)	PET	5	REM	N
Peigneux et al. (2001)	PET	12	REM	N
Balkin et al. (2002)	PET	27	NREM2	Y
Kjaer et al. (2002)	PET	8	NREM1	N
Maquet et al. (2005)	PET	22	SWS, REM	N
Kaufmann et al. (2006)	fMRI	9	NREM1, NREM2, SWS	Y
Picchioni et al. (2008)	fMRI	4	NREM1	N
Andrade et al. (2011)	fMRI	25	NREM1, NREM2, SWS	N
Koike et al. (2011)	fMRI	12	NREM2, SWS, REM	N

fMRI: functional magnetic resonance imaging; N: no; NREM: non-rapid eye movement sleep; PET: positron emission tomography; REM: rapid eye movement sleep; SWS: slow wave sleep; Y: yes.

Concurrent with this tentative evidence for visual cortical activation in NREM 1, most studies have found evidence for deactivation of prefrontal executive regions, including in the superior frontal gyrus (BA 6) (Kjaer et al., 2002; Picchioni et al., 2008) and middle frontal gyrus (BAs 9 and 10) (Kaufmann et al., 2006; Picchioni et al., 2008).

Neural Correlates of NREM 2 Sleep

Similar to NREM 1, only a small handful of studies have investigated "pure" NREM 2 (Andrade et al., 2011; Balkin et al., 2002; Kaufmann et al., 2006; Koike, Kan, Misaki, & Miyauchi, 2011). Unlike NREM 1, however, a general pattern of activations is less easily discernible. For instance, one study found widespread activations during NREM 2, including in medial (BA 9) and lateral (BAs 10 and 46) prefrontal areas, anterior cingulate and insula, and a variety of subcortical and brainstem regions (Balkin et al., 2002). In stark contrast, another study found almost exclusively deactivations throughout the brain associated with NREM 2, including in the prefrontal cortex, inferior parietal lobule, superior temporal gyrus, insula, and various thalamic nuclei; indeed, only a single significant activation in the inferior frontal gyrus was observed (Kaufmann et al., 2006). Adding to this confusing picture, a study examining hippocampal functional connectivity throughout the brain found that there were no greater areas of connectivity for waking versus NREM 2, but, conversely, that a wide variety of regions showed increased coupling with hippocampus during NREM 2 versus waking, including many regions implicated in waking self-generated thought (Fox et al., 2015), such as the posterior cingulate cortex, lingual gyrus, inferior parietal lobule, temporopolar cortex, and insula (Andrade et al., 2011).

The neural correlates of NREM 2 sleep therefore remain elusive and the limited data available difficult to synthesize. Part of the problem may be the intermediate (and by implication, highly variable) levels of cognitive activity and dreaming present in NREM 2, which might be related to the similar variability of results observed in neuroimaging studies; that is, two given segments of sleep both scored as NREM 2 based on relatively superficial similarities among EEG markers, and then pooled in neuroimaging analyses, might in fact be characterized by very different psychological content depending on the subjects recruited as well as the time of night (Cavallero, Cicogna, Natale, & Occhionero, 1992; Cicogna, Natale, Occhionero, & Bosinelli, 1998) and therefore might result in correspondingly distinctive patterns of brain recruitment (as observed in the studies to date). Further neuroimaging research into the neural basis of NREM 2 accompanied by collection of mentation reports following laboratory awakenings would greatly help to clarify this situation.

Neural Correlates of NREM 3–4 Sleep (SWS)

In contrast to NREM 1 and NREM 2, NREM 3–4 (SWS) has been characterized mostly by widespread *deactivations* (relative to waking) throughout the brain (Andrade et al., 2011; Braun et al., 1997; Maquet et al., 1997; Maquet et al., 2005). For instance, Braun and colleagues (1997) found deactivations in SWS in prefrontal executive regions, such as the dorsolateral (BA 46) and ventrolateral (BA 11) prefrontal cortex, as well as in a variety of regions implicated in waking self-generated thought (Fox et al., 2015), including the medial prefrontal cortex (BA 10), temporopolar cortex (BA 38), and anterior insula. Widespread deactivations were also observed in subcortical structures, including the basal ganglia, thalamus, and cerebellum (Braun et al., 1997). Similarly, Maquet and colleagues (1997) found SWS to be negatively correlated with regional cerebral blood flow in prefrontal areas such as the orbitofrontal cortex (BA 11/25) and anterior cingulate cortex (BA 24), as well as some visual areas like the precuneus (BA 19/7) and a variety of subcortical structures. Maquet and colleagues (2005) found further evidence for deactivations predominantly in executive, default, and visual areas. Finally, a connectivity study using the hippocampus as the seed region found widespread reductions in functional connectivity during SWS as compared to waking, again primarily in prefrontal regions and default network areas such as the inferior parietal lobule, medial prefrontal cortex, and posterior cingulate cortex (Andrade et al., 2011).

The predominant pattern in SWS, based on the limited evidence to date, is deactivation (and/or disintegration of functional connectivity) throughout the brain—especially in prefrontal executive areas, default network regions, and subcortical structures.

Neural Correlates of REM Sleep

REM sleep has been associated with the recruitment of widespread brain regions (Braun et al., 1997; Braun et al., 1998; Finelli et al., 2000; Maquet et al., 1996; Maquet et al., 2005; Peigneux et al., 2001). A sufficient number of studies have been conducted to allow for a preliminary meta-analysis of brain activations during REM sleep, which we recently executed in an effort to quantitatively assess the consistency of these activations (Fox et al., 2013). Combining our meta-analytic results with a qualitative assessment of individual studies, REM sleep appears to be associated with activation of the medial temporal lobe bilaterally; multiple regions within the default mode network, including clusters in medial prefrontal cortex (BA 24 and 9/32), dorsomedial prefrontal cortex (BA 9), and orbitofrontal cortex (BA 25); and numerous visual network areas, centered on the lingual gyrus (BA 18/19) (Domhoff & Fox, 2015; Fox et al., 2013). Deactivations are most salient in prefrontal executive regions, including the dorsolateral (Braun et al., 1997; Braun et al., 1998; Maquet et al., 1996) and ventrolateral prefrontal cortex (Braun et al., 1997; Braun et al., 1998; Maquet et al., 2005).

Neural Correlates of Lucid REM (LREM) Sleep

Only a single study to date has compared neural correlates of lucid REM sleep to regular REM sleep (Dresler et al., 2012), and this study relied on data from a single subject able to attain dream lucidity repeatedly in the scanner. Nonetheless, results of this pioneering (if tentative) study are intriguing. LREM, compared to standard, non-lucid REM sleep, was associated most notably with increased activation of default, visual, and frontoparietal control network regions (Dresler et al., 2012). These heightened activations are commensurate with the subjective qualities of LREM sleep, discussed further in the following sections.

Discussion

Default and Visual Network Activation and Their Relationship to Self-Generated Thought and Imagery Throughout the Sleep Cycle

Dreaming can be thought of as an unconstrained, hyper-associative, and highly immersive form of self-generated thought that is largely detached from external sensory inputs (Christoff et al., 2016; Fox et al., 2013; Windt, 2010). We therefore might expect that areas involved in memory recall and recombination, self-referential thinking, and audiovisual imagery would show heightened recruitment compared to a restful waking baseline in all sleep stages that have some appreciable amount of thought or dream content (especially REM sleep, but also potentially stages NREM 1 and NREM 2).

Generally speaking, the NREM sleep stages are associated with considerably lower rates of dreaming than REM sleep (see Table 28.1)—and the mentation that does occur tends to be less visuospatial and immersive, and more of a conceptually focused inner monologue (Hobson et al., 2000; Nielsen, 2000; Nir & Tononi, 2010). During NREM 1, however, highly vivid visual imagery and occasionally full-blown (if short-lived) dreaming can occur (Hayashi et al., 1999; Hori et al., 1994; Nielsen, 1992; Stenstrom, Fox, Solomonova, & Nielsen, 2012). Consistent with these phenomenological reports, NREM 1 is primarily associated with the activation of secondary and tertiary visual regions, including the fusiform gyri bilaterally, the middle occipital gyrus (BA 19), and the cuneus (BA 18). Absent, however, are any notable activations in default network regions; this absence of activation, however, can be reconciled with the typical brevity and diminished sense of self (compared to other sleep stage mentation reports) that characterize sleep onset imagery (Cicogna et al., 1998).

Late in the night, when REM sleep predominates in the sleep cycle, NREM 2 can give rise to a high frequency of immersive dream experiences indistinguishable from REM sleep reports (Cicogna et al., 1998). Cognitive activity of some kind is relatively frequent during early-night NREM 2 (~50% of awakenings), but dreaming proper is more rare, reported from roughly 15%–25% of NREM 2 awakenings (Goodenough, Lewis, Shapiro, Jaret, & Sleser, 1965; Nielsen, 1999, 2000). As discussed earlier, however, the neuroimaging results concerning NREM 2 are somewhat contradictory and do not lend themselves to any clear synthesis as of yet. Future work placing greater emphasis on first-person reports and substage specificity may clarify this situation.

The frequency of dream experience is lowest by far in NREM 3–4 (SWS) (Hobson et al., 2000; Nielsen, 2000). Indeed, considerable numbers of participants can *never* recall cognitive activity or dreaming of any kind from SWS awakenings, despite multiple nights spent in the laboratory (Cavallero et al., 1992). Consistent with this very modest level of self-generated thought, SWS generally shows deactivation throughout major default network hubs, including medial prefrontal cortex and posterior cingulate cortex. Deactivations are also frequently reported in multiple subcortical brain areas, including the hypothalamus, thalamus, and pons. These subcortical deactivations are consistent with the overall decreased arousal and blockade of sensory inputs in SWS (Hobson et al., 2000).

REM, the sleep stage with by far the highest rates of dreaming (80%–90% of the time; Hobson et al., 2000), shows heightened activation in numerous regions implicated in self-generated thought and imagery (Fox et al., 2015), especially widespread activation of the medial prefrontal cortex, the medial temporal lobe, and medial occipital areas (Domhoff & Fox, 2015; Fox et al., 2013). All of these activations are consistent with the endogenous generation of a self-referential narrative situated in a largely visual imaginal world.

These overall trends in activation patterns across the sleep stages are paralleled by changes in functional connectivity: connectivity among default mode network hubs, for instance, decreases monotonically throughout the NREM sleep stages (Sämann et al., 2011; Wilson et al., 2015). Consistent with these results, PET investigations have found a monotonic decrease in cerebral energy metabolism across NREM stages 1–3 (Maquet, 1995), whereas energy metabolism in REM sleep is equal to (Braun et al., 1997; Madsen et al., 1991; Maquet et al., 1990) or higher than (Buchsbaum et al., 1989; Heiss, Pawlik, Herholz, Wagner, & Wienhard, 1985) waking rest.

Finally, lucid REM sleep (LREM), in stark contrast to NREM sleep, shows activations *greater* even than non-lucid REM sleep in many regions. The most striking difference is the reappearance of activity in the frontoparietal control network, discussed in more detail in the following section. Also apparent is heightened activity in areas already hyperactive in REM sleep, including medial prefrontal cortex and a large swath of medial occipito-parietal cortex—potentially explained by anecdotal reports that lucid REM sleep experiences are much more vivid and detailed than regular REM dreams (Dresler et al., 2012; Green, 1968; Sergio, 1988; Yuschak, 2006).

Prefrontal Executive Deactivation, Cognitive Control, and Meta-Awareness Throughout the Sleep Cycle

As discussed elsewhere (Fox et al., 2015), waking self-generated thought involves a co-activation of default network areas alongside executive frontoparietal control network regions, most notably the dorsal anterior cingulate cortex, rostrolateral prefrontal cortex, and anterior inferior parietal lobule. These results are not particularly difficult to rationalize when it is recalled that cognitive control and meta-awareness, two of the principal functions tied to the latter network, are in fact quite prevalent in waking self-generated thought (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Christoff et al., 2016; Klinger, 1978, 2008; Klinger & Cox, 1987; Klinger & Kroll-Mensing, 1995; Kroll-Mensing, 1992; Seli, Risko, Smilek, & Schacter, 2016)—even if lower than in typical externally directed cognition and tasks.

Conversely, executive and metacognitive functioning is largely absent or deficient in NREM and REM sleep cognition. Although dream reports show strong thematic continuity with the emotional and personal concerns of waking life (Cartwright, Lloyd, Knight, & Trenholme, 1984; Fox et al., 2013; Kuiken, Dunn, & LoVerso, 2008), actual goal-related thinking or top-down control and planning are rare. Further, activities involving sustained top-down control of attention, such as reading, writing, or using a phone or computer, occur only very rarely in dreams (Hartmann, 1996; Schredl, 2000). Although logical and paralogical thinking indeed take place in sleep and dreaming (Hall & Van de Castle, 1966; Kahn & Hobson, 2005), overall such thinking is only peripherally goal-related at best, and is deficient in many other respects (Kahn & Hobson, 2005).

Metacognitive functioning is similarly compromised. Natural rates of meta-awareness of one's true state during sleep (i.e., lucid dreaming or lucid sleep) are estimated to be only about 1%, even in experienced lucid dreamers (Schredl & Erlacher, 2004, 2011; Snyder & Gackenbach, 1988), and might occur only a handful of times throughout the entire lifespan in normal individuals (Barrett, 1991; Zadra, Donderi, & Pihl, 1992). Moreover, employing a variety of interventions in an effort to increase meta-awareness during sleep (including psychological training, pharmacological agents, and external electrical stimulation), even among highly motivated participants, tends to result in only very modest and poorly validated gains (Stumbrys, Erlacher, Schädlich, & Schredl, 2012). Meta-awareness of other features of experience, such as bizarre or impossible situations and discontinuities of time and place (Dorus, Dorus, & Rechtschaffen, 1971), is likewise compromised (Kahn & Hobson, 2005).

Consistent with these many executive and metacognitive deficiencies throughout the sleep cycle, all sleep stages show at least some evidence for deactivation of prefrontal executive regions critical to cognitive control and meta-awareness. In stark contrast to these results throughout the rest of the sleep cycle, the unusual state of lucid REM (LREM) sleep instead shows *activation* of frontoparietal control network regions, including rostrolateral and dorsolateral prefrontal cortices, as well as in the anterior inferior parietal lobule bilaterally—consistent with restored cognitive control and meta-awareness (Dresler et al., 2012; Fox & Christoff, 2014).

Limitations

Four major limitations of our discussion should be emphasized. The first is that the subjective reports of nighttime dreaming and cognition have been collected largely independently of the functional neuroimaging data that speak to brain recruitment during the various sleep stages; that is, although differences in subjective experience across sleep stages are in general reliable and well-replicated (Hobson et al., 2000; Nielsen, 1999, 2000), the studies that have used functional neuroimaging to examine these same sleep stages have rarely actually collected dream or mentation reports from their participants (for instance, of the eight studies we reviewed of REM sleep, only one confirmed dreaming had indeed been taking place in the REM sleep periods examined in the PET scanner: Maquet et al., 1996). In the absence of such reports collected directly following functional neuroimaging of sleep and dreaming, any putative relationship between sleep stage neurophysiology and subjective content remains, at best, inferential and probabilistic. The obvious solution to this problem is for future functional neuroimaging studies of sleep to actively awaken and interrogate participants as to their subjective experiences across various sleep stages. The putative links between subjective experiences and brain activation discussed here are therefore almost entirely inferential and are based on statistical averages of content reports generated in independent studies that did not use PET or MRI scans to assess brain activation. The apparent linkages we speculate on here are therefore, at best, crude approximations of average experiential intensity and average brain activation across many different subjects. Although intriguing, these correspondences need to be further explored and corroborated with more detailed and targeted research before they can be considered reliable, much less definitive.

A second major concern is the small number of studies that have so far investigated any given sleep stage. Although we took pains to search the literature thoroughly and review every well-controlled and rigorously executed study, nonetheless the field of neuroimaging of sleep remains small. Accumulating research in this domain, however, will gradually mitigate this concern, as more powerful and representative syntheses become possible.

Third is the fact that a full half of all studies we consulted sleep-deprived their participants the night before brain scanning in order to facilitate the maximum amount of sleep in the scanner. Aside from non-specific effects, such as stress, sleep deprivation is known to affect the architecture and EEG correlates of the sleep cycle (Borbély, Baumann, Brandeis, Strauch, & Lehmann, 1981), and might therefore influence neuroimaging measures of brain recruitment as well. In principle, this concern could be addressed by comparing brain activation and deactivation for given sleep stages across studies that did and did not employ sleep deprivation, but a much larger body of research is required before any such comparison is possible.

A fourth and final concern that should be reiterated is that sleep stages are probably as much a convenient abstraction as they are a concrete neurophysiological fact; that is, while not strictly categorical, general differentiation between distinct sleep stages is justifiable and represents a valid and useful explanatory tool. We refer the reader back to the introductory material for a more detailed consideration of this important issue.

Conclusions

We have here provided some new evidence in favor of the view that sleep stages can be differentiated at the neurophysiological level, based on an overview of functional neuroimaging studies across every stage of the sleep cycle. We have presented preliminary evidence that subjective experiences and neurophysiological markers covary across the sleep cycle, with the most intriguing finding being that default network and visual network activation might track the occurrence and immersiveness of self-generated thought, whereas frontoparietal control network deactivation might track the general loss of cognitive control over, and meta-awareness of, one's psychological state. Overall, these results provide an intriguing example of complex, but nonetheless coherent, patterns of brain-mind isomorphism (Cacioppo & Tassinary, 1990). We hope that this tentative synthesis will serve as a useful stepping-stone on the path to a much deeper understanding of sleep and dream neurophysiology.

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CHAPTER

29

Spontaneous Thought, Insight, and Control in Lucid Dreams

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Abstract

Dreams are sometimes described as an intensified form of spontaneous waking thought. Lucid dreams may seem to be a counterexample, because metacognitive insight into the fact that one is now dreaming is often associated with the ability to deliberately control the ongoing dream. This chapter uses conceptual considerations and empirical research findings to argue that lucid dreaming is in fact a promising and rich target for the future investigation of spontaneous thought. In particular, the investigation of dream lucidity can shed light on the relationship between metacognitive insight and control, on the one hand, and the spontaneous, largely imagistic cognitive processes that underlie the formation of dream imagery, on the other hand. In some cases, even lucid insight itself can be described as the outcome of spontaneous processes, rather than as resulting from conscious and deliberate reasoning. This raises new questions about the relationship between metacognitive awareness and spontaneous thought.

Key Words: lucid dreams, insight, metacognition, control, consciousness, self-consciousness, spontaneous thought, REM sleep

There is one very remarkable thing in dreams, for which I believe no one can give a reason. It is the formation of visions by a spontaneous organization carried out in a moment—a formation more elegant than any which we can attain by much thought while awake. To the sleeper there often occur visions of great buildings which he has never seen, while it would be difficult for me, while awake, to form an idea of even the smallest house different from those I have seen, without a great amount of thought. [. . .] Even such unnatural things as flying men and innumerable other monstrosities can be pictured more skillfully than a waking person can do, except with much thought. They are sought by the waker; they offer themselves to the sleeper. There must therefore necessarily be some architectural and harmonious principle, I know not what, in our mind, which, when freed from separating ideas by judgment, turns to compounding them.

—Leibniz (1956, Vol. I, pp. 177–178)

Dreams are often described as a paradigmatic example of spontaneous thought, or even as an intensified form of waking mind-wandering (Domhoff, 2011; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; see also Domhoff, Chapter 27 in this volume). Here, we approach this topic from the perspective of lucid dreaming, which we argue is a key target for the investigation of spontaneous cognitive processes in sleep.

This strategy might seem surprising. Lucid dreams are characterized by metacognitive insight into the fact that one is now dreaming, which is typically associated with the ability to control the ongoing dream, as well as with dissociative phenomena, such as seeing oneself from the outside

(Voss & Hobson, 2015; Voss, Schermelleh-Engel, Windt, Frenzel, & Hobson, 2013). For this reason, dream lucidity might seem to be an obvious counterexample to the claim that dreaming is a form of spontaneous thought. One possibility could be that dream control, coupled with metacognitive insight, suppresses the spontaneous processes that underlie non-lucid dreaming. If this were the case, lucid control dreams would be a subgroup of dreams in which the element of spontaneity has been lost or at least greatly reduced. A slightly stronger view would be that the example of lucid dreaming casts doubt on the claim that dreaming in general can be described as a form of spontaneous thought. In both cases, the investigation of lucid dreaming could not meaningfully contribute to a discussion of spontaneous thought.

In this chapter, we argue that the opposite is true. Contrary to first appearances, lucid dreams are in fact a rich target phenomenon for investigating, both conceptually and experimentally, spontaneous cognitive processes in sleep, as well as their interplay with volitional control, metacognitive insight, and dissociative phenomena. Lucid dreams show that metacognitive insight and control are not necessarily opposed to spontaneity, but that the two can coexist alongside one another. Dissociation plays a particularly important role in this context, as it is itself the outcome of spontaneous cognitive processing, but nonetheless may facilitate the occurrence of insight and control.

We begin by offering some general considerations on the description of dreaming as a form of spontaneous thought. In the second section of the chapter, we give an overview of the main empirical findings on lucid dreaming, with special emphasis on the role of cognition and volition as key determinants of lucidity, as well as on the underlying neurophysiological processes. We suggest that the spontaneous aspects of dream lucidity are most probably related to the involvement of not only cortical but also subcortical brain structures. The third section raises a number of more general theoretical questions about the relationship between lucid insight, dream control, and the subjectively realistic and often unexpected elements of lucid dreams. We conclude that lucid dreams are spontaneously occurring mental states in which lower-level imagistic cognitive processing is largely unpredictable and beyond the reach of volitional control. This explains both the continuity between lucid and non-lucid dreams and why lucid insight is often accompanied by illogical thought. The fourth and last section raises questions and challenges for future research, with a specific focus on the comparison between lucid dreams and spontaneous thought in wakefulness.

Is Dreaming a Kind of Spontaneous Thought?

Spontaneous thought is sometimes used as a blanket term for a range of mental activities involving mind-wandering, daydreaming, and creativity. All of these are commonly contrasted with goal-directed thought (Christoff, Gordon, Smith, Vartanian, & Mandel, 2011; Fox & Christoff, 2014; Christoff et al., 2016) and are described as being largely independent of sensory stimuli and ongoing tasks (Smallwood & Schooler, 2015). While the early literature focused on the detrimental effects of mind-wandering on cognitive performance and mood (Killingsworth & Gilbert, 2010; Schooler et al., 2011), the newer literature emphasizes possible benefits, such as creativity, future planning, and memory consolidation (Fox & Christoff, 2014; McMillan, Kaufman, & Singer, 2013; Smallwood & Andrews-Hanna, 2013; Smallwood & Schooler, 2015). Philosophers have been slow to consider empirical research on mind-wandering, but a discussion on the nature of mind-wandering and its relationship to attention, goal-directed thought, and cognitive agency is now slowly taking shape (Carruthers, 2015; Dorsch, 2015; Irving, 2016; Metzinger 2013, 2015). For now, we wish to remain noncommittal about the details of these different emerging positions; rather than starting out with a closely circumscribed notion of spontaneous thought and mind-wandering, we begin with a fairly loose working definition, with the hope that our discussion of lucid dreaming can help fill in the details.

With this restriction in mind, we will (unless explicitly indicated otherwise) use the terms *spontaneous thought* and *mind-wandering* interchangeably to denote conscious cognitive processes (including memories and emotions) that are largely determined by intrinsic brain activation and only weakly constrained by ongoing tasks and the demands of the external environment (Smallwood & Schooler, 2015; Christoff et al., 2016).[1] Importantly, episodes of spontaneous thought involve phenomenal consciousness. There can be *something it is like* to experience a vivid daydream even if one does not realize that one's thoughts have wandered away from the task at hand; the episode still has subjective, qualitative character. At least retrospectively, after the daydream has terminated, one will also often be able to report its occurrence and describe its subjective or qualitative character—even though the exact contents and the subtle phenomenological details can be strangely elusive (for the difference between self- and probe-caught episodes of mind-wandering, see Schooler et al., 2011; for a general discussion of the difficulty of reporting spontaneous fantasies, see Schwitzgebel, 2011; Windt, 2015a, Chapter 4).

All of this is, it would seem, directly applicable to dreaming. Even though (with the exception of lucid dreaming) we do not realize that we are dreaming while we are dreaming, dreams are *reportable* experiences. This is compatible with saying that most dreams are in fact forgotten; the main point is that under appropriate conditions—such as following timed awakenings in the sleep laboratory—dreams and other experiences occurring in sleep can be remembered and reported (Windt, 2013, 2015a, b).

Dreams are also commonly taken to be a paradigmatic example of subjective or phenomenal experience unfolding almost completely independently of sensory input and motor output (Metzinger, 2004; Revonsuo, 2006). Mind-wandering involves sensory attenuation, a dampening, as it were, of environmental and peripheral bodily stimuli (Kam & Handy, 2013). During dreaming, this disconnection is even stronger. Rapid eye movement (REM) sleep paralysis mostly prevents the outward enactment of movements experienced within the dream, and responsiveness to environmental stimuli is greatly reduced or even absent (Hobson et al., 2000). This is not quite to say that dreaming is entirely independent of contemporaneous sensory stimuli—dream experience continues to be modulated by bodily sensations (Nielsen, 1993), and sounds or smells in the sleeper's environment can also leave their mark on dreams (Rahimi et al., 2015; Schredl et al., 2009; for discussion and further references, see Windt 2015a, Chapter 8; Windt, 2017). But where the daydreaming mind is briefly distracted, as it were, by its own musings, sleep is the naturally and regularly occurring state in which we come closest to almost completely losing our perceptual and cognitive grip on our surroundings.

While the onset and timing of sleep can, to an extent, be deliberately controlled, dreaming itself is typically held to be involuntary and perhaps even incontrollable. The opposition between dreaming and volitional control has a long history, and philosophers have traditionally found the unruly nature of dreaming to be quite disturbing. Augustine (1991) famously wondered whether he was morally responsible for sins committed in his dreams, such as adultery, but finally decided that he was not. The chasm between sleep and wakefulness was just too great, he thought, for dreams to be a cause of moral concern. The involuntariness of dreaming is also connected to the epistemological problem of dream skepticism: it is precisely because dreams confront us with a seemingly realistic, mind-independent world that they are thought to be deceptive (Descartes, 2013). Others, perhaps most notably Leibniz (1956), were fascinated by the spontaneous character of dreams, but also by their vivacity and creativity, which were thought to exceed the imaginative abilities of the waking mind. But the predominant view is that dreaming is a state of cognitive deficiency resulting from a loss of critical thought and volition, comparable to pathological wake states such as hallucinations and delusions (Hobson, 1999; see Windt & Noreika, 2011, for discussion and further references).

The involuntary and allegedly deceptive character of dreaming is closely related to the vividness of dream imagery and the intensity of dream emotions. But this also points to a difference between dreaming and waking mind-wandering. Dreams are immersive in a way that even vivid daydreams are not (Fox et al., 2013); while the ongoing flow of sensory perception prevents us from getting completely lost in a daydream, we feel more robustly present in our dreams in part because there are less competing sensory stimuli, as well as fewer critical thoughts that could counteract this feeling of presence (Windt, 2015a, Chapter 12).

While scientific dream research long suffered from the lack of a commonly agreed-upon definition, there is now increasing agreement that dreaming is a kind of conscious mental simulation (Revonsuo Tuominen, & Valli, 2015a, 2015b). According to these simulation views, dreaming involves the experience of being a self in a world. While the details differ, this convergence is an important step toward a unified theory of dreaming.[2] At the same time, the description of dreaming as involving world simulation is, however, antithetical to the claim that dreaming is a kind of spontaneous *thought*, at least where this is understood as a phenomenological claim. Because of their immersive character as well as their apparent uncontrollability, dreams *feel* distinctly unlike waking thoughts. Importantly, to ask *whether dreaming is a spontaneous thought process* is different from asking whether *spontaneous thoughts occur in dreams.* The first question, unlike the second one, is not about whether in a dream, the dream self, or the character with which I identify in the dream, experiences spontaneous thoughts, or indeed any thoughts at all; it asks whether the process of dreaming as such can be meaningfully described as a kind of thinking.[3] Dreaming involves spontaneous mental activity during sleep, but on the phenomenological level of description, it is not a kind of *thinking*. Only the thoughts experienced by the dream self, within the dream, are thoughts in this phenomenological sense.

This move minimizes conceptual ambiguity. As noted earlier, there is a long tradition, both in philosophy and in scientific dream research, of describing dreaming as a state of cognitive deficiency in which conscious thought and self-reflection are either completely absent or, if present, are irrational and confused, resembling wake-state delusions and confabulation (Hobson, 1999; Hobson, Pace-Schott, & Stickgold, 2000; Metzinger, 2004). Roughly, if dreaming is itself conceived of as a kind of thinking, this leaves little room for conscious thought processes occurring *within* the dream (McGinn, 2009; empirical support for this view comes from Fosse, Stickgold, & Hobson, 2001, 2004). This view, however, is likely too restrictive: Even non-lucid dreams often involve the phenomenology of thinking (Kahan, 2001; Kahn & Hobson, 2005; see Windt, 2015a, Chapter 9, for discussion and further references). By reserving the term *conscious thought* for thoughts experienced *within* a dream and by the dream self, we want to propose that investigating the relationship between conscious thought and the lower-level, largely imagistic cognitive processes that make up the experienced dream world and the dream self is a worthwhile project.[4]

What about spontaneity? As noted earlier, spontaneous thought is standardly contrasted with attention and goal-directedness (Christoff et al., 2011), though this does not exclude the possibility that mind-wandering can still be guided by unconscious goals. According to Smallwood and Schooler (2015), the crucial factor is that in mind-wandering, thought contents are self-generated, meaning that they are determined intrinsically, rather than directly cued by sensory input. We have to tread carefully here though, because the notion of self-generated, conscious mental activity is, again, ambiguous. On the strongest reading, we might want to say that for a mental state to be self-generated, it must be experienced as being generated by oneself and as actually being under one's control. Metzinger (2013, 2015) argues that cognitive agency of this sort is exactly what is lost in episodes of mind-wandering. As he puts it, "during full-blown episodes of mind-wandering, we are not epistemic agents, neither as controllers of attentional focus nor as deliberate thinkers of thoughts, and we have forgotten about our agentive abilities" (p. 282, 2015). He casts mind-wandering as a subpersonal process, akin to breathing: It is not something we, as persons, do; it is something that happens to us, that we cannot control, and of whose occurrence we are typically unaware. It is only after gaining metacognitive insight into the fact that our minds have wandered that we once again acquire the ability for self-determined thought and cognitive agency. But because this also terminates the episode itself, mind-wandering cannot be described as a *self*-generated or *self*-determined process.

What we need to describe spontaneous thoughts as *self*-generated, then, is a weaker reading of spontaneity that encompasses internally generated behaviors and not just personal-level mental actions. Hanna and Thompson (2003) appear to take this kind of view, writing that "subjective experience is partially constituted by its being at once underdetermined or uncontrolled by external influences (inner plasticity), and also self-determining or self-controlling (inner purposiveness)" (p. 137). Using largely automatic shifts in multi-stable images (such as switching back and forth between two interpretations of Wittgenstein's duck-rabbit) as an example, they explain that the spontaneity of conscious experience is "constituted by the fourfold fact that the precise, qualitative character of conscious states (1) is not determined by anything external to the conscious subject; (2) is self-generated; (3) is not self-generated by a prior conscious intention; and yet (4) can under some conditions be controlled by a conscious intention" (p. 147). What they mean by self-generated but nonetheless spontaneous mental states is consequently more inclusive than Metzinger's sense; it encompasses lower-level shifts in brain dynamics as well as attempts to deliberately bring these about. Spontaneous thought is not necessarily sub-personal, but can even be guided by intentions, as long as these intentions themselves are formed, as it were, on the fly.

Here, we opt for this weaker type of account, in which spontaneity refers to conscious mental events that subjectively are experienced as internally caused or self-determined, rather than being tightly constrained either by ongoing tasks and environmental stimuli or by pre-existing conscious intentions. This notion of spontaneity will be most useful for cases that nonetheless have the potential for coming under our deliberate control; spontaneous mental events are not in fact guided by previous intentions, but they could be. Moreover, because spontaneity of this type is a phenomenological notion, there is no requirement that the experience of spontaneity be veridical: even though I experience my thoughts, for instance, as unfolding independently of external conditions and previous intentions, this impression could be false; I might simply fail to be aware of what is actually causing the shifts in my ongoing experience. Subjective impressions of spontaneity can be deceptive.

This distinction between the first-person phenomenological reading of spontaneity and the third-person epistemological one is important for methodological reasons: For investigating the contents of mind-wandering episodes, but also dreams, one has to rely on self-report, and so the participant's own judgment will be crucial for identifying spontaneous mental processes and distinguishing them from those that were experienced as deliberately controlled or directly prompted by external sensory stimuli. An interesting next step, then, would be to investigate the extent to which subjectively spontaneous daydreams are in fact closely modulated by external sensory cues.

How does this phenomenological conception of spontaneity apply to the case of sleep and dreaming? On the one hand, the occurrence of sleep and dreaming is certainly spontaneous in the sense of being internally rather than externally regulated. On the other hand, the timing and duration of sleep and dreaming are highly ordered processes. Sleep is governed by a circadian rhythm, and sleep architecture is made up of cyclically recurring sleep stages. The timing of sleep is mostly driven internally and to a lesser degree is modulated by external influences, such as lighting. The timing of sleep can also be controlled deliberately, but only to an extent. To be sure, I can intend to go to sleep and dream and to deliberately stay awake beyond my bedtime. It is noteworthy, however, that such attempts to deliberately control the onset of sleep can also be disruptive and may even be one of the factors leading to insomnia. As Espie and colleagues (2006) put it, "sleep–wake automaticity can be inhibited by selectively attending to sleep, by explicitly intending to sleep, and by introducing effort into the sleep engagement process" (p. 217).

Something similar seems to be true for dreaming. The sleep-stage correlates of dreaming remain controversial and it is now commonly recognized that dreams occur in all stages of sleep (Nielsen, 2000, 2014; Windt et al., 2016). Yet if we focus on the example of REM-sleep dreams, it is clear that the timing and duration of dreaming are again systematically controlled and intrinsically orchestrated. Dream reports increase in length as the duration of REM periods increases throughout the night, and generally, dream reports from the second half of the night are more vivid and emotionally intense, as well as longer than reports from the first half of the night (Domhoff, 2013; Kramer, 2013). The rhythmic and carefully orchestrated timing of sleep and dreaming appears to set them apart from spontaneous waking thoughts, which do not seem to adhere to any close schedule, either internal or external.[5]

Do the contents of dreams have a similarly ordered nature as the timing and duration of dreaming? It is now increasingly clear that the different stages of sleep contribute to different kinds of memory consolidation (Diekelmann & Born, 2010; Stickgold, 2005), even though the exact mechanisms underlying the formation of dream content remain unclear. In some accounts, the contents of dreams are without specific function or meaning, the product of random, brain-stem driven activation (Hobson et al., 2000). But there is also much evidence that dream content has an ordered nature, for instance by being continuous with waking experiences, thoughts, and concerns (Domhoff, 2013). Research on the so-called dream-lag effect suggests that there is a temporal pattern for the incorporation of waking memories in dreams, such that we are most likely to dream of events experienced the preceding day ("day residue"), but also of those experienced 5–7 days before, and less likely to dream of events from days 2–4 before (see van Rijn et al., 2015, for discussion and further references). This effect is specific to REM-sleep dreams. Moreover, the memory sources of sleep mentation become increasingly remote throughout the night, often involving semantically related memories from different periods of one's life (such as two pets that one had at different times; Stenstrom, Fox, Solomonova, & Nielsen, 2012; see also Verdone, 1965). Currently, however, too little is known about the contents of dreams and their relation to waking life events to reach any final verdict on this question.

Another relevant distinction is between the content of dreams and the formal features of dreaming. Broadly speaking, content analysis is interested in the topics one dreams about and their relation to current concerns or real-life experiences (Domhoff, 2013), whereas formal analysis focuses on the types of imagery (visual, auditory, etc.) and emotions associated with these contents (Hobson, 1988). It is noteworthy that the formal features of dreaming seem to be much more generic than the contents of dreaming, which are harder to predict and more idiosyncratic. Movement sensations, for instance, are described almost as frequently in the dreams of congenital paraplegics as they are in those of healthy participants (Voss, Tuin, Schermelleh-Engel, & Hobson, 2011). By comparison, the contents of dreaming are much harder to predict—and this unpredictability is a major challenge to the scientific investigation of dreaming and its contribution, if any, to memory consolidation in sleep. Generally, the most promising targets for investigating spontaneous conscious processes will be those that have the highest degree of inter-individual variation, have the potential to be deliberately controlled, and are the hardest to predict. This is likely the case for the content of dreaming, but not for its formal features, nor for its timing and duration.

This is why dream lucidity is directly relevant to questions concerning the spontaneity of dreaming. Dream lucidity is often associated with the ability to control the ongoing dream at will. As will become clear later, the clearest examples of dream control concern the contents rather than the formal features of lucid dreams; and often, control is exercised in response to spontaneously formed intentions. At the same time, the ability of experienced lucid dreamers to act upon previously formed intentions can turn specific forms of dream content into a systematically investigable and to an extent predictable target for laboratory dream research. We now turn to a brief summary of the main research findings on dream lucidity.

Lucid Dreaming: A Brief Review of the Main Scientific Findings

Lucid dreaming is associated with changes in subjective experience and cognitive functioning that are atypical for ordinary REM-sleep dreams. In its purest form, a lucid dream is accompanied by insight into the fact that one is dreaming while the dream continues, meaning that the dreamer is aware of the fact that what they are now experiencing is virtual, not real. A less conservative yet empirically substantiated definition includes dreams that are additionally accompanied by heightened control and/or dissociative elements (see Voss et al., 2013; Voss & Hobson, 2015, for discussion and further references). Lucid dreams may be entered from wakefulness by means of meditative relaxation or hypnagogic/hypnopompic states during sleep onset (wake-initiated lucid dreams, or WILDs) or develop spontaneously out of REM sleep (REM-initiated lucid dreams, sometimes also referred to as dream-initiated LDs, or DILDs; see LaBerge, 1990). Even though the frequency of lucid dreaming can be augmented through autosuggestion and training, it has not, so far, been possible to reliably predict the timing of a lucid dream, and the success rate for different lucid dream induction techniques is still comparatively small (Stumbrys, Erlacher, Schädlich, & Schredl, 2012).

Especially during childhood and early adolescence, lucid dreams appear to occur spontaneously and without previous effort or intent (Schredl et al., 2012; Voss et al., 2012). In adulthood, REM-initiated lucid dreams are much less frequent, and in our experience, many participants experience this method as more difficult to master successfully. Once lucid, adults also find lucidity more difficult to maintain. Especially for participants with no previous lucid dream experience, lucid dreams appear to be much easier to initiate from wakefulness, and so this method enjoys great popularity. We therefore assume that most lucid dream reports posted on Internet platforms refer to WILD dreams in which the dreamer uses either meditative relaxation or hypnagogic/hypnopompic states to enter a lucid dream during sleep onset.

With regard to emotion, it is noteworthy that many lucid dreams reported on Internet platforms and in the lucid dream literature are described as positive or even euphoric. By contrast, the majority of lucid dreams investigated in laboratory studies are emotionally neutral (Voss et al., 2013; Voss et al., 2014), suggesting that an effect of lucidity on emotions cannot be considered conclusively established. According to the participants in our study (Voss et al., 2013), lucid dreams occurring in the laboratory were generally also shorter and more difficult to maintain than those experienced at home. Further, they were all initiated from REM sleep.

Several different interpretations are available. One is that the difference in emotional tone is due to an underlying contrast between REM-initiated lucid dreams and WILDs. Another is that the sleeping environment influences the emotional tone of lucid dreams independently of whether they were initiated from wakefulness or from REM sleep. A third possible explanation could be that the euphoria anecdotally ascribed to lucid dreams actually sets in after awakening. In this reading, the dreamer would experience euphoria about just having been able to produce a lucid dream, but these positive emotions would not necessarily have been present in the dream itself. For subjects awakened directly following a REM phase in the laboratory, the experimental protocol and the perceived pressure to produce and report a lucid dream may counteract this euphoria. The positive emotional tone of lucid dreams would then be an artifact of the sleeping environment and the conditions under which the dream is reported. This question has not, to our knowledge, been investigated experimentally, but it would fit in well with the fact that timed awakenings in the sleep laboratory are generally regarded as the gold standard for gathering reliable dream reports.[6]

Scientifically, REM-initiated lucid dreams are very appealing because they present a unique opportunity to study the neuro- and electrophysiological correlates of emerging metacognitive awareness and executive ego functions (e.g. logical thought, self-reflection, decision-making, and volition) against a background of a steady state (i.e., a relatively stable state of arousal). Lucidity is plausibly related to a change in self-related processing and (meta-) cognitive functioning (Metzinger, 2004; Windt & Metzinger, 2007). For lucid dreams emerging from non-lucid REM-sleep dreams, it therefore becomes possible to contrast the transition between different levels of subjective experience and cognitive functioning, as well as their neural correlates. By contrast, because WILDs are set against a background state that is ambiguous and constantly fluctuating between wakefulness and sleep onset, the assignment of subjective (dream report) and objective (neuroimaging data, EEG) data represents an even greater challenge than for REM-initiated lucid dreams. With regard to REM-initiated lucid dreams, data from different laboratories have identified several typical patterns of brain activation, including a frontal REM-atypical increase in lower gamma frequency band activity (Voss, Holzmann, Tuin, & Hobson, 2009), as well as an augmented activation of frontotemporal (Dresler et al., 2012) and frontopolar cortical areas (Filevich, Dresler, Brick, & Kühn, 2015).

History of Lucid Dreaming

Dreams involving metacognitive insight into the fact that one is now dreaming have been known since antiquity (Aristotle, 1996), but first became a target of experimental research in the late nineteenth century (Maury, 1861; Saint-Denys, 1982). The term *lucid dreaming* was coined by van Eeden at the beginning of the twentieth century. Van Eeden was mainly interested in using lucid dreams as a vehicle for self-experimentation and self-observation, for instance for describing the sheer variety of dreams and sleep-related conscious experiences (van Eeden, 1913; see also Arnold-Forster, 1921). The crucial step toward the laboratory-based scientific investigation of lucid dreaming occurred in the 1980s. Stephen LaBerge (1985, 1990) in the United States and Keith Hearne (1978) in Great Britain introduced a methodological approach enabling an outside observer to monitor the progression of lucid dreams via voluntary eye movements made by the dreamer. By conducting a previously arranged pattern of gaze shifts (for instance, right, left, right, left) in their lucid dreams, participants can control their actual eye movements; these eye movement patterns then show up on electro-oculogram (EOG) recordings of eye muscle movements. When participants confirm, after awakening, that they indeed were lucid and performed the gaze shifts within their dream, the foregoing sleep phases can be scored as lucid (so-called signal-verified lucid dreams). In Germany, it was primarily Paul Tholey (Tholey & Utecht, 1987) who focused on the scientific aspects of lucid dreams. He introduced the German word "Klartraum," which can be roughly translated as "clear dream" and is meant to describe the overall clarity of reasoning and of dream imagery in the lucid dream state.

These early developments notwithstanding, the scientific study of lucid dreaming did not receive the recognition it deserved until the early twenty-first century. Instead, lucidity was mostly ascribed to parapsychology and esotericism, perhaps owing to the strong interest it received in these circles (e.g., Green, 1968). A long-held belief in the scientific community was that lucid dreams were not sleep phenomena per se, but instead were somnolent experiences arising out of brief arousals (Hartmann, 1975). This assumption is appealing at first sight and may indeed accurately characterize at least a subgroup of WILDs. However, at least for REM-initiated lucid dreams, this view has been refuted. As recent electroencephalograph (EEG) (Voss et al., 2009) and fMRI studies (Dresler et al., 2012) show, these lucid dreams alter REM sleep without suspending the state of sleep. There is now solid scientific evidence for saying that REM-initiated lucid dreams are genuine sleep phenomena, rather than artifacts of intermittent awakenings from sleep.

Definitions of Lucid Dreaming

Up until now, several definitions of lucid dreaming have existed alongside each other. Major differences in existing definitions pertain to the level of voluntary control and overall cognitive functioning, including the availability of waking memory and critical reasoning ability. Some authors regard insight into the fact that one is now dreaming as the sole defining feature (LaBerge, 1985), whereas others apply a broader definition of lucid dreams as involving full intellectual clarity, including the availability of autobiographic memory sources, the ability to actively control the dream, as well as an overall increase in the intensity of multimodal hallucinatory imagery (Tart, 1988). An important question is whether the coexistence of these factors is strictly necessary, or if any of these factors is sufficient for classifying a dream as lucid even when it occurs in isolation from the other factors. Can a dream be called lucid only when the dreamer reports having exercised dream control, for instance by altering the course of the dream? If yes, how much control would be needed to do so? And would dream control be sufficient to score a dream as lucid even if the report did not explicitly describe that the dreamer was aware that she had been dreaming?

With the help of the Lucidity and Consciousness in Dreams scale (LuCiD scale; Voss et al., 2013), we attempted to construct a tool that identifies the different determinants of consciousness in dreams and allows for their measurable quantification. The LuCiD scale was developed by an interdisciplinary team of researchers from psychology (Ursula Voss and Clemens Frenzel), philosophy (Jennifer Windt), statistics (Karin Schermelleh-Engel), and psychiatry (Allan Hobson). Its purpose was to put theory-based assumptions about dream lucidity to the test and establish concrete differences between normal REM sleep dreams and lucid dreams. Structural factor analysis revealed that unambiguous lucid dreams (i.e., those accompanied by insight) were also reported to contain control over the dream plot as well as dissociative experiences. In lucid dreams, dreamers typically also were able to voluntarily change objects (control), and they often saw themselves from the outside, reminiscent of autoscopic phenomena or out-of-body experiences (OBEs; see Blanke & Mohr, 2005). Often, participants reported having experienced the dream as an observer rather than actively participating in the dream, for instance saying that the dream "played out like a movie." We concluded that the three factors that most clearly distinguish lucid dreams (where this refers to dreams identified as lucid by our participants) from non-lucid ones are (1) insight into the fact that one is currently dreaming, (2) control over the dream plot, and (3) dissociation akin to de-personalization and de-realization.[7] These three factors are correlated, meaning that in the majority of lucid dreams, they will occur together.

Still, this is not the same as saying that any or all of these factors are strictly necessary for lucidity to occur. Statistically speaking, it is possible that a dream can be considered as lucid even in the absence of insight but, instead, in the presence of only dissociation and control. For now, however, this point is primarily of theoretical interest. For methodological reasons, we assume that insight is a core factor of lucidity, meaning that while explicit insight may or may not co-occur with control and dissociation, a dream cannot be scored as lucid unless the dream report explicitly describes that the dreamer realized, in the dream, that she was now dreaming. This assumption is also in line with the fact that in all studies conducted thus far, the categorization of a dream as lucid was based at least in part on subjects' claims that they had achieved insight in their dream (for discussion, see Windt, 2015a, Chapter 4).

Finally, it is important to note that the factors of insight, control, and dissociation are themselves internally complex and can vary by degree. For instance, lucid dreamers may be able to control their own actions, but not those of other dream characters; or dreamers may know they are dreaming but not realize the full consequences of this fact. Therefore, we must also ask how much of lucid insight, control, and/or dissociative elements suffice to justify the label "lucid," and one advantage of the LuCiD scale is that it allows us to tease apart these different factors. Being able to determine the quantitative level of different aspects of dream experience is an important research target because it enables not just an empirically informed definition of lucid dreaming, but also its measurability and predictability (Noreika, Windt, Lenggenhager, & Karim, 2010; Voss & Hobson, 2015; Voss & Voss, 2014). It is also a condition for transferring insights from the investigation of dream lucidity to clinically relevant altered conscious states such as locked-in-syndrome or vegetative state (see, for instance, Naro, Bramanti, Leo, Russo, & Calabro, 2016).

Brain-Physiologic Correlates of Lucid Dreaming

In the tradition of Freud, sleep is often still defined as a state of unconsciousness. The question of whether dreams are conscious experiences occurring in sleep dominated the philosophical discussion of sleep and dreaming well into the twentieth century (Dennett, 1976; Malcolm, 1962). Today, most accept that dreams are phenomenal states; they have qualitative or subjective character, meaning there is something it is like to dream, and not just to remember having dreamed (see Windt, 2013, for discussion). Moreover, since the discovery of REM sleep and its correlation with dreaming in the 1950s (Aserinsky & Kleitman, 1953; Dement & Kleitman, 1957), dreams have turned into a target of scientific investigation. The science of lucid dreaming is the next and latest step in this development. The investigation of dream lucidity and its contrast with non-lucid dreams is particularly promising because the method of signal-verified lucid dreaming, combined with retrospective dream reports, allows researchers not only to determine when specific types of dream experience—such as performing a gymnastics routine (Erlacher et al., 2013) or clenching one's fist (Dresler et al., 2012)—are occurring in real time, but also to time their duration and identify their neural correlates.

Our studies on lucid dreams show that consciousness in sleep is also susceptible to experimental manipulation, allowing us to go beyond correlation to investigate the causal contribution of different brain activation patterns to conscious experience in sleep. This shows that changes in the level of experience of the type that accompany the onset of lucidity can be initiated not only spontaneously or with the help of different cognitive methods such as autosuggestion (Voss et al., 2009), but also via electrical stimulation of relevant brain areas (Voss et al., 2014). Importantly, this is even the case when participants are not themselves experienced lucid dreamers and do not use any of the cognitive techniques that are typically used to induce lucidity. Results on electrophysiology and subjective experience in lucid and non-lucid dreams suggest that lucid dreaming represents an extraordinary state of consciousness in which EEG correlates of waking coexist with those typical for REM sleep dreaming (Voss et al., 2009; Voss et al., 2014).

Figure 29.1 shows that at the cortical level, frontal and temporal areas appear to be activated to a degree that is atypical of ordinary REM sleep (Dresler et al., 2012; Voss et al., 2009), especially in the lower gamma frequency band centered around 40 Hz (Voss et al., 2009). Although much reduced from waking, 40 Hz activity over the frontal, dorsolateral, and prefrontal cortices is more akin to waking than to sleep. As is the case for 40 Hz activity, these areas are associated with executive functions such as planning, voluntary action, and decision-making (Baddeley, 1992; Goleman & Davidson, 1979; Scott & Schoenberg, 2011; Stuss, 2011).

At the same time, lucid dreaming is accompanied by a clearly REM sleep-like pattern in lower frequencies. Figure 29.2 illustrates the similarity between ordinary REM-sleep dreams and lucid ones, as well the clear distinction of both from wakefulness. The frequency-specific activation underlying non-lucid REM-sleep dreams and lucid dreams diverges only in the higher frequency bands, beginning around 32 Hz. By contrast, wakefulness (eyes closed) is characterized by comparatively reduced activity in the lower frequency bands up to about 6 Hz and a peak in alpha activity between 8 and 12 Hz. Because we corrected for eye movements, this difference between wakefulness and both non-lucid REM sleep dreams and lucid dreams cannot be due to oculomotor activity. This should not be taken to imply that REM sleep is devoid of alpha activity; it means only that the pattern of alpha activity differs between REM sleep, lucid dreams, and wakefulness.

Finally, aside from the cortical changes observed in lucid dreams, recent studies suggest that subcortical structures are involved. Evidence for the participation of the cortico-thalamic-limbic network comes from patients who have suffered a thalamic stroke and subsequently report emotionally disturbing lucid dreams (Sagnier et al., 2015). The authors suggest that "this anxious and emotional context probably influenced the emergence of lucid dreams that could be explained by limbic cortical and subcortical structures" (p. 771). While this report relies on data from only two patients, it raises the question of whether thalamic processes may typically serve to suppress lucid dreams or make their occurrence unlikely. The frequency of autoscopic elements in lucid dreams additionally suggests an involvement of subcortical structures (Kaliuzhna, Vibert, Grivaz, & Blanke, 2015). Autoscopy is closely related to out-of-body experiences (OBEs). It refers to a broad range of visual hallucinations of a bodily image, for example seeing a doppelgänger or seeing oneself as if from the outside, often from an elevated perspective (as in OBEs). The autoscopic, visual image may be a more or less accurate duplicate of one's real body (Brugger et al., 1997). Although scientific reports are scarce, it appears as if at least transient dysfunctions in limbic and thalamic structures were involved (Brugger et al., 1997; Blanke et al., 2004).

In our study, the coexistence of apparently contrary activation patterns initially led to the characterization of lucidity as involving a hybrid state between sleep and wakefulness (Hobson & Voss,

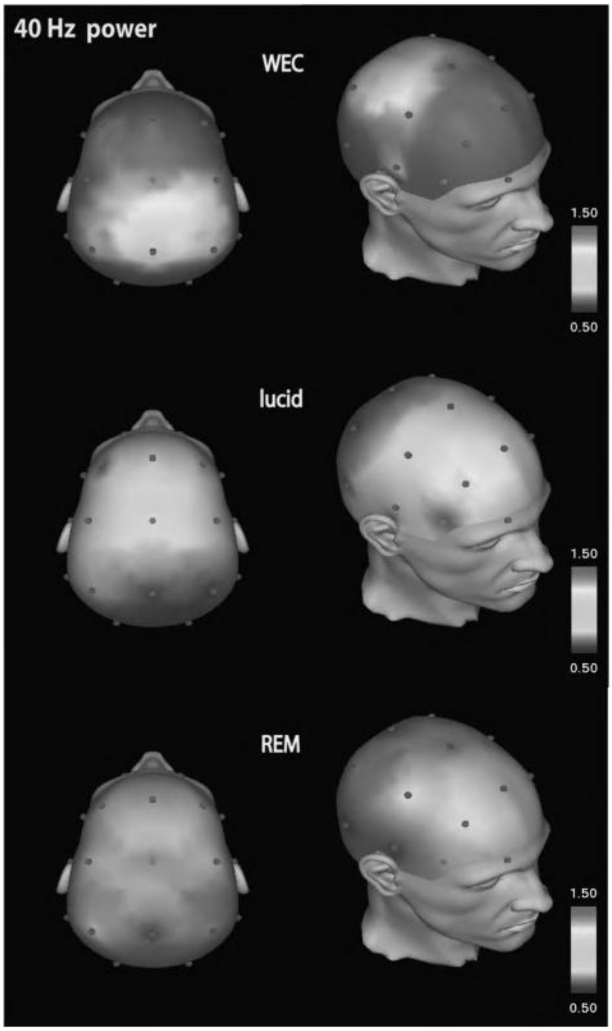

Figure 29.1. (See Color Insert) Standardized current source density power (CSD) in a waking participant with eyes closed (top), during a lucid dream (middle), and during ordinary REM sleep (bottom). Topographical images are based on movement-free EEG episodes and were corrected for eye movements. WEC refers to waking with eyes closed. Darker color corresponds to higher 40 Hz activity. For a full color picture, see Voss et al., 2009. Source: Voss et al. (2009).

2010, 2011). A different interpretation that we now favor is that lucidity involves a change in ordinary REM sleep, but without thereby causing awakening (Czisch et al., 2014; Voss & Hobson, 2015; Voss & Voss, 2014). Here, we want to propose that this change is best characterized by describing lucidity as arising during a distinct substage of REM sleep.

Introducing the distinction between lucid and non-lucid REM sleep makes room for describing lucid dreaming as a genuine sleep phenomenon, but may also help refine sleep-stage scoring. The terminology for describing different sleep stages is conventional, and scoring rules are occasionally adjusted to optimally reflect new scientific findings (for a discussion from a philosophical perspective, see Thompson, 2014, 2015a, 2015b; Windt, 2015a, b; Windt et al., 2016). The current rules for scoring non-REM (NREM) sleep were proposed by the American Academy of Sleep Medicine in 2004; they revised the rules proposed by Rechtschaffen and Kales in 1968 (see Silber et al., 2007, for discussion and further references). Different taxonomies for describing and scoring sleep stages can also coexist. For instance, within the period stretching from wakefulness via NREM 1 into early NREM 2, 9 EEG substages can be distinguished, and they bear a complex relationship to different types of mental activity and subjective judgments of sleep or wakefulness (Stenstrom et al., 2012; for a discussion of so-called microdreams, or dream-like experiences

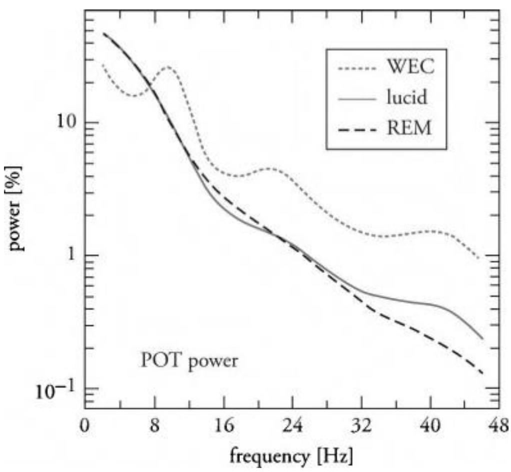

Figure 29.2. (See Color Insert) EEG Power (POT = scalp potential) in the analyzed frequencies from 1 to 48 Hz, averaged over three lucid dreams and for all electrode recording sites, corrected for eye movements (Gratton et al. 1983). Dotted line: Waking, eyes closed (WEC), lying down. Black line: lucid dream sleep. Broken line: non-lucid REM sleep. Source: Voss et al. (2009).

occurring during sleep onset, see also Nielsen, 2017). In order to determine the neural correlates of mental activity during sleep, more fine-grained sleep-stage scoring of this type may be required. What we are proposing here is a similar refinement of the taxonomy for describing REM sleep. In the future, the distinction between lucid and non-lucid REM sleep might lead to distinct scoring criteria. And perhaps, with time, even more fine-grained categories and scoring criteria can be introduced, describing differences between REM sleep involving dreams and occasionally dreamless REM sleep, or even different types of dreams arising in REM sleep. In this process, the distinction between lucid and non-lucid REM sleep is a first, but important, step. The characterization of lucid dreams as arising during an altered stage of REM sleep rather than a hybrid state between sleep and wakefulness also reflects the fact that subjectively, dream lucidity is clearly not a wake-state phenomenon. The following reports following stimulation during REM sleep (for details, see next section) show this clearly:

Example 1: "I saw myself lying there. I was somehow . . . I looked wounded. I was telling someone about this while I was lying there, and then I saw myself crying, but not in the dream, and now there were only the other people there and I told them how this happened. And that's when I seem to have noticed that I was dreaming, in the dream."[8]

Example 2: "I was sitting at my computer with my grandfather and I was explaining something to him and then I suddenly thought, 'whoops, am I dreaming? If so, I could just get up and walk around,' and so that's what I did. I walked around for about 20 seconds. I didn't do anything else. The floor was colored, like a mosaic. I walked through the house, went outside, and then I noticed that all of the floors were somehow paved with mosaic stones."

The bizarreness and incoherence of these reports illustrate, we think, the degree to which lucidity (and its precursors) involves a change in ordinary REM sleep, but without thereby causing awakening. The investigation of the transition between non-lucid and lucid dreaming can thus help determine the extent to which levels of awareness that have traditionally been assumed to be restricted to wakefulness are in fact compatible with sleep, but also highlights the inherently dreamlike character of lucid dreams, which is so prominent in both of these reports. The compatibility of insight and otherwise dreamlike conscious thought, in particular, is important from an empirical perspective, but also challenges the commonly accepted taxonomy of mental states by blurring the conceptual distinction between sleep and wakefulness.

Induction of Lucid Dreams Through Frontotemporal Low Current Electrical Stimulation at 40 Hz

An important question that is associated with investigating the neural correlates of lucidity is how to increase the frequency of lucid dreams, especially under the systematic and controlled conditions of the sleep laboratory. A related question concerns the causally enabling conditions for lucidity to arise. After numerous failed attempts to induce lucidity with the help of light or acoustic signals (which had low success rates at best; see Stumbrys et al., 2012), we were able to use electrical stimulation at 40 Hz during REM sleep to induce changes in experience of the type normally associated with spontaneous lucid dreaming—almost as if stimulation were pushing initially non-lucid dreams in the direction of lucidity (Voss et al., 2014). We used the method of transcranial alternating current stimulation (tACS). In line with evidence from spontaneous lucid dreams, we stimulated bilaterally over frontotemporal brain areas at several low frequencies (see gray rectangles in Figure 29.3 A and B). The electric current had been determined based on pilot studies so as to minimize the likelihood of awakening during stimulation (250 μA). We also applied a local analgesic to the stimulated patches of skin. As noted earlier, all of our participants reported having no prior experience with lucid dreams.

In this comprehensive double-blind study, we tested six different conditions, including repeated measurement (stimulation at 2 Hz, 6 Hz, 12 Hz, 70 Hz, 100 Hz, contrasted with pseudostimulation/sham). Our participants spent up to four nonconsecutive nights in the laboratory; stimulation was conducted during REM sleep, with the first stimulation beginning after 3 a.m. The duration of stimulation was 30 seconds and participants were awakened immediately afterward. With the help of specific algorithms (Voss et al., 2014), we filtered the stimulation signal out of the EEG data in order to ensure that stimulation had not led to an interruption of REM sleep. During each experimental night we alternated between two conditions (e.g., between 2 Hz and 40 Hz or between 12 Hz and 70 Hz, with a balanced design for participants and nights).

The only stimulation frequencies to induce changes in the lower gamma band were 25 Hz and 40 Hz. Figure 29.3 illustrates the effect of stimulation at 6 Hz (no change in the theta frequency band

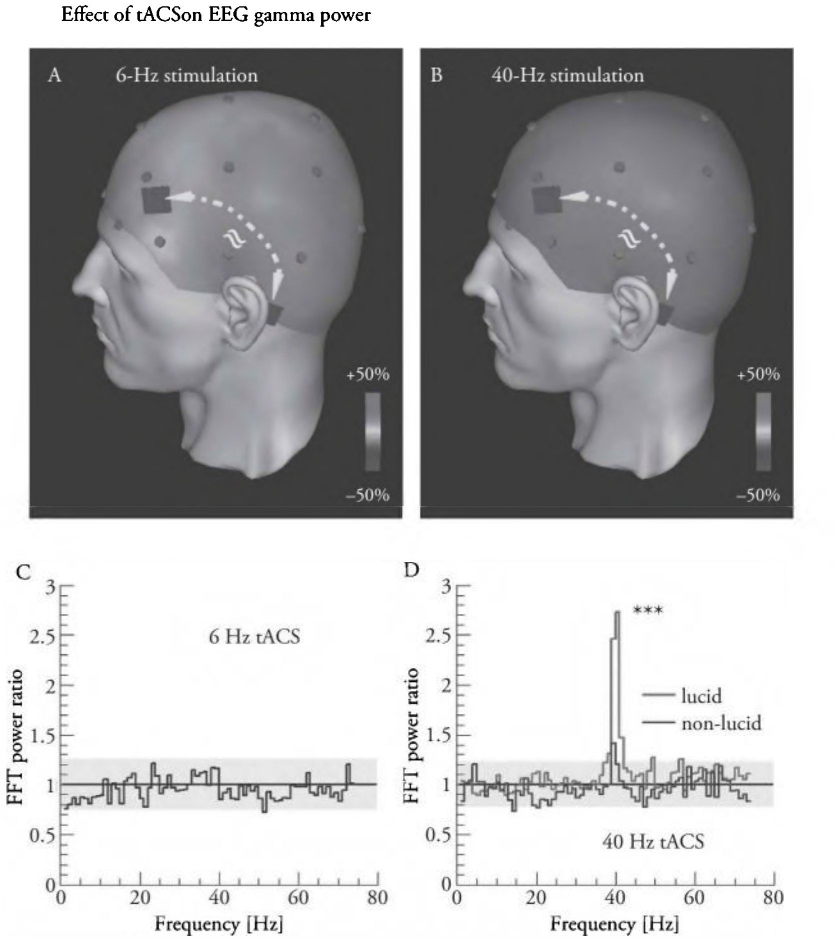

Figure 29.3. (See Color Insert) Effect of transcranial alternating current stimulation (tACS) on EEG gamma power (37–43 Hz). tACS electrodes were placed bilaterally at frontal and temporal positions (black rectangles) and current was flowing back and forth between these electrodes. EEG electrode placements are indicated as dark dots. (A) Stimulation with 6 Hz resulted in no change in lower gamma activity around 40 Hz (37–43 Hz). (B) Stimulation with 40 Hz led to a strong increase in lower gamma activity around 40 Hz. (C) Grand average Fast Fourier Transform (FFT) power ratios of activity during versus activity prior to stimulation for the 6-Hz stimulation condition. Gray shading represents mean values ± 2 standard errors (s.e.). Any excursions outside of this range would be considered significant at least at the $p < .05$ level. However, with 6 Hz, we see no significant stimulation-induced increase in 6 Hz activity. (D) Grand average FFT power ratios of activity during versus activity prior to stimulation for the 40-Hz stimulation condition. Gray shading represents mean values ± 2 standard errors (s.e.). Note that lucid dreams (gray line) are accompanied by a significantly larger increase in the 40 Hz frequency band than non-lucid dreams (black line) (independent two-sided t tests between lucid and non-lucid dreams during stimulation with 40 Hz: $t_{40Hz} = 5.01$, df = 35, $p < 0.001$). Source: Voss & Hobson (2015).

or any other frequency) and 40 Hz (strong increase in the lower gamma frequency band). Importantly, even 40 Hz stimulation did not always lead to subjective reports of lucidity. When participants did report a lucid dream after awakening, however, activity in the lower gamma frequency band was clearly elevated. This leads us to assume that, on the one hand, activity in the lower gamma band is necessary (but not sufficient) to induce lucidity, and on the other hand, that dream lucidity further increases activity in this frequency band.

Difficulties and Limitations

As mentioned earlier, the frequency of spontaneous REM-initiated lucid dreams is very low in adults (Voss et al., 2009; Voss et al., 2013), and somewhat paradoxically, being asked to produce a lucid dream in a sleep laboratory may further reduce the likelihood of success. The following examples from trained lucid dreamers illustrate this point:

Example 3: "It is not easy to become lucid in a dream or to stay lucid. Lucidity is fragile and basically, it is always about keeping the right balance between control and looseness." (27-year-old female)

Example 4: "For me, a lucid dream is always an exceptionally exciting experience. . . . This condition feels like a brain battle between maintaining the dream scenery and waking up. In these short periods of clarity the acting dream body and the real body that lies in bed exist simultaneously and it costs great effort and concentration to keep up the balance between the two." (22-year-old female)

The possibility of inducing lucid dreams through electrical stimulation of the brain constitutes a new and promising method to increase the frequency of lucidity under laboratory conditions. However, this method is quite demanding, and at this point, we must consider it possible that electrically induced lucid dreams differ from spontaneous ones. Dodet et al. (2014) have observed that narcolepsy patients often report lucid dreams and propose to use these patients as subjects and thereby bypass the recruitment problem that hampers many lucid dream studies. Here, too, the question is how similar the lucid dreams of narcolepsy patients are to those occurring independently of sleep disturbances.

Another important question refers to causality. We found that lucidity can be triggered through the external application of a 40 Hz current, but also that stimulation with 40 Hz does not always lead to a measurable lucid dream. Our induction study was very elaborate, and we tested a large number of subjects across several nights. Yet while the effect was statistically significant, the average questionnaire scores suggest that we achieved only small changes in absolute terms. Also, while stimulation with 40 Hz led to an increase in lower gamma band activity, this increase was much greater when it was accompanied by a lucid dream. It is thus possible that the 40 Hz activity we managed to induce experimentally was insufficient to initiate lucidity. This once more raises the question of the predictability and scoring of lucid dreams. Under what conditions is it justified to score a period of REM sleep as lucid when the frontal lobe is activated in the 40 Hz frequency band? How long and how intense must frontal 40 Hz activity be to lead to a remembered lucid dream? In light of our earlier suggestion of introducing lucid REM sleep as a substage of REM sleep, it will be imperative to eventually answer these questions, and we hope that future studies will help make progress toward doing so.

Insight, Control, and Spontaneous Cognitive Processing in Lucid Dreams

Based on our review of some of the main scientific findings on dream lucidity, we can now return to our original question: What role does spontaneous cognitive processing play in lucid dreams? Are lucid dreams, like non-lucid ones, still paradigmatic cases of mind-wandering? Or does realizing that one is dreaming, coupled with the ability to control the dream, effect such a radical change in overall processing that the analogy with wake-state mind-wandering is broken? We can begin to tackle these questions by asking about the extent and limits of lucid dream control. As noted earlier, this also will help identify those aspects of dreaming that are most interesting for the investigation of spontaneous cognitive processes.

While the extent to which skilled lucid dreamers can control not just their own actions but also effect changes in the dream environment is impressive, it seems that even in systematically performed lucid dream experiments involving signal-verified lucid dreams in the laboratory, there is still much room for spontaneity and surprise. To begin with, the success rate for actually carrying out one's waking intentions in a lucid dream is comparatively small. According to one study, lucid dreamers remembered their waking intentions, for instance to perform a particular dream experiment, only about half the time, and less than half of these remembered intentions were successfully carried out in dreams (Stumbrys, Erlacher, Johnson, & Schredl, 2014). This suggests that while the contents of lucid dreams can in principle be brought under deliberate control, they mostly unfold spontaneously, rather than according to waking intentions.

This appears to be reflected in the subjective experience of dream lucidity. Dresler and colleagues (2013) asked experienced lucid dreamers to assess the level of volition in lucid dreams, non-lucid dreams, and wakefulness. They found that self-determination, or the ability to act freely according to one's will, obtained higher ratings for lucid dreams and wakefulness than for non-lucid dreams. Planning ability received high ratings for wakefulness but low ones for lucid and non-lucid dreams, and intention enactment, or assessing how promptly intentions are executed, was highest in lucid dreams and lower but comparable in wakefulness and non-lucid dreaming. This seems to suggest that lucid dreamers are aware of their ability to control their dreams independently of real-world constraints, but mostly enact spontaneous intentions rather than ones formed in wakefulness. In fact, they may even have the experience that their ability to act upon long-standing, waking intentions is diminished in lucid dreams as compared to wakefulness.

A slightly stronger point would be that the association between lucid dream control and spontaneous cognitive processes is not just statistically frequent, but systematic. Experienced lucid dreamers often say that lucid dreaming involves a kind of balancing act between active participation and critical, reflective distance (LaBerge, 1985, pp. 104–108; see also Examples 3 and 4, earlier in this chapter). The deliberate suspension of disbelief may even be used to facilitate dream control; for instance, treating dream characters as if they were real may help "fill in" the overall situation and stabilize the dream by making it feel more real (Schatzman et al., 1988, pp. 171–172). Even when lucid dreamers successfully act upon their waking intentions, the result is often not exactly what they were expecting. The following example shows that even high levels of insight and control are compatible with spontaneous, subjectively unexpected, and surprising dream contents:

Example 5: "I am on a large, cobbled square in a fantastically beautiful port city that reminds me of some of the locations from Hayo Mizayaki's *Howl's Moving Castle*. Sky and water are shining in a bright azure, so that the horizon is barely visible; there is not a single cloud in sight. 'Too bad that this isn't a lucid dream,' I think, but then in the very next moment I hear myself say, internally: 'Well, then just turn it into one!'

At that same moment, I become lucid and my visual field expands rapidly. Everything looks much clearer and more sharply defined. I am immediately aware that I am now able to do anything imaginable, no matter how absurd or surreal, and I feel immense euphoria. I pull a silver hand mirror out of a pants pocket that is comparatively much too small and check my eye movements. Left, right, left, right. My reflection in the dream mirror does not quite correspond to my waking one, but I recognize myself nonetheless.

I place the mirror back in my pocket and use both feet to push away from the ground. Flying has always been my first intention when I became lucid. I circle above the peer for a few rounds, together with the seagulls, my hair blowing in the soft ocean breeze. An indescribable sense of freedom. If I now really have the opportunity to do anything I like, I should seize it, I think. I decide to look for Albert Einstein. I continue to fly, hoping to see him from above, but then realize that this is an inefficient method and decide to land. I have another idea.

Resolutely, I walk towards the next-best hotdog cart, traditionally painted with red and white stripes. The friendly vendor is about to start praising his hotdogs, but I am faster and wipe over his face with my right hand. Again, left, right, left, right. And as his red-cheeked, moon-shaped face pales with every wipe, the famous features of Albert Einstein slowly take its place; in black and white.[9] My plan has worked.

I introduce myself and ask if he can explain the world formula to me. Out of nowhere, a piece of paper appears in his right hand and a pen in his left. It's really simple, he explains, and begins to write red numbers on the piece of paper. He starts with 532 and subtracts another number, then divides by another one. I don't completely follow the point of this calculation; to the contrary, it seems to be completely arbitrary. But against my expectations, he continues to perform simple calculations with relatively small numbers. Not a single Greek letter appears.

When the whole page has been filled with writing, I wake up. I can't remember the result of the calculation but it wasn't 42." (23-year-old-female, mathematics student)

As this report was taken from a home diary, we have no way of knowing which sleep stage the dream occurred in, whether this was a WILD or a REM-initiated lucid dream, and whether it was reported immediately upon awakening. Judging from the wording, it does seem heavily edited. But if we take the report at face value, then it nicely illustrates that even successful dream control is the result of interacting with the dream environment: control is a matter of modulating the dream as it unfolds, rather than forcing it in another direction entirely. Control and insight are also compatible with the subjective sense of spontaneity. For the same reason, some level of dream control is important to counteract the loss of lucidity itself; if one engages too fully with the dream, one too easily forgets that it is just, after all, a dream (Brooks & Vogelsong, 1999).

The sense of effort involved in the maintenance of dream lucidity is nicely complemented by the importance of dissociative phenomena and derealization, which, as mentioned earlier, are hallmarks of lucidity. Control may also precede lucid insight, with dreamers carrying out their waking intentions, for instance to conduct a specific dream experiment, *without* having explicitly realized that they are now dreaming. Sometimes, this type of lucid dream behavior then leads to the cognitive realization that this is actually a dream (Brooks & Vogelsong, 2000). This complex relationship between the different factors characterizing fully lucid dreams means that lucid dreams are a rich opportunity for investigating the interplay between deliberate control and lower-level, automatic cognitive processes of the type underlying the process of dream formation. This is true not only theoretically and scientifically, but also subjectively. As illustrated by the following report by Frederik van Eeden, lucid control dreams are an opportunity for introspectively observing the interplay of these factors as the dream unfolds—and we suspect that the element of surprise accounts for a large part of the fascination with lucid dreaming:[10]

Example 6: "On Sept. 9, 1904, I dreamt that I stood at a table before a window. On the table were different objects. I was perfectly well aware that I was dreaming and I considered what sorts of experiments I could make. I began by trying to break glass, by beating it with a stone. I put a small tablet of glass on two stones and struck it with another stone. Yet it would not break. Then I took a fine claret-glass from the table and struck it with my fist, with all my might, at the same time reflecting how dangerous it would be to do this in waking life; yet the glass remained whole. But lo! when I looked at it again after some time, it was broken.

It broke all right, but a little too late, like an actor who misses his cue. This gave me a very curious impression of being in a fake-world, cleverly imitated, but with small failures. I took the broken glass and threw it out of the window, in order to observe whether I could hear the tinkling. I heard the noise all right and I even saw two dogs run away from it quite naturally. I thought what a good imitation this comedy-world was. Then I saw a decanter with claret and tasted it, and noted with perfect clearness of mind: 'Well, we can also have voluntary impressions of taste in this dream-world; this has quite the taste of wine.'" (van Eeden, 1913)

The spontaneous and often surprising aspects of lucid dreaming also facilitate the types of naïve-realistic beliefs in the reality of dream events that are normally thought to characterize only non-lucid dreams. So-called lucidity lapses, or instances in which lucid dreamers fail to realize the full consequences of the fact that they are now dreaming, can be fairly localized and often seem to reflect some of our most deeply ingrained beliefs and expectations. Often, they arise with respect to events that would be dangerous in waking life (such as cutting oneself with a knife or jumping off a cliff), and they also often have a social component, such as feeling embarrassed, being convinced that another dream character is a real person, or even thinking that one is sharing the dream with someone else (Green & McCreery, 1994, pp. 28–29; Levitan, 1994). Some lucidity lapses appear to involve spontaneous thought in the narrow, phenomenological sense of experiencing oneself as a thinker of thoughts introduced in the first section of this chapter. To the extent that these spontaneous thoughts are prompted by the experiential character of the dream (e.g., the seemingly realistic behavior of other dream characters), these are examples of how spontaneous, conscious thought can be shaped by lower-level imagistic cognition.

Do lucidity lapses mean that thinking even in lucid dreams is marked by the same cognitive deficiencies as in non-lucid dreams and should be set apart from waking thought? Not necessarily. It is noteworthy that in virtual reality experiments, social interactions and potentially threatening situations, such as walking to the edge of a cliff, enhance the subjective feeling of presence (Sanchez-Vives & Slater, 2005; Slater, 2009). Social interactions, in particular, seem to be even more important for generating the illusion of presence in virtual environments than perceptual realism (Slater, 2009)—and again, note that this is true for healthy participants who are awake and fully aware that what they are experiencing is just a high-tech simulation, not reality. For instance, participants with a fear of speaking in public feel similarly nervous when asked to speak in front of a group of virtual characters (Sanchez-Vives & Slater, 2005). This suggests that in both sleep and wakefulness, insight is compatible with the subjective feeling of presence, and often with behavioral and emotional reactions that would be appropriate if the events in question were occurring in the real world, and not just in a virtual or dreamed one. So-called lucidity lapses therefore do not appear to be unique to lucid dreams or to be confined to sleep. This leads to an interesting conceptual point: Whereas the occurrence of lucid insight in sleep puts pressure on attempts to cast metacognitive awareness, insight, and critical self-reflection as strictly "wake-like" forms of thinking, the similarity between lucidity lapses and reactions prompted by virtual environments in healthy, waking participants raises doubts about the alleged deficiency underlying "dreamlike" conscious thought. To be clear, we are not denying that such differences between thinking in dreams and in wakefulness exist—we are just suggesting that they are less clear-cut than is often assumed.

Lucidity lapses are also interesting because they may indicate which types of dream content fit our phenomenological notion of spontaneous cognitive processing. Again, social interactions between the dream self and other dream characters in lucid dreams are a nice example. The status of dream characters that are experienced as distinct from the self has long been a source of fascination. Social imagery plays an important role in dreams, with social interactions being even more frequent in dreams than in waking life (McNamara, McLaren, Smith, Brown, & Stickgold 2005). Non-self dream characters are rarely bizarre and are typically experienced as highly realistic. They are also often experienced as having a mind of their own, and dreamers frequently ascribe thoughts, feelings, and intentions to other dream characters (Kahn & Hobson, 2005b). Recently, the wealth of social imagery in dreams has even been suggested to shed light on the evolutionary function of dreaming (Revonsuo et al., 2015a). Social interactions in lucid dreams might thus be particularly interesting for investigating the interplay between spontaneous contents and deliberate control. A prediction would be that the ability to control the actions of a non-self dream character should be inversely related to the degree of experienced spontaneity and perhaps realism. If another dream character's actions can be controlled, we would expect this character to be experienced as not quite distinct from the self, whereas experienced difficulties in controlling a non-self dream character might prompt lucidity lapses, such as believing that the dream character is actually a real person.

This prediction appears to be supported by existing studies of social interaction in lucid dreams. Stumbrys et al. (2011) investigated the abilities of dream characters to solve simple mathematical problems in lucid dreams. Overall, the dream characters performed quite poorly and their answers were comparable to those of primary school students. For present purposes, however, *how* the dream characters reacted to these questions is more interesting. One dream report described that when asked to calculate 18 minus 6, the dream character refused, complaining that the question was much too private—a response that the dreamer found both baffling and inspiring. Two other reports described that dream characters, when confronted with mathematical problems, ran away or even started to cry. Other times, the dream characters came up with the correct answers, even though the dreamer had anticipated a false one. In these cases, the answers given by non-self dream characters were not directly accessible to the dreamers—they were experienced as surprising and as distinct from their own thought processes.

In another online experiment, Schmidt et al. (2014) instructed lucid dreamers to ask another dream character to guess how many fingers they were holding up behind their backs, or, in reverse, to themselves attempt to guess how many fingers other dream characters were holding up behind their backs. Generally, the success rate was higher than one would expect in waking participants engaging in real social interactions, indicating, not very surprisingly, that non-self dream characters are incompletely differentiated from the dream self. But the most important factor predicting the outcome of the dream experiment were the dreamers' own expectations before the experiment. If dreamers thought they would be able to "guess" the number of fingers other dream characters were holding up behind their backs, they were much more likely to be able to do so than if they expected this to be difficult. Even subjectively surprising dream contents may thus be biased by the dreamer's own unconscious expectations.

Windt et al. (2014) attempted to investigate the relationship between control and non-self dream characters in lucid dreams in a slightly different manner. Our question was whether it would be possible, in a lucid control dream, to tickle oneself or to be tickled by another dream character. This is interesting because in wakefulness, it is impossible to tickle oneself. Put simply, the sensory outcome of self-initiated actions is expected, and so it is attenuated, preventing self-induced tickles from feeling ticklish. There are, however, exceptions: schizophrenic subjects are able to tickle themselves (Blakemore, Wolpert, & Frith, 2000), as are healthy participants who have just been awakened from REM sleep and say they have been dreaming (Blagrove, Blakemore, & Thayer, 2006). In both cases, the lack of attenuation for the sensory consequences of self-initiated actions is likely due to disturbances in agency and self-other distinctions. In our study, we found that at least in the context of lucid control dreams, the distinction between tickling oneself and being tickled by another dream character was obliterated. This makes sense: Directing the actions of another dream character involves a sophisticated form of dream control, and often, the participants in this online study reported that they did not succeed. Yet when they did, the tickles administered by other dream characters tended to not feel very ticklish—they felt more like tickling oneself, both in lucid dreams and in wakefulness. Control, expectation, and experienced self-other distinctions are closely linked, and this relationship appears to be reflected on the level of phenomenal experience in lucid control dreams as well.

Expectation can also blur the distinction between lucid dream control and standard, non-lucid dreaming in another way. This is connected to the narrative structure of dreams. Many authors have remarked on the tendency of dreams to fluidly respond to dreamers' thoughts and concerns—sometimes even in a way that appears to preempt explicit insight into the fact that they are now dreaming. Some have thought that this means dreams are the product of unconscious authorship (McGinn, 2009); others have emphasized the similarity between dreaming and confabulation (Hobson, 1999). We want to suggest a more neutral reading, in which there is no sharp distinction or strict cutoff line between the lower-level imagistic processes underlying dream formation and higher-level, conceptually mediated insight and control, as in lucid dreams. These are simply different expressions of the same underlying process, though at different levels. As Pace-Schott puts it, "dream hallucinosis itself may generate low-level narrative coherence by associative processes in which images evoke related images . . . that are successfully woven together by this putative tendency to organize experience as a story" (2013, p. 2). This does not happen deliberately, but seemingly automatically—and while the factors determining the success of attempts to induce lucid control dreams are unknown, this might be why, as remarked earlier, suspending disbelief and "going with the flow" is often an effective way of indirectly exercising lucid dream control. Put differently, control in the context of lucid dreams may just be the special case in which expectations are deliberately used to nudge the largely spontaneous process of dream formation in the desired direction. Successful dream control may thus result when conscious and explicit intentions are temporarily aligned with the non-conscious processes and implicit expectations that drive the largely spontaneous process of dream formation. This comparatively tighter coupling between conscious thought and the ongoing flow of dream events would explain why the balance between critical distance and active participation in lucid dreams is so hard to maintain, but also why dream thinking is easily captured or even corrupted (Windt, 2015a) by dream imagery, resulting in lucidity lapses. For the same reason, this close connection between expectation and dream imagery production can also prevent explicit lucid insight. Take the following example:

Example 7: "I noticed that immediately in front of me, a house appeared to be standing on its head, and concluded that I must be dreaming. But then I noticed that I was wearing glasses, and immediately thought that the reversed visual effect must be caused by the glasses. In order to ascertain whether this was the case, I removed the glasses, whereupon I saw the house in its correct position. This led me to falsely conclude that I was awake after all." (Tholey & Utecht, 1987, p. 88; translation by J. W.)

What about the occurrence of lucidity itself? To what extent should we regard lucid insight into the fact that one is now dreaming as a spontaneous thought process, and to what extent is this insight itself controllable? To begin with, while lucid dreaming is a learnable skill, it is difficult to master, and perhaps increasingly so in adulthood. As mentioned earlier, the comparatively high frequency of lucidity in childhood and adolescence may be related to brain maturation, especially as the peak frequency in lucid dreaming coincides with the final stages of frontal lobe myelination and at a time of synapse expansion and dendritic growth. As Voss and Hobson (2014) point out, these natural processes might facilitate the activation of frontal areas in REM sleep in adolescence and thus lead to dream lucidity. In addition, adolescence is associated with changes in the timing of sleep and a maturation of circadian processes. Adolescents require as much sleep as pre-adolescents, but their sleep patterns undergo a phase-delay, leading adolescents to stay up later and, in association with early school times, to experience an increase in daytime sleepiness (Wolfson & Carskadon, 2003). This might be another factor that facilitates the occurrence of lucidity in adolescent sleep—especially as lucidity tends to occur in the second half of the night and especially toward morning or during morning naps (LaBerge, Phillips, & Levitan, 1994) and in our experience is more easily initiated from wakefulness than from within the dream state (but see Stumbrys et al., 2012). The association between spontaneous lucidity and shifts in circadian rhythms also fits well with our earlier observation of lucidity being a transitional state between sleep and wakefulness, as well as with anecdotal reports describing lucidity as a balancing act between non-lucid dreaming and awakening. In this reading, lucidity, at least when occurring in adolescence, can be described as a spontaneous glitch, a byproduct of brain maturation and associated shifts in circadian processes underlying the timing of sleep.

A related point is that the timing and duration of lucid dreams are largely dependent on the occurrence and duration of REM phases. Lucid dreams can be voluntarily terminated: Because of the correspondence between real-eye and dream-eye movements, lucid dreamers can wake themselves up by fixing their gaze on something and thus interrupting the rapid eye movements (LaBerge, 1985). But lucid dreams cannot be prolonged indefinitely, and while lucid dreams occurring at home may be longer and more easily maintained, the majority of lucid dreams occurring in the laboratory are very short, lasting around two minutes (Voss et al., 2013).

Tellingly, even experienced lucid dreamers seem unable to suppress visual imagery for prolonged periods, or at least not without waking themselves up. At the same time, other types of imagery that are normally rare in dreams (for instance, smell or taste) can, apparently, be induced successfully (Worsley, 1988; see also Example 6). Visual imagery, however, may be so central to the process of dream generation that its suppression leads to a disruption of REM sleep. All of this suggests that lucidity is, for the most part, a spontaneously occurring cognitive process: The contents of lucid dreams can, to an extent, be deliberately controlled, lucid dreams can often be terminated at will (though it would seem that more often, they end spontaneously), and induction techniques can facilitate the onset of lucidity. But voluntary control involved in initiating and maintaining lucidity often fails and might exert a mostly modulatory influence.

An important question in this context is whether the core feature of lucidity, namely the cognitive realization that one is now dreaming, is itself the outcome of a process of deliberate reasoning or occurs spontaneously, as a form of intuitive insight, rather than as an intellectual achievement. Here, it would seem that both variants exist—sometimes, lucid dreamers engage in a complex line of reasoning to conclude that they are now dreaming, whereas other times, the insight that they are dreaming seemingly comes out of nowhere; dreamers *just know* that this is a dream (see, for instance, Examples 1 and 2). We might say that in these cases, lucid insight results from a spontaneously occurring metacognitive feeling (Dokic, 2012), rather than from an explicit and deliberate attempt at cognitive evaluation. This feeling—, for instance an impression that everything has taken on a dreamlike character,—then acts as a precursor to the explicit and conceptually mediated thought that this is a dream. According to one study, the onset of lucidity was associated with a "dreamlike sense" in 48%–67% of cases (Gackenbach, 1988, p. 193), whereas the recognition of an incongruent element triggered lucidity in only 11%–19%. The situation is further complicated by the fact that experienced lucid dreamers may recognize the dream state by sheer familiarity; they may *just know* they are dreaming without ever conceptualizing or explicitly thinking about this fact at all. Such cases of "tacit" lucidity may be extremely hard to detect in dream reports, and subjects themselves may even be uncertain as to whether or not a given dream of their own was lucid (Brooks & Vogelsong, 1999, pp. 26–31; LaBerge & DeGracia, 2000; Worsley, 1988, p. 341). Perhaps, tacit lucidity can be seen as the outcome of unconscious goal representations (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001), for instance of the intention to become lucid. The Einstein dream cited earlier (Example 5) seems to be a good example of tacit lucidity of this type preceding explicit insight. The report's wording suggests that in this case, the onset of lucidity itself can be experienced as something spontaneous, as an automatic process: the dreamer *hears* herself say, "this is a dream," rather than experiencing this insight as the outcome of a conscious and deliberate reasoning process.

If insight into the fact that one is now dreaming can arise spontaneously, seemingly independently of rational thought, this brings with it an interesting problem: Spontaneous metacognitive insight of this type does not seem categorically different from cases in which dreamers subjectively *just know* that they are now awake. The explicit belief that one is awake, even though one is in fact dreaming, is the hallmark of false awakenings and pre-lucid dreams. Again, two variants exist, which complement the ways in which lucidity can be attained (see Windt, 2015a, Chapter 10, for details). First, dreamers can conclude that they are awake as a result of faulty reasoning. For instance, they might try to engage in reality testing by attempting to fly and then conclude that they are awake because they have floated off the ground.[11] Second, dreamers might *just know* they are awake, and this conviction may be driven by the seemingly realistic quality of dream imagery that subjectively leaves little room for conscious doubts. These cases of *just knowing* that one is awake seem analogous to cases of *just knowing* that one is now dreaming: Both involve explicit beliefs about one's current conscious state and both are driven by lower-level cognitive processing, rather than by conscious self-reflection and reasoning. From an epistemological perspective, this is quite worrisome: Despite having opposite truth values and different content (I am dreaming versus I am awake, where in reality one is dreaming), both result from the same type of metacognitive processing, and on the level of phenomenal experience, they carry with them the same subjective conviction. The experience of certainty and of knowing, far from being a sure guide to truth, can be deeply deceptive (cf. Metzinger & Windt, 2014, 2015). For now, another point is more important: Whether or not the dreamer hits on the correct conclusion and becomes lucid might largely be a matter of chance.

In this context, recall that Voss et al. (2014) found that tACS over prefrontal areas led not just to lucidity, as defined by knowing that one is dreaming, but also to dissociation. Participants reported seeing themselves from above, having the feeling of being in a computer game, being watched, or even being asked to describe their sensory experiences in dreams. As the participants in this study were not experienced lucid dreamers, this finding makes sense: It is almost as if electrical stimulation pushed them in the direction of lucidity by activating the kinds of metacognitive processing and imagery that are typically associated with insight, but without thereby generating the explicit, conscious thought that this is a dream. In some cases, participants even explicitly thought that they were awake. The information that one is now dreaming can be reflected on different levels. It can be reflected on the level of dream content—for instance, in a dreamlike sense, in the feeling that this is not quite real, or that one has separated from one's body—but also on the level of conscious thought, in the realization that one is now dreaming or, conversely, in the now firmly held belief that one is awake. Only in the case of correctly and explicitly realizing that this is a dream can the report be scored as describing a lucid dream; but there is a deep continuity with these other examples nonetheless.

Finally, just as dreamers can *just know* they are dreaming because the dream has taken on a strange, dreamlike quality, lucidity can also be lost because the dream just seems too realistic to be a dream. In this example, the dreamer's attempts to ascertain whether she really is dreaming seem to prompt exactly the types of imagery that finally lead to a loss of lucidity.

Example 8: "I am on my way to the bathroom, open the door and find myself in the wrong bathroom. Rather than standing in my own bathroom, I am in the bathroom in my parents' house. This is not at all where I wanted to be and it makes me mad. I walk through the bathroom and keep telling myself, 'this can't be true.'

I can't believe that this is true, so I look for indications that this could be a dream. I am very excited and a little bit angry because I don't want to be here. My mirror image looks normal; in fact everything looks authentic, just like in reality. This makes me even angrier, because I know that this is a dream—I shouldn't be here.

My cellphone rings, but I ignore it (who would be calling me now—my brain is letting it ring, this isn't real). I say out loud what I am thinking: 'This is a dream!' I open a window because I figure that my brain won't also create the entire garden behind the house. But it does: it's foggy, gray and wet—just as it should be. I notice an ugly ceramic frog and a race car in the garden—but immediately concoct an explanation (my brother has a new car, my father doesn't know the first thing about garden decoration). I accept what is happening and give up on trying to unmask what I am seeing as a dream. Continue to dream normally. . . ." (unpublished dream report from a student group headed by Ursula Voss)

Both the onset and the termination of lucidity can be the outcome of spontaneous metacognitive processing.

Conclusions and Future Challenges

Throughout this chapter, we have argued that lucid dreams involve an intricate interplay between spontaneous, largely imagistic cognitive processing and metacognitive insight, deliberate control, and dissociative phenomena. The next step is to place the investigation of dreaming in general and lucid dreaming in particular in the context of research on mind-wandering and spontaneous waking thought. In this concluding section, we suggest what we take to be some of the most exciting research questions for investigating spontaneous cognitive processing across the sleep-wake cycle.

A first and basic aim is to gather mentation reports across the sleep-wake cycle, ideally under the same conditions. As timed awakenings, followed by immediate reporting, are the gold standard for gathering dream reports, a similar method of immediate retrospection seems well suited to gathering reports of spontaneous waking activity as well (Windt, 2013, 2015). Existing studies (Stickgold, Malia, Fosse, & Hobson, 2001; Siclari, LaRocque, Postle, & Tononi, 2013) comparing reports from active and quiet wakefulness to those from different sleep stages suggest that participants give the longest reports following REM sleep awakenings, followed by active wakefulness, quiet wakefulness, NREM sleep, and sleep onset. This somewhat intriguingly suggests that dreams are more easily reported than, for instance, daydreams. Future studies should aim to carefully compare dream and mind-wandering reports in terms of length, content, imagery, and emotions. Such studies would, we expect, substantively enrich our understanding of subtle fluctuations in experience, meta-awareness, control, and thought contents across the sleep-wake cycle.

A set of more specific questions follows from our sharpened reading, proposed in the first section of this chapter, of what it means to say that dreams are spontaneous cognitive processes. There, we introduced the distinction between thinking in dreams (or conscious thoughts occurring within an ongoing dream) and dreaming as a spontaneous cognitive process. The motivation for distinguishing these two readings was primarily phenomenological: Dreaming as such does not feel like thinking; subjectively, dreaming involves the experience of moving through a dream world and interacting with other persons and objects in it. Dreams are more vivid and immersive, in this respect, than even vivid daydreams, which are still experienced as one's own thought processes. Given this distinction, one can then investigate the relationship between spontaneous thoughts experienced within a dream and the lower-level, imagistic, and largely automatic cognitive processes that underlie the experience of dreaming.

A next step would be to investigate how lucid insight into the fact that one is now dreaming affects the occurrence and character of conscious thought within dreams. Based on the occurrence of lucidity lapses, we suggest that even in lucid dreams, thought is only weakly differentiated from the lower-level processes underlying the production of dream imagery. But a similar question can now be asked for waking mind-wandering episodes as well. What exactly is the relationship between imagistic daydreams and accompanying consciously experienced thoughts (i.e., thoughts occurring within or about a daydream)? And how does the presence and absence of insight into the fact that one is now dreaming or that one is now daydreaming, respectively, alter this relationship?

We also proposed that the timing and duration, but also the formal features of dreaming (i.e., the modality-specific types of imagery experienced in a dream) do not count as *spontaneous* cognitive processes in an interesting sense. Spontaneous cognitive processes are idiosyncratic and hard to predict; they are also amenable, at least in principle, to deliberate control. By contrast, the timing and duration of dreams, as well as its formal features, are highly predictable, generic, and governed by internal circadian rhythms. What is presently unclear is whether the same is true for dream lucidity. Lucid dreams cannot be prolonged at will, but they can, to an extent, be initiated voluntarily via autosuggestion. Quite frequently, however, lucidity occurs spontaneously, as a developmental glitch, a side effect of brain maturation in adolescence. It is also likely influenced, at least in part, by subcortical processes. This is further supported by the observation that in many dreams, the realization that this is just a dream is the result of *just knowing*; it is a spontaneous insight, rather than the outcome of a conscious reasoning process, and hence cannot be regarded as an intellectual achievement. Future research should aim to determine more precisely the factors that underlie the onset and maintenance of lucidity.

Again, similar questions can also be applied to the study of spontaneous thought in wakefulness. A first step would be to investigate the timing and duration of mind-wandering episodes themselves: Can they be ascribed to a breakdown in attention and control over one's conscious thought processes? Or are they governed by a similar internal rhythm as is the case for non-lucid dreams? If fluctuations in waking conscious thought were found to be regulated by an internal clock, this would profoundly impact a host of educational and therapeutic measures.

Attempting to deliberately prevent or reduce the occurrence of mind-wandering might then appear as similarly futile as attempts to reduce, over long periods of time, the amount and timing of sleep. The investigation of disturbed sleep and its relation to mind-wandering would also seem to be central in this context.

But the contrast between lucid and non-lucid dreaming might also elucidate the role of metacognitive insight and control for spontaneous thought in wakefulness. For example, what exactly are the cognitive mechanisms underlying insight into the fact that one's mind has wandered, and to what extent can this be trained deliberately, as for instance in mindfulness meditation? There is, of course, a long tradition in Indian philosophy and contemplative traditions linking mindfulness to lucid insight in dreams (Thompson, 2014). Recently, it has also been suggested that lucidity is not restricted to dreaming, but that meditation might also enhance lucid awareness of dreamless sleep (Thompson, 2015a, 2015b; Windt, 2015b; Windt et al., 2016). A next step would be to investigate this relationship in more detail. How exactly do different styles of meditation enhance the frequency of lucidity in dreams and in dreamless sleep, but also in waking mind-wandering? Do experienced lucid dreamers report fewer episodes of waking mind-wandering, perhaps because they more easily notice when their thoughts are about to drift away from an ongoing task? Or do they experience more frequent and more vivid daydreams, but are simultaneously more aware of mind wandering throughout the episodes? To what extent, in other words, are metacognitive insight and control compatible with spontaneous thought in wakefulness, much as we have been arguing is the case for dreaming (see also Fox & Christoff, 2014; for a discussion of intentional versus unintentional mind-wandering and their relation to mind-wandering with and without awareness, see Seli et al., 2016a, b)?

Finally, the experimental induction of lucid dreams via tACS raises a number of questions about the nature of lucidity itself. Is the transition between lucid and non-lucid dreaming really as sharp as suggested by enthusiastic descriptions in the literature, where lucidity is often said to involve an all-pervasive change in the clarity of imagery and reasoning? Or do lucid dreams rather lie on a continuum with non-lucid ones, with pre-lucid dreams, false awakenings, tacit lucidity, dissociative phenomena, and control occupying intermediate positions on the spectrum? If lucid insight, as suggested here, often exists alongside the types of spontaneous cognitive processing, including erratic reasoning, that characterize many non-lucid dreams, this would suggest that the difference between lucid and non-lucid dreams is gradual rather than absolute.

But we can also ask about the necessary and sufficient conditions for the induction of dream lucidity at the level of brain activation. We have already pointed out that 40 Hz activity in prefrontal areas appears to be necessary but not sufficient for dream lucidity. This is closely linked to the question of whether, as we tentatively proposed in the second section of this chapter, lucid REM sleep can be identified as a separate substage of REM sleep. If so, this could lead to a refinement of sleep-stage scoring criteria as well. To achieve this, the experimental induction of lucidity will have to be optimized in order to turn lucidity into a predictable and easily replicable phenomenon. Future research should aim to determine the precise duration and strength of stimulation that is sufficient to induce lucidity, even in inexperienced participants. A next step would be to investigate the effect of 40 Hz stimulation outside of REM sleep. Would stimulation not only in waking participants, but also in NREM sleep increase the probability of insight and control over ongoing thought content, as well as dissociative phenomena? For instance, might stimulation lead to perspective changes in ongoing daydreams? Interestingly, Axelrod, Rees, Lavidor, Bar (2015) have recently reported that the application of transcranial direct current stimulation (tDCS) to lateral prefrontal areas increases the number of episodes of mind-wandering. However, as Fox and Christoff (2015) point out, the actual effect may have been an enhancement of meta-awareness of mind-wandering, prompting a higher number of reports, instead of an actual increase in the frequency of mind-wandering episodes. If so, this would again suggest that insight and spontaneous thought are not just consistent, but perhaps intimately and systematically related.

Clearly, researchers are only beginning to address these questions, and many of the points we make throughout this chapter are preliminary and speculative. But we hope that they are nonetheless useful in identifying points of contact between emerging lines of research that so far remain largely separate: the scientific investigation of dreaming, including lucid dreaming, and research on mind-wandering and spontaneous thought in wakefulness. Bringing these lines of research together is, we think, a promising and exciting project for the future, and we hope to have shown how the analysis of dream lucidity can contribute to this, both theoretically and experimentally.

Notes

1. Note that on a purely semantic level, task- and stimulus-independence do not appear to be necessary for spontaneous thought. One might well have spontaneous thoughts about a task to which all of one's attentional resources are currently directed and in which one is fully absorbed; and these thoughts might well be triggered by environmental stimuli. In our definition, these cases still count as spontaneous to the extent that they are only weakly constrained, rather than directly determined, by the tasks and/or external stimuli they are arising in response to. This is a subtle difference, but it opens the door to saying that spontaneous thoughts can be task-relevant, for instance by being guided by unconscious goal representations. Empirical evidence suggests that goals can indeed be activated and pursued automatically; explicit awareness of one's intentions is apparently not necessary for the guidance of goal-directed behavior (Bargh et al. 2001). We return to this point later, in section 3. For now, we merely want to emphasize that there is no conceptual contradiction involved in saying that spontaneous thought can be goal-directed and can contribute to the solution of ongoing tasks.
2. Simulation views also give a clear sense to types of experience occurring in sleep that do not count as dreamful because they are not immersive and lack the experience of a self in a world (Windt et al., 2016). Asking how these types of dreamless sleep experience relate to spontaneous thought in wakefulness is an important question for future research.
3. A related question, which is mostly confined to the philosophical literature and tends to run parallel to the discussion of dreaming in the context of psychological and neuroscientific theories of mind-wandering and spontaneous thought, is whether dreaming involves the same kind of mental state as perceiving and hallucinating or whether dreams are imaginative experiences. The imagination view of dreaming is sometimes tied to the phenomenological claim that dreaming actually feels like daydreaming and imagining (McGinn 2009; Ichikawa 2009); the experience of presence in a dream is, in this view, similar to being deeply absorbed in a novel or movie. This view has interesting consequences for thinking about the relationship between dreaming, imagination, and control. While spontaneous thought and mind-wandering are typically described as involving a *loss* of control, imagination, at least in the philosophical literature, is often held to be active and controllable and is contrasted with the passive character of perception. The challenge then becomes how to account for the seemingly passive and uncontrolled nature of dreaming. Here, a common move is to say that dreams, like imaginings but unlike percepts, are not actively controlled, but are nonetheless subject to the will (Ichikawa, 2009) or even the product of unconscious authorship involving a psychic split between the dream self, or the audience of the dream, and the dream producer (McGinn, 2009). There are numerous issues in the background, and this is not the place to enter into this debate in any detail (but see Windt, 2015a, Chapter 6); but it is noteworthy that the imagination view construes the relationship between dreaming and control in a way that is diametrically opposed to the claim that dreaming is a spontaneous, uncontrolled process.
4. A particularly interesting question is whether thoughts experienced within a dream are experienced as spontaneous or as deliberately caused. Do we experience ourselves, in other words, as cognitive agents in our dreams? A related question that is only beginning to be explored is whether phenomena such as thought insertion and auditory verbal hallucinations, which are frequent in schizophrenia and are likely related to a disturbance in agency, exist in dreams. See Rosen (2015) for discussion.
5. It is also possible, however, that similar temporal patterns exist for spontaneous waking thoughts as well. Older research indicates the existence of a circadian rhythm in spontaneous, task-unrelated thoughts (Giambra & Rosenberg, 1989), and there may also be a general association between mind-wandering, sleep quality, and chronotype (Carciofo et al., 2014).
6. Interestingly, Fox et al. (2014) found a mild positive bias in all studies on mind-wandering, regardless of whether recordings were collected in the laboratory or at home. Further investigating this question in relation to dreaming might shed light on the complex relationship between mind-wandering and well-being (Franklin et al., 2013; Ruby et al., 2013).
7. One way of understanding this study, consequently, is that it sets out from the folk-psychological distinction between lucid and non-lucid dreams—as measured by what participants score as a lucid dream—and seeks to render it more precise by identifying those factors that most strongly distinguish lucid and non-lucid dreams. The reasoning behind this approach is that this will lead to a theoretical account of lucidity that is both theory-driven and empirically plausible—and that, because of its grounding in folk psychology, is also likely to match participants' understanding. This last point is important because lucid dream research, as is the case for all dream research, is constrained, for methodological reasons, by dream reports (Windt 2013, 2015a).
8. Unless indicated otherwise, all of these examples are unpublished reports from the experiments described in Voss and colleagues 2009, 2013.
9. This is strikingly reminiscent of a finding that when participants are asked to imagine famous persons, visual images of individuals from the black-and-white media era, such as Albert Einstein, are also experienced as less colored (Pearson & Hollings 2013).
10. The observation that lucid dream control often brings about unintended effects also fits in well with findings on thought suppression in wakefulness. In the white-bear effect (Wegner et al., 1987; Wegner & Zanakos 1994), attempting to control one's thoughts by suppressing certain types of thought contents ironically enhances exactly those kinds of thoughts one wanted to avoid—for instance, white-bear thoughts. The effect has also been investigated for sleep-onset imagery. In one study, participants often dreamed about persons they had been asked to *not* think about before sleep—and they were more likely do so than participants who had been asked to think about the target person (Wegner et al., 2004). In another study, suppressed thoughts seemed to occur in exactly those contexts that the participants had used as distractors. For instance, one participant had talked about her parents' garden to suppress white-bear thoughts during wakefulness. As she drifted off to sleep, she saw

    > a picture of cherries with a text column alongside, which resembled a recipe in a magazine she had read in the afternoon as she explained in the morning

interview. Then, a vision of a myriad of small leaves pervaded her mind, abruptly followed by an image of a fern in a pot on the white, round table in her parents' garden. At this point, the picture of the face of a white bear intruded upon her. (Schmidt & Gendolla 2008, p. 721)

The resurfacing of suppressed thoughts—including feelings of regret, shame, and guilt—at sleep onset and in the presleep period may even be associated with disturbed sleep and insomnia (Schmidt & van der Linden 2009, 2013; see also Schmidt et al., 2011). The general picture seems to be that when control is relaxed, both before sleep, but also at sleep onset, unwanted thoughts return. It would be interesting to explore how this is related to cases in which lucid dream control leads to unexpected or even unwanted results. A prediction would be that because the maintenance of lucidity and the exercise of dream control involve a sense of effort, resulting cognitive depletion may actually foster spontaneous and perhaps even unwanted cognitive processes—including, perhaps, the total or partial loss of lucidity itself, as well as lucidity lapses (see later discussion).

11. In other scenarios, the conclusion that one is awake might even be rational by waking standards: presumably, dreamers could diligently engage in reality testing, and the results could consistently but falsely indicate that they are indeed awake. This would correspond to the classical Cartesian scenario of dream deception.

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CHAPTER

30 Microdream Neurophenomenology: A Paradigm for Dream Neuroscience

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Abstract

The fleeting dream images of sleep onset afford a rare glimpse at how experience is transformed from the perceptually grounded consciousness of wakefulness to the hallucinatory simulations of dreaming. These images, or *microdreams*, are briefer, simpler, and more accessible to phenomenological scrutiny than are the long REM dreams traditionally recorded in the sleep lab. This chapter shows that a focus on microdream phenomenology has thus far contributed to (1) developing a classification system for dreaming's core phenomenology (*Windt`s oneiragogic spectrum*), (2) establishing a structure for assessing dreaming's multiple memory inputs (*multi-temporal memory sources*), (3) furthering Silberer's project for sleep onset imagery by uncovering two new types of imagery (*autosensory imagery, exosensory imagery*), and (4) providing a larger framework for explaining some microdreaming processes (*multisensory integration approach*). A continued focus on microdream neurophenomenology may help resolve outstanding questions about dreaming's core features, neurophysiological correlates, and memory sources.

Key Words: sleep onset, dreaming, neurophenomenology, microdream, neurophysiology, memory

Introduction

Nightly transitions into sleep are, typically, brief and uneventful. But in the sleep laboratory these transitions afford a unique opportunity to observe how consciousness shifts abruptly from veridical waking perception to hallucinatory dreaming simulation. The present chapter focuses specifically on these brief transitions. It considers imagery in the sleep-onset transition as an alternative object of study to dreaming as traditionally studied in the sleep lab. Because of their simplicity and accessibility, the microdreams of sleep onset may help resolve some of the more intractable problems of dreaming research—especially questions about dreaming's neurobiological correlates and its representational sources in memory.

Limits of Traditional REM Sleep Dream Studies

The discovery that vivid dreaming accompanies recurrent bouts of rapid eye movement (REM) sleep (Aserinsky & Kleitman, 1953; Dement & Kleitman, 1957) was heralded as a major methodological breakthrough for the study of dream neurophysiology. The advantages were clear: investigators now possessed a method that gave immediate and predictable access to a vast reservoir of oneiric activity—activity that could be recorded in near-real time with a minimum of distortion and under controlled experimental conditions. Researchers were quick to exploit REM sleep to address fundamental questions about dreaming, such as: *Is there a biological need for dreaming?* and *How does dreaming vary with sleep stage?* And although progress was made on some fronts using these laboratory methods, many fundamental questions about dreaming remain unanswered. In particular, questions about the *neurophysiological correlates of dreaming* have not been satisfactorily resolved, despite repeated attempts to assess both macro- and micro-physiological sleep events in the laboratory. Rechtschaffen's (1978) early theoretical paper signaled a frustration with research's inability to find such correlates, declaring dreaming to exist in isolation from "organismic state" variables. Later, Pivik's (1991) comprehensive review concurred in finding no persuasive evidence for a pattern of physiological changes accompanying the presence, vividness, or specific contents of dreaming in either REM or non-rapid eye movement (NREM) sleep. This was the case even when very brief or "phasic" measures of physiological fluctuation were assessed. He suggested that researchers may be "demanding an impossible degree of introspective precision from subjects" (1991, p. 247). Evidence supporting psychophysiological isomorphism was so scant that Foulkes (1985, p. 4), one of the principal laboratory-based researchers at the time, considered psychophysiological studies to have failed and abandoned them in favor of a more strictly cognitive framework for understanding dreaming.

More recently, the situation has improved only slightly. Some insights into the neurophysiology of dreaming have been gleaned from neuropsychological assessments of brain-lesioned individuals (e.g., Doricchi & Violani, 1992; Solms, 1997) and from neuroimaging and polysomnographic studies of REM sleep (Cipolli, Ferrara, De Gennaro, & Plazzi, 2016; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013), but the relationships uncovered remain relatively imprecise and fall short of clarifying either the specific brain networks that sustain dreaming or the electrophysiological measures that reliably index it (see also, in this volume, Domhoff, Chapter 27, and Fox & Girn, Chapter 28). One approach that has provided some clarity treats REM sleep as a neuromarker for the presence of dreaming and relates neural changes in REM sleep (relative to wake) to general phenomenological characteristics of dreaming (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013). To illustrate, using meta-analytic methods, Fox et al. (2013) found relative activation, during REM sleep, in neural circuits that normally subserve high-level visual processing (hippocampal place area, fusiform gyrus, lingual gyrus) and episodic memory processing (parahippocampal cortex, entorhinal cortex)—both common features of dreaming—but relative deactivation in circuits subserving higher-level cognition (prefrontal cortical regions). These findings have been interpreted (Domhoff & Fox, 2015) to provide convergent validity for findings from brain lesion patients (e.g., Solms, 1997), but nevertheless fall short of providing hard evidence for the neurophysiological correlates of specific types of dream content.

And even among the many studies that have attempted to link dream recall or attributes of dream content with specific neurophysiological indicators, most commonly electroencephalograph (EEG) measures, mixed results have been reported, at best. To illustrate, researchers have found the recall or the vividness of REM sleep dreams to be preceded by reduced alpha power (Bertolo, Paiva, Pessoa, Mestre, Marques, & Santos, 2003; Esposito, Nielsen, & Paquette, 2004), especially reduced frontal alpha power (Chellappa & Cajochen, 2013); but others report associations with reduced delta power (Esposito et al., 2004; Siclari, Baird, Perogamvros, Bernardi, LaRocque, Riedner, Boly, Postle, & Tononi, 2017), reduced frontal beta power (Chellappa, Frey, Knoblauch, & Cajochen, 2011), reduced 4 to 14 Hz power (Lehmann, Dumermuth, Lange, & Meier, 1981), increased 40 Hz power (Llinas & Ribary, 1993), increased occipital gamma power (Siclari, et al., 2017), increased occipital beta power (Chellappa et al., 2011), and increased theta power (Marzano, Ferrara, Mauro, Moroni, Gorgoni, Tempesta, Cipolli, & De Gennaro, 2011; Scarpelli, D'Atri, Gorgoni, Ferrara, & Gennaro, 2015). Similarly for NREM sleep, while some studies again find dreaming to be associated with reduced alpha activity (Esposito et al., 2004; Hong, Jin, Potkin, Buchsbaum, Wu, Callaghan, Nudleman, & Gillin, 1996), others report reduced delta (Chellappa et al., 2011; Esposito et al., 2004; Siclari, et al., 2017), reduced 12 to 15 Hz (spindle) activity, increased beta power (Williamson, Csima, Galin, & Mamelak, 1986), increased occipital gamma power (Siclari, et al., 2017), or no differences at all (Morel, Hoffmann, & Moffitt, 1991). Thus, while some EEG studies converge in identifying reduced alpha power as a correlate of dreaming, others suggest a variety of different markers. There is even less evidence that specific EEG signatures accompany specific qualities of dream content, such as emotion, color, or complexity (but see Siclari, et al., 2017 for a preliminary study).

The discovery shortfall in dream neuroscience may be due, paradoxically, to an overabundance of information—both phenomenological and neurophysiological. Research has attempted to quantify, in parallel, extended multisensory episodes of dreaming on the one hand, and multifactorial arrays of neurophysiological information on the other. Yet, approaches that attempt to align such complex phenomena are largely unstandardized, with little agreement on what levels of description and types of measurement are appropriate to assess phenomenal and physiological events in parallel. This is ultimately a problem of isomorphic mapping (Nielsen, 2000) or, more recently, of delineating the neural correlates of consciousness (Hohwy & Bayne, 2015).

The pitfalls of undertaking such a multicomponent task are too numerous to enumerate here, but they include factors such as use of subjects who are untrained in the introspective reporting of dreams, failure to control for inaccuracies in recalling and reporting long dream sequences, assessment of EEG signals in the frequency (not the time) domain, and use of broad-band EEG definitions (alpha, theta, etc.) and a limited number of EEG leads (e.g., C3), among others.

Despite the scarcity of discovery and the methodological pitfalls in previous research, there has been no shortage of speculation about dreaming's neurophysiological basis. REM sleep has routinely been treated as a proxy for dreaming, and REM sleep mechanisms largely equated with dreaming mechanisms. This allowed early investigators to propose dreaming theories, such as the activation-synthesis model (Hobson & McCarley, 1977) or the genetic programming model (Jouvet, 1998), that were supported principally by animal studies of REM sleep. More recent human neuroimaging studies have also enabled speculative theories (Domhoff & Fox, 2015; Maquet, Ruby, Maudoux, Albouy, Sterpenich, Dang-Vu, Desseilles, Boly, Perrin, Peigneux, & Laureys, 2005; Pace-Schott, 2005) but, again, most such studies have not assessed whether dreams were present during the brain scans, nor have they correlated dream content attributes with neural activity patterns; studies by Maquet's group (Maquet, Péters, Aerts, Delfiore, Degueldre, Luxen, & Franck, 1996) and Gottschalk's group (Gottschalk, Buchsbaum, Gillin, Wu, Reynolds, & Deborah, 1991; Gottschalk, Buchsbaum, Gillin, Wu, Reynolds, & Herrera, 1991) constitute a few important exceptions.

In sum, the laboratory methods of REM-period awakenings for sampling dreaming have not resulted in a decidedly clearer portrait of dreaming's neurophysiological underpinnings. While there is convergence from some domains, on the whole findings are mixed (e.g., EEG) or based on interpretations of REM sleep neurophysiology (e.g., PET). Rather, it may be that the overabundance of information and an intractable isomorphic mapping problem have prevented researchers from demonstrating reliable relationships between these two domains of measurement—neurophysiological theories notwithstanding.

An Alternative Approach: Microdynamic Neurophenomenology

Alternative methods that may hasten discovery in dream science focus on the microdynamics of dreaming. One neurophenomenological approach (Petitmengin & Lachaux, 2013) applicable to dream science employs a convergence of phenomenological and neural descriptions aimed at brief cognitive events. The phenomenological component of this approach describes the microdynamics of brief experiential events. Applied to imagery, the approach employs a mode of attending to features of "how" an experience appears, rather than "what" appears in it (Petitmengin & Lachaux, 2013):

> . . . if a mental image is emerging into our consciousness, we have to reorient our attention from the content of the image (for example a blooming cherry tree), toward the dynamics of appearance, the genesis of this content: the rapid phases which precede its stabilization, and at each phase, the subtle inner micro-gestures that we perform to elicit, stabilize, recognize, evaluate, rule out, or enrich this image. Becoming aware of this microdynamics requires a particular mode of attention, which is both unfocused, diffuse, receptive, and very acute, sensitive to the most subtle discontinuities. (Petitmengin & Lachaux, 2013, p. 2)

Petitmengin explores various methods for applying this attentional mode: "first-person" accounts, "second-person" elicited descriptions, autobiographical reports from trained individuals (e.g., poets, meditators), and others (Petitmengin, 2006; Petitmengin & Bitbol, 2009; Petitmengin & Lachaux, 2013). Thus, using an *elicitation interview* (Petitmengin, 2006; Petitmengin & Lachaux, 2013), Petitmengin successfully elicited descriptions of subtle early signs of epileptic seizures or of how a concept matures from a "fuzzy and blurred" feeling to a "clear and distinct" idea. First-person applications have allowed her to describe the pre-reflective, pre-conceptual "source" of thoughts (Petitmengin, 2007) and the introspective process itself (Petitmengin & Bitbol, 2009). Such microdynamic phenomenology has not yet been attempted for dream experience; there may be practical obstacles to doing so, as summarized previously. But the approaches are particularly well-suited for brief dreaming events occurring at sleep onset. I developed a first-person self-observational approach to study sleep-onset imagery (Nielsen, 1995) and subsequently adapted it to a second-person approach for use with untrained laboratory subjects (Germain & Nielsen, 2001). The first-person method is the basis for the discovery of two new microdream phenomena reported in later sections.

For the neural analysis component of the microdynamic approach, intracranial EEG (iEEG) has been given particular attention. iEEG has been applied successfully to the study of object naming (Hamame, Alario, Llorens, Liegeois-Chauvel, & Trebuchon-Da Fonseca, 2014), face processing (Musch, Hamame, Perrone-Bertolotti, Minotti, Kahane, Engel, Lachaux, & Schneider, 2014), perceptual learning (Hamame, Cosmelli, Henriquez, & Aboitiz, 2011), and visual imagery (Hamame, Vidal, Ossandon, Jerbi, Dalal, Minotti, Bertrand, Kahane, & Lachaux, 2012). iEEG has the advantage of providing fine time resolution (in the order of milliseconds), fine spatial resolution (in the order of cubic millimeters), single-trial precision (high signal-to-noise ratio) and even real-time feedback. While iEEG is not practical for use with non-epileptic subjects, the feasibility of microdynamic neural approaches is supported by advances in brain imaging, such as the delineation of EEG microstates (Milz, Faber, Lehmann, Koenig, Kochi, & Pascual-Marqui, 2015) and the development of high-density EEG procedures (Mouthon & Huber, 2015), together with increasingly precise descriptions of sleep-onset EEG events.

In sum, rather than grappling with the overly large data sets of traditional research, dream science could benefit from focusing a microdynamic lens on the neurophysiological fluctuations that accompanying ultra-brief sleep-onset images.

Historical Antecedents to Microdynamic Dream Study

A handful of studies have anticipated, and support the feasibility of, microdynamic approaches to dream neurophenomenology. These have delimited the amounts of dreaming and accompanying neurophysiology to test specific isomorphism hypotheses. In one early study (Gardner, Grossman, Roffwarg, & Weiner, 1975), subjects reported only the last 15 seconds of dream content, starting with the last item recalled (and remembering in reverse order), and these were assessed against quantified occurrences of upper and lower dream limb movements; electromyogram (EMG) tracings revealed significant correspondences between dreamed movements and real limb activity that occurred within 5 seconds of waking up. At an even finer scale of measurement (Herman, Erman, Boys, Peiser, Taylor, & Roffwarg, 1984), subjects were trained to report only the last "few seconds" of dreamed content, paying particular attention to virtual reorientations of the eyes and head, while real eye movements (EOG) occurring immediately before waking up were recorded. Again, correspondences between the directionality of dreamed and real eye movements were found. Two studies (Foulkes & Pope, 1973; Molinari & Foulkes, 1969) applied a similar approach to test a *tonic-phasic* model, which predicts that dream contents will differ for sleep periods whose physiology is relatively constant in nature (tonic), that is, containing no phasic activations such as eye movements or sawtooth waves, versus those that do contain such brief activations (phasic). Subjects reported their "very last experience" before awakening with polysomnography (PSG) signals being assessed for rapid eye movements and sawtooth waves within 10–30 seconds of awakening. REM-phasic awakenings were associated with discrete sensory dream events like seeing (88%) more often than were REM-tonic awakenings (20%); the latter were associated more with conceptual content like thinking or wondering (80%) than were the former (12%).

A final example relevant specifically to sleep-onset microdreaming (Germain & Nielsen, 2001) had subjects signal precisely when brief dream images appeared in awareness. EEG activity was sampled from 9 seconds preceding the signal, subjected to spectral analysis and compared with wake EEG taken 35 seconds earlier. Specific relationships between subject-reported image modality and EEG frequency and topography were found; kinesthetic images had higher delta power in frontal regions (Fp1, Fp2, F3, Fz, F8) than did visual images, and visual images had higher delta power in a dispersion of mainly left central and temporal leads (F7, C3, Cz, T3, T5).

These studies demonstrate the feasibility of applying microdynamic methods to the laboratory study of brief dream imagery and its neural correlates, but especially to imagery occurring at sleep onset. While the question of isomorphism remains unresolved, these studies converge in suggesting that neural correlates may be found when very brief imagery samples are targeted. They also raise the important issue of widening the scope of physiological measurement beyond the EEG, as other measures such as the EMG and EOG appear sensitive to the multifactorial correlates of dreaming including, especially, its kinetic or movement features.

The Spectrum of Sleep-Onset Imagery

Multiple studies (see reviews in Mavromatis & Richardson, 1984; Oswald, 1962; Schacter, 1976; Vogel, 1991) attest to the presence of vivid dreams during the sleep-onset transition (Ogilvie, 2001), dreams that vary considerably in structure, specificity, length, clarity and presence or absence of different sensory modalities (Figure 30.1). Both anecdotal and empirical studies identify a resplendent variety of imagery, ranging from very elaborate and dream-like to extremely simple and almost subliminal. This spectrum includes images that appear to arise out of the waking state. At one extreme are the complex elaborate dreams that accompany sleep-onset REM (SOREM) and partial SOREM episodes. Their commonness is revealed by the fact that 13%–23% of normal subjects exhibit at least one SOREM episode on the standardized Multiple Sleep Latency Test (Bishop, Rosenthal, Helmus, Roehrs, & Roth, 1996; Singh, Drake, & Roth, 2006); in fact, as little as one hour of nighttime sleep disruption can induce SOREM episodes when subjects return to sleep (Fukuda, Miyasita, & Inugami, 1987; Miyasita, Fukuda, & Inugami, 1989).

Partial SOREM episodes, during which some (but not all) signs of REM sleep are visible, are also common; episodes of muscle atonia—a defining feature of REM sleep—are particularly likely to occur at sleep onset, a phenomenon referred to as *muscle atonia in NREM sleep*, or MAN (Tinguely, Huber, Borbely, & Achermann, 2006; Werth, Achermann, & Borbely, 2002).

Less complex and elaborate dream imagery occurs in NREM Stage 1 (N1) and Stage 2 (N2) sleep. However, recall of any item of dream imagery is high at these times, 90%–98%, for sleep-onset stages N1 and N2 (Figure 30.2; Foulkes & Vogel, 1965; Vogel, 1991); even higher than the average level (80%) for nocturnal REM sleep (Nielsen, 2000). More complex dreaming, defined as involving hallucinated dramatic episodes, is more scarce from N1 and N2 (31%–76%; Vogel, 1991) than from REM sleep. At the other extreme of this spectrum are the microdream images most suitable to a microdynamic analytic approach. These tend to occur during drowsiness and waking reverie and, although they appear to be less elaborate or complex than images from other sleep stages, nonetheless share the pseudohallucinatory qualities of the latter.

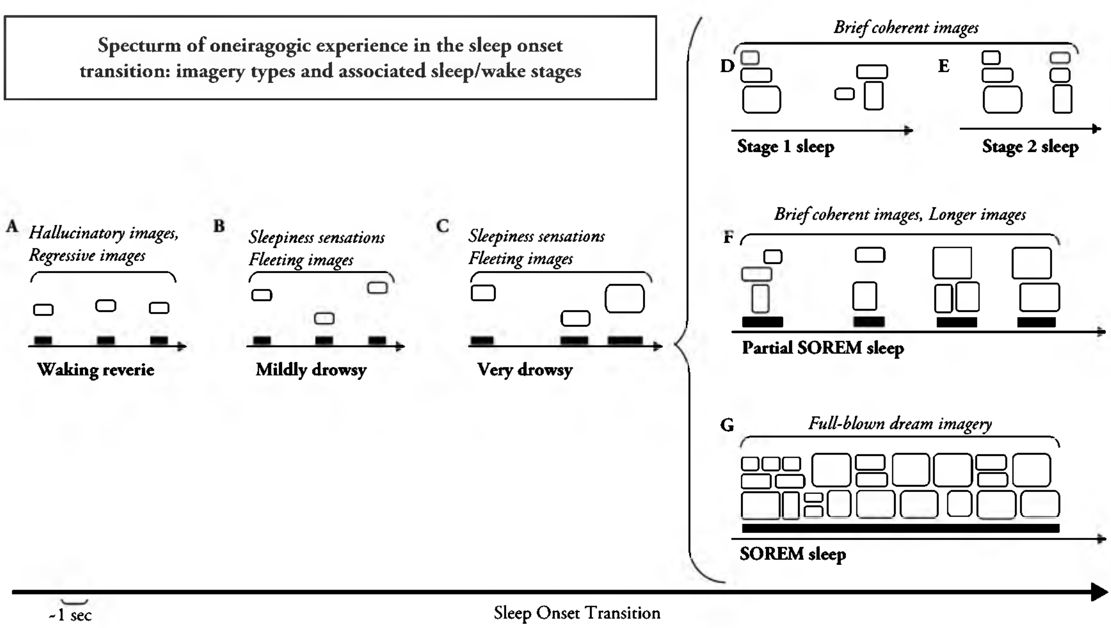

Figure 30.1. (See Color Insert) Some varieties of experience falling on the oneiragogic spectrum (i.e., the phenomenological events characterizing the sleep-onset transition). Experiences of increasing complexity are proposed to occur during passage through different sleep-onset states, as described in the text. The briefest and least complex events are presumed to occur during microsleeps that may take place during (A) waking reverie (blue bars) or (B) mildly or (C) very drowsy wakefulness (red bars) and more complex events during (D) Stage 1 and (E) Stage 2 NREM sleep (purple bars). Longer images and full-fledged dreaming occurs during either (F) Partial SOREM sleep, when only some signs of REM sleep (e.g., muscle atonia, alpha EEG reduction) are visible (green bars), or (G) SOREM sleep, when all basic signs of REM sleep are visible. SOREM events are very prevalent, occurring under various situations of sleep disruption, including especially combinations of low NREM and high REM propensity.

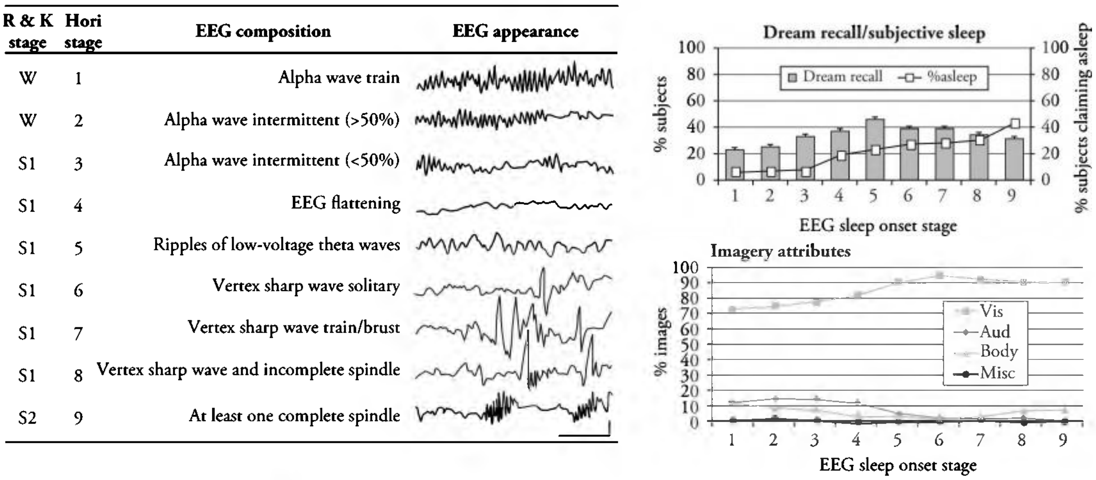

Figure 30.2. (See Color Insert) Left panel: definitions of Hori sleep-onset substages (Hori stage) in relation to standard Rechtschaffen and Kales sleep/wake stages (R&K stage). Right panel: Percentages of subjects reporting dreams and claiming to be asleep (upper panel) and sensory attributes of reported imagery for 9 EEG-defined sleep-onset substages. Note that visual imagery can occur in the earliest substages. W = wake; S1 = stage 1; S2 = stage 2. *Source*: Hori, Hayashi, & Morikawa, (1994).

More detailed analysis of the physiological changes accompanying sleep-onset imagery (Hayashi, Katoh, & Hori, 1999; Tanaka, Hayashi, & Hori, 1998a, 1998b) led to a subdivision of standard W, N1, and N2 stages into a progression of nine, more precise, EEG-based substages (Figure 30.2, left panel). Subjective sleepiness ratings validate the claim that these Hori sleep-onset (HSO) stages reflect a gradual progression into sleep. However, the likelihood of recalling dream mentation is present to some degree even at HSO stage 1, and increases progressively up to stage 5 (Figure 30.2, upper right, bars). Assessment of imagery attributes (Figure 30.2, lower right) reveals that visual quality is high for all substages, but reaches a plateau at stage 5, at which point the incidence of all other sensory attributes diminishes. Together, the results suggest that dreamlike imagery is particularly apt to arise early in sleep onset, when alpha drops out and theta appears (HSO stages 4–5). Our own study (Germain & Nielsen, 2001), which used a phenomeno- rather than a neuro-centric[1] method for sampling spontaneously arising images, confirmed this: the vast majority of images signaled (93.4% or 112/120) were from HSO stages 4–5.

Finally, dreamlike imagery is sometimes reported when objective and subjective measures indicate wakefulness; almost 25% of reports in two studies of quiet wakefulness were dreamlike and distinct from waking mentation such as mind-wandering or being lost in thought (Foulkes & Fleisher, 1975; Foulkes & Scott, 1973). As these studies remain unreplicated, it is unknown whether the observed images are distinct attributes of waking-state imagery or, in fact, microdreams for which the sleep signs were too subtle to quantify with methods available at the time. They may have occurred during *microsleeps*, which are sleep intrusions as brief as a fraction of a second (Tirunahari, Zaidi, Sharma, Skurnick, & Ashtyani, 2003). Microsleeps are associated with localized deactivations of the brain in some regions (thalamus, posterior cingulate, occipital cortex) and localized activations in others (frontal, posterior parietal, parahippocampal) and display the smallest brain changes when they are the briefest (0.5–5 s) (Poudel, Innes, Bones, Watts, & Jones, 2014). Subjects commonly—sometimes adamantly—deny having slept during microsleep episodes, despite clear electrophysiological (e.g., EEG) and behavioral (e.g., response failure) evidence to the contrary (Oswald, 1962, pp. 63–65). Oswald (1962) attributes this denial to the failure of introspective capacities while subjects are momentarily unconscious.

An Oneiragogic Spectrum

Windt (2010, 2015), better than any previous author, offers a comprehensive framework for describing the variety of sleep-onset imagery, which she dubs the spectrum of *oneiragogic experience.* This new term refers to the progression of phenomenological events leading from drowsy wakeful perception to full-fledged dreaming (Table 30.1, items

Table 30.1 Summary of the Oneiragogic Experiential Spectrum Including Five Constitutive Dimensions and a Proposed Amendment

ISTH Dimension	Description	Simple Extreme (Closer to Waking)	Complex Extreme (Closer to Dreaming)
1. Visuospatial scene	The sense of being located at a specific point in a larger spatial expanse ("here")	Isolated, static	Dynamic, prolonged, immersive
2. Phenomenal embodiment	Progression from passive observation to active participation	Partial body awareness (e.g., sleepiness feelings)	Full-body awareness
3. Temporal reference frame	The sense of being located in a specific moment within a succession of moments ("now")	Brief, isolated instant	Prolonged, organized narrative
4. Waking memory sources	Integration of recent with increasingly remote memory sources	Recent, episodic memories	Remote, abstract, but semantically-related memories
5. Autobiographical historicity	The sense that an image is part of one's autobiographical experience/memory ("recallability")	Barely graspable as own experience, difficult to recall	Integration in autobiographic memory, easily recalled
6. Kinesis (proposed)	The sense of dynamism, movement	Ultra-brief movements	Complex movements

ISTH = immersive spatiotemporal hallucination.

Source: Windt (2015).

1–5) or "the trajectory underlying the shift in self-location from a perceptual to a hallucinatory (or dreamlike) reference frame" (Windt, 2015, p. 536). In other words, one's sense of immersion in space and time (*here* and *now*) shifts progressively from a veridical framework (the *real* world) to an hallucinatory framework (the *dream* world). She considers the oneiragogic spectrum analogous to, but distinct from, the *hypnagogic state*, which describes a progression of physiological changes from wake to sleep. The oneiragogic spectrum forms part of a broader conceptual framework for dream phenomenology, the *immersive spatiotemporal hallucination* (ISTH) model (see Windt, 2015, Chapter 11). Five dimensions are proposed to constitute the oneiragogic spectrum; I suggest adding a sixth, kinesis, to describe movement quality (Table 30.1, item 6).

Whereas the concept of microdreams has been used by several authors to describe all sleep-onset imagery (see review in Oswald, 1962), the oneiragogic spectrum advances the phenomenological triage of imagery types and facilitates the identification of particularly brief images of interest to the microdynamic approach. I suggest using the term *microdream* in the present context in a more limited sense to refer to those images falling on the simpler extreme of the oneiragogic spectrum.

Microdreaming

Because existing studies have typically treated sleep-onset imagery as of a single type, only rarely are simpler images systematically contrasted with more complex ones, despite the fact that difference in the lengths of dream reports has remained a central methodological concern of researchers who compare REM and NREM dream reports (Hunt, Ruzycki-Hunt, Pariak, & Belicki, 1993). The only systematic studies I am aware of that have attempted to identify the simplest forms of images are my own self-observational studies. From a set of over 250 sleep-onset images recorded under either laboratory or naturalistic conditions, and for which I have presented preliminary phenomenological descriptions (Nielsen, 1991, 1995), I identified a subgroup of images referred to as "fleeting images" but that I now consider a type of microdream. I distinguished these brief images from "fully formed" images in respect to their timing, duration, simplicity, ineffability, and association with sleepiness feelings. In short, fleeting images were found to

- occur in the very earliest stages of a self-observation trial (i.e., during mild drowsiness);
- be so brief that they often require an established intent (if not introspective training) to observe;
- possess primarily unimodal sensory content;
- frequently fall outside of the normal range of experience, thus defying easy description;
- be accompanied by subtle feelings of falling asleep.

Fully formed images, in contrast, were found to

- occur later in the sleep-onset transition;
- be longer and easier to recall;
- possess a more complex, multimodal structure;
- be easier to describe;
- often mask accompanying sleepiness feelings.

Using the oneiragogic spectrum terminology, fleeting images may now be described to

- implicate an isolated spatiotemporal location ("here");
- include a sense of body awareness, however ephemeral (e.g., sleepiness feelings);
- occur in a discrete instant ("now");
- draw upon a few recent, episodic memories (e.g., ongoing sensory stimuli);
- be often barely graspable and difficult to recall;
- possess a subtle kinetic quality (i.e., sensed movement of self or setting).

Fully formed images, in contrast, more closely resemble common dreams. That is, they are spatiotemporally elaborate (multimodal), possess a greater measure of embodiment, are temporally extended, draw upon a wider swath of remote memory elements, are more fully integrated into one's historical context (easily recalled), and are more obviously dynamic in character.

There is still no validated method for distinguishing fleeting microdreams from fully formed images, but the oneiragogic spectrum—possibly with the addition of the kinesis dimension—provides a thorough framework for drawing such distinctions clearly and reliably. With further development, it could serve as a standardized tool for classifying the phenomenological attributes of sleep-onset imagery.

Example of a Microdream

An example of a microdream recorded in our sleep laboratory is shown in Figure 30.3. The precise timing of this primarily kinesthetic image was signaled with a handheld switch, which allowed its accompanying neurophysiological changes to be examined in some detail. EEG, EOG, and EMG changes accompanied an episode of microsleep of about one second in duration, and included a decrease in occipital alpha activity, neck and chin muscle atonia (MAN), and the appearance of slow eye movements.

The image was very brief and unusual in that it consisted of apparent sensations of touch ("knocking") and motion ("moving") that occurred inside the head. On the oneiragogic spectrum, this image displays (1) rudimentary spatiality ("inside"), including vague visuospatiality ("someone else's head"); (2) minimal embodiment ("head"); and (3) minimal temporal extension ("[the knocking] is moving"). There was no report of (4) memory sources, but (5) minimal historicity is suggested by the difficulty in recall ("vague visual impression"). Finally, these attributes possess (6) a clear spatially kinetic character in that the sensations changed dynamically over time ("knocking," "moving"). Note that although the memory sources of this image were not reported or probed, many other images of this type were recorded in the previous study (Nielsen, 1995) and were found to relate directly to sensations that either just preceded the image (e.g., ongoing sensations of cutaneous pressure) or were present as the image emerged (e.g., the head abruptly nodding). This feature is dealt with in more detail in discussion of multi-temporal memory associations in a following section.

Simple oneiragogic experiences such as the one in Figure 30.3 can be mined for evidence of the elusive defining features of dreaming's phenomenal core. These defining features are likely to be *more* easily discernible in simple imagery than in complex REM sleep imagery because simple images *lack* the common, albeit non-essential, features so typical of complex imagery (e.g., emotion, visual/auditory details, or narrative structure). Windt (2015, pp. 517–520) makes the case that dreaming, including especially sleep-onset dreaming, may be purely spatial in nature, an argument bolstered by the observation that congenitally blind subjects report vivid dreaming despite their total absence of visual imagery (Kerr & Domhoff, 2004; Kerr, Foulkes, & Schmidt, 1982).

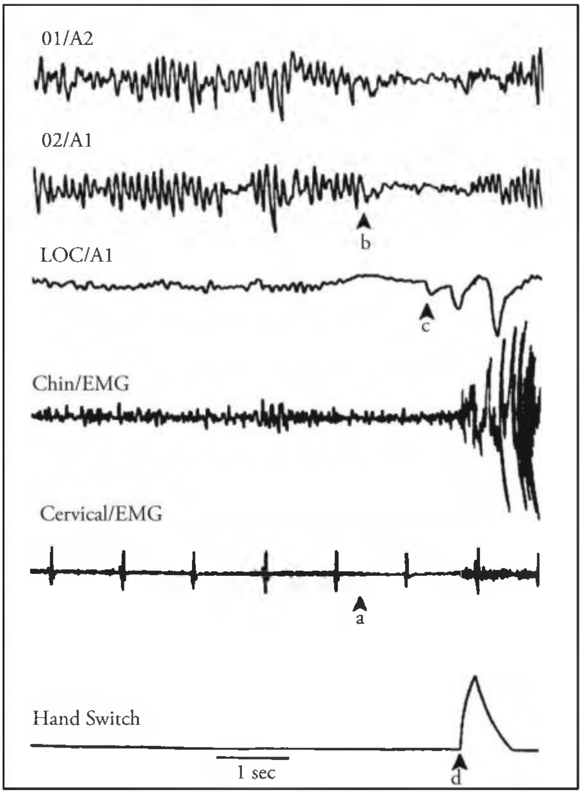

Figure 30.3. Sample microdream recorded using a phenomeno-centric signaling procedure. The signaled image was primarily kinesthetic in nature ("I feel a knocking inside my head and a sense that it is moving; also a vague visual impression of seeing someone else's head"). Recorded correlates of the experience define a microsleep of slightly more than one second in duration, including (a) an abrupt decrease in cervical and chin EMG, (b) a sudden bilateral decrease in occipital alpha waves and the appearance of a low amplitude, slow eye movement on the LOC/A1 channel. This pattern changes abruptly to wakefulness (alpha with movement) at (d) when the end of the image is signaled. The appearance of (c) two brief rapid eye movements just prior to the signal may reflect an oculomotor component to the image or part of an awakening reaction. Cardiac activity is visible on the cervical EMG channel at a steady 60 bpm through the sequence. Source: Nielsen (1995).

Because the available evidence concerning microdreams still stems largely from self-observational studies and because replication studies are still lacking, I continue to consider examples such as the ones presented here to constitute provisional findings—proofs in principle of microdreaming and a basis for the generation of hypotheses to be tested, rather than evidence of established facts. Further, although I claim that microdreams are the simplest form of oneiragogic experience, research with subjects of different personalities and under different conditions and who are highly trained in self-observation may well uncover even simpler images than have been reported thus far. The limits of imagery simplicity remain uncharted. Exploring these limits may well challenge existing findings and methodologies, but such revelations would constitute a welcome outcome of the microdynamic dreaming project.

Spatiotemporal Kinesis

The kinetic attributes of an organism are its capacity to move or react in its environment, usually in response to sources of stimulation. Analogously, an image's kinetic qualities refer to its inherent dynamism, vitality, or moment-to-moment changeability within its hallucinatory context—and possibly also in response to its various memory sources. Full-blown dreaming is clearly kinetic in this respect, rich with immersive self-movement, character actions, and environmental flux that can be linked to memory source elements. However, microdreams, too, express this feature—even in their simplest, most ephemeral forms—and in this respect their phenomenal core is the same as that of dreaming. Kinesis manifests most often as a realistic apparent movement of the self (or part of the self) or of another character, or of an apparent movement felt to take place inside the body. It also manifests as apparent movement of the environment in proximity to the self. But it may even occur in ways that are less obviously related to visuospatial modulation. For example, images containing vivid isometric tension or sensations of an imminent action or impending contact with something else may reflect a variant of spatial kinesis. In this respect, then, my description of microdreams differs somewhat from that of Windt in that I do not view the simple extreme of microdreams to be *static*, as is suggested by her description of the visuospatial scene dimension in Table 30.1. Rather, I hypothesize that microdreams are by nature kinetic and that this feature is as integral to the immersive nature of microdreams as it is to completely hallucinatory dream experiences.

Microdream Memory Sources

The study of microdreams offers unique possibilities for developing experimental methods to clarify how and why images are formed. These possibilities hinge on identifying an image's memory associations—associations that are widely assumed to index the memory sources from which the image derives (Freud, 1900; Nielsen & Stenstrom, 2005). The following sections deal with three advantages of memory source analysis that microdreams confer, including how such work may contribute to the development of experimental methods for investigating imagery formation. These advantages include the following: access to memory sources that arise from multiple time periods (*multi-temporal memory sources*); access to memory sources rooted in waking cognitions and somatic sensations occurring prior to image formation (*autosymbolic imagery*); and access to observations that suggest causal relationships between memory sources and image elements (*autosensory imagery, exosensory imagery*).

ACCESS TO MULTI-TEMPORAL MEMORY ASSOCIATIONS

The memory sources of microdreams are readily accessible even while being restricted in number. Clearly, an image less than a second in duration would be expected to derive from fewer source memories than would a lengthier, REM sleep, dream. Also, because the observation of images occurs so close to a waking state, access to their memory sources may be optimal. Using a self-observational approach, we previously demonstrated both the feasibility of identifying memory sources of sleep-onset images and that these sources are relatively few in number (Stenstrom, Fox, Solomonova, & Nielsen, 2012). Figure 30.4 shows all memories associated with a total of 31 sleep-onset images collected over two nights from a single subject, classified by the memories' times since occurrence. The number of memories for each image is clearly restrained: an average of 2.6±1.1 (range: 1–5) per image.[2] For a majority of these images, memories were drawn simultaneously from both recent and remote time periods, a finding consistent with other research for dream imagery (Verdone, 1965). Further, variations in the temporal distance of these memories from the image suggest that their access may have been modulated by time of night and, possibly, day of week factors. For example, on both Nights 1 and 2 memories for elements that were encountered just prior to sleep (e.g., lab technician, EEG equipment) were clearly reported for the first four images of the night; yet, for Night 2 these very recent memories persisted even for later night images, while for Night 1 they tended to diminish. Such variation may mean that circadian factors modulate access to memory sources (for a review, see Nielsen, 2011) or that habituation to the laboratory and the self-observational method takes place before access to memory sources is completely stable. In either case, this study illustrates the ease of both collecting memory sources at sleep onset and evaluating their temporal distances from a target image.

Sample Memory Source Analysis

The following example describes the memory sources of a single, brief microdream arising from multiple prior time periods. The description further illustrates a hypothetical model that could explain formation of the image (for a detailed presentation of this analysis, see Nielsen, 1995). I suggest a multi-temporal classification of memory sources that consists of four general categories differentiated by their temporal distance from the target image:

1. *Immediate memory*: thoughts, perceptions, and sensations that are ongoing or that occurred only moments before image onset. These might include sensations of pressure in the arms, legs, or neck that manifest as images in which arm, leg, or head movement figures centrally.
2. *Short-term memory*: experiences that occurred minutes to hours prior to image onset. These are relatively easy to identify, occurring only a short time before the observation session.
3. *Medium-term memory*: experiences that occurred one or more days prior to the image. They include previous-day memories (day-residue

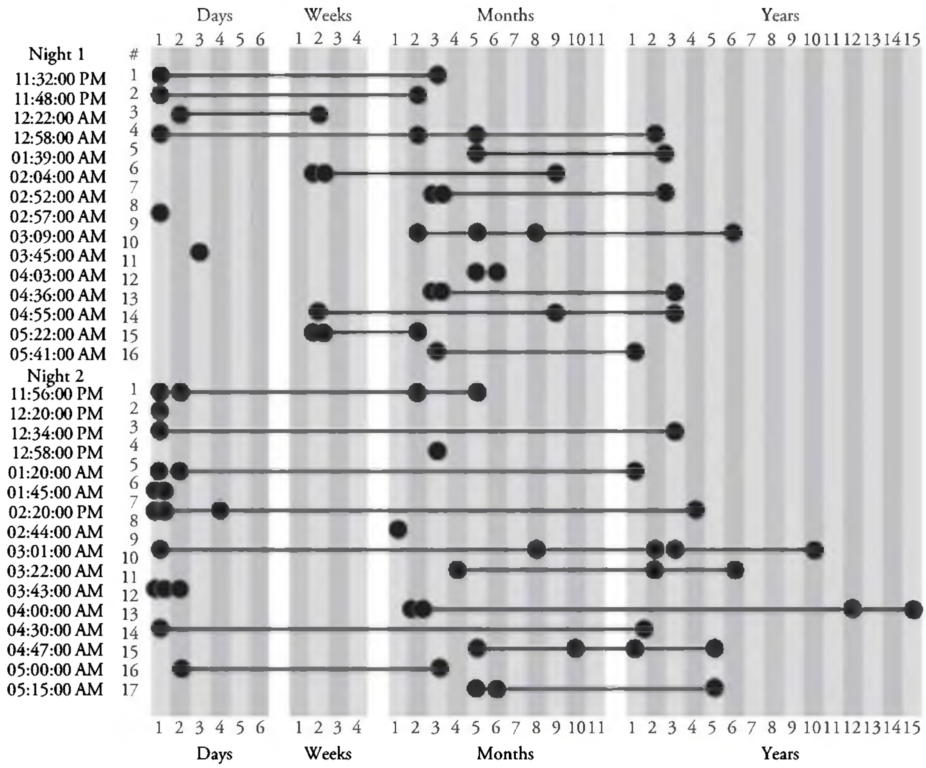

Figure 30.4. Temporal distances between sleep-onset images and their memory sources collected over two nights from a single subject. Circles denote sources situated in time (*x* axis) for images collected over two nights (*y* axis); black lines denote sources from the same image. Source: Stenstrom, Fox, Solomonova & Nielsen (2012).

effect; (Freud, 1900; Nielsen & Powell, 1992) and memories from six to eight days earlier (dream-lag effect; (Nielsen, Kuiken, Alain, Stenstrom, & Powell, 2004; van Rijn, Eichenlaub, Lewis, Walker, Gaskell, Malinowski, & Blagrove, 2015). These may be difficult to retrieve, but access may be facilitated by systematically reviewing events from the previous week.

4. *Long-term memory*: experiences that occurred weeks, months or years prior to the image. These may be difficult to identify reliably and have been investigated only minimally. They are often rooted in declarative memory and thus resemble the "semantic knowledge" memory-source category (Cicogna, Cavallero & Bosinelli, 1991).

Figure 30.5 illustrates a single, one-second microdream (right panel) arranged chronologically (left panel, bottom row). Its associated memory elements are classified according to the four-part scheme (left panel, Y-axis). The memory sources are also arranged in a hypothetical chronological sequence, and hypothetical causal influences among them and the image elements are indicated by black arrows.

A comparison of the image and memory elements suggests that the image is a close, but not exact, reproduction of a medium-term episodic memory fragment (i.e., of performing a quasi-reflexive arm movement during a volleyball game from six days earlier). This portion of the episodic memory[3] possesses a sequential structure that is mirrored in the microdream: the visually perceived approach of the ball, the rapid motor response of the arm, and the cutaneous feedback from contact with the ball that were all experienced during a real volleyball game are represented in slightly altered form, but in the same chronological sequence, in the brief image. This "primary" memory fragment is modified by several "secondary" memory fragments such that the image does not directly depict the episodic memory. For example, the original quasi-reflexive arm movement became completely reflexive in the image; the ball's trajectory was altered; the ball's size and weight sensations became sensations appropriate to a larger, lighter beach ball; and so forth. Such transformations of episodic elements may reflect the piecemeal nature of episodic memory storage (e.g., Brady, Konkle, Alvarez, & Oliva, 2013) or the influence of

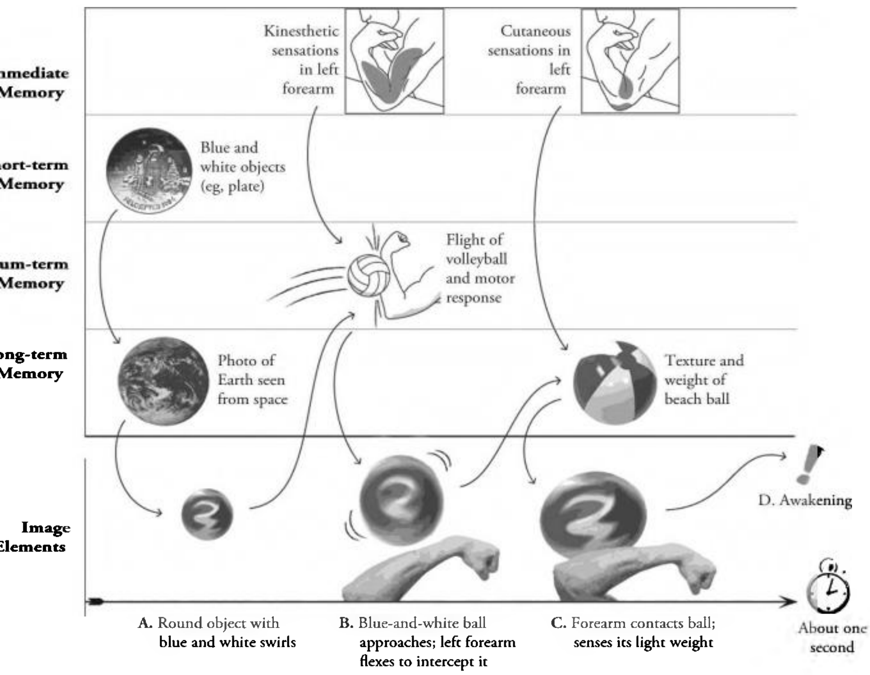

Image: I see a small blue-and-white object fa off to my left. Its colors are very bright and fo a swirled pattern. It suddenly and unexpected flies toward me, horizontally but with a sligh arc. It was as if someone had thrown it at m Close to me it is about the size of a basketbal make a quick, reflexive movement with my l arm as if to strike or intercept it. For an insta feel a sensation on the upper part of the elbo and forearm as the ball makes contact with m From this I perceive that the ball is much lig and thinner in consistency than I had expect like a beach ball. Though I expect it to boun stays in my arm as if I had caught it there. However, I wake up abruptly at the momen contact, before anything else can happen. I w surprised by the image.

Color Insert) Multi-temporal description of memory sources associated to a single, one-second microdream (right panel) and hypothetical model of their combinati tegories of memory elements (*y*-axis) combine to produce elements of the microdream as they unfold chronologically (X-axis). Arrows indicate possible causal influe ess referred to as ***transformative priming***. The image is proposed to unfold in three steps: (1) a combination of several short-term and one long-term memory elemen hite object seen at a distance; (2) combination of the prior result with immediate memory impressions (kinesthetic) and one medium-term memory (flight of ball, r med image of an approaching ball and reflex motor response; (3) combination of the prior result with further immediate memory impressions (cutaneous), and a lo l) to produce a transformed image of object contact with cutaneous feedback. Elements are thought to transform subsequent elements as they trigger ("prime") then econscious level. The result is a continuous, de novo integration of memory elements that reflects features from all of the contributing memories but which expunge e primary memory element—a reflex arm movement—is modified by several secondary elements: features such as color, trajectory, weight, and texture are changed, ming may sustain the spatiotemporal coherence of the imagery sequence, may account for its persistently novel character, and may explain why larger episodic mem :: Nielsen (2017; 1995).

consolidation mechanisms that transform episodic into semantic memories (e.g., Stickgold, 2002).

The memory sources identified by this simple descriptive analysis lend themselves to hypothetical causal models of image formation. One type, a *real-time model*, might stipulate that the image memory sources are combined successively in the chronological order shown. The notion of *transformative priming* is suggested as a basic mechanism of such combination: Each memory source both triggers ("primes") and merges with ("transforms") a subsequent memory or imagery element. Alternatively, an *off-line model* might suggest that the image sequence emerges fully formed into awareness, without the need for real-time integration. Integration might have occurred in the days, hours, minutes, or even seconds prior to the image, and only a brief trigger may be needed to activate it in its entirety. Immediate memory sources (cutaneous, kinesthetic sensations) may thus serve to activate the preformed imagery associatively. Other models might be proposed that stipulate combinations of real-time and off-line influences. Figure 30.5 is but a starting point, meant to demonstrate that much of the evidence needed to explore such hypotheses is accessible from a thorough description of memory sources. And, unlike previous efforts that have attempted analyses of the memory sources of lengthy dream reports (Foulkes, 1978; Freud, 1900), microdreams offer a much simpler set of observations and a more limited number of hypothetical constructs to explain their phenomenology.

ACCESSING COGNITIVE AND SOMATIC IMAGERY SOURCES: AUTOSYMBOLIC IMAGERY

Microdreams are particularly useful for exploring the potential influence of immediate and short-term memory sources on image formation. This is amply demonstrated by Silberer's (1909/1951) study of *autosymbolic images*, or images that automatically and symbolically reflect ongoing waking states, thoughts or feelings. The three types he observed differed in the nature of the memory source represented:

1. *Material images*: reflect the contents of pre-imagery thoughts, such as an abstract idea (e.g., thinking about the nature of trans-subjectivity) being represented by a perceptual image (e.g., dreaming of a transparent sphere with peoples' heads in it).
2. *Functional (effort) images*: reflect attributes of the thinking process itself, such as a quality of cognitive activity (e.g., losing one's train of thought) being reflected symbolically (e.g., image of a line of text with no ending).
3. *Somatic images*: reflect the influence of sensations of any kind, such as somatic sensations (e.g., taking a deep breath) being reflected metaphorically (e.g., dream of lifting a table high in the air).

Silberer believed that autosymbolic images offered opportunities to experimentally examine dream production mechanisms. For example, by holding in mind a particular thought content or by administering a particular type of somatic stimulus, one could observe how image formation processes incorporate these memory sources. Such experimental methods have, in fact, been used to influence the dreams of REM sleep (see review in Arkin & Antrobus, 1991). While I share this view of the potential usefulness of microdreams, it is critical to recognize that post hoc observations of juxtapositions between waking and sleeping cognitions do not guarantee that they are causally linked. It is possible that some underlying factor spanning sleep/wake states produces both the waking cognition and its closely related dream image. For causality to be demonstrated, stimuli would need to be administered experimentally (i.e., with suitable control conditions). Notwithstanding this caveat, however, a limited set of self-observations does strongly support Silberer's causality assumption. While anecdotal, these observations bolster the feasibility of developing more thorough experimental approaches to investigate microdreams and to model their formation mechanisms. Some of these observations are described in the following sections.

ACCESSING CAUSAL FACTORS IN IMAGE FORMATION

I suggest broadening Silberer's three-part classification to include instances in which memory stimuli are more obviously linked in a causal fashion to images. Specifically, I suggest adding a fourth type of autosymbolic imagery—*autosensory imagery*—as well as expanding upon Silberer's third type of imagery (somatic) to include *exosensory imagery*.

Autosensory Imagery

Autosensory imagery is shaped by self-generated stimuli that occur immediately prior to an image's appearance. The self-generated stimuli usually stem from neuromuscular events like a muscle twitch, body jerk, or nodding of the head, but may also include sounds such as snoring, wheezing, or even speaking. These stimuli may arise from one image but are integrated identifiably with a subsequent image. Thus, a stimulus may originate in an image that produces an overt behavioral response, or dream-enacting behavior, such as poking an object with a dream finger, which induces a real finger twitch, and this may evoke a sensation of touch in another body region—a sensation that modifies a subsequent (autosensory) image. An autosensory image such as this one, which involves touch, could be described as "autosomatic." My observation is that autosomatic images are the most common type of self-induced image, although other types are possible, such as "auto-acoustic" images for auditory stimuli (e.g., hearing one's own voice or sounds of movement), or even "auto-vestibular" and "auto-optical" images for vestibular and visual stimuli, respectively, although these are rare. Note that the dream-enacting behavior eliciting an autosensory image may provoke an awakening, even as the new image takes hold in awareness. An example of an autosomatic image is presented to highlight its clear causal implication in imagery formation (see Table 30.2).

The example, in fact, begins with a Silberer Type 1 (*material*) autosymbolic image for which ongoing reflection on placing fingers in a specific guitar chord shape is followed by an image in which the same fingers unscrew a plastic bottle cap. This dream action leads to very slight movements of the real fingers, which trigger touch sensations where they are resting on the forehead. The latter, in turn, evoke the autosensory image of someone abruptly appearing and touching the same spot on the forehead. The behavioral enactment and subsequent cutaneous stimulation trigger an awakening just after the autosensory image enters awareness. The precise chronological order of events could be discerned and, thus, a causal connection inferred.

In light of this clear phenomenological sequence, the question arises as to how a self-induced cutaneous sensation produces a contextualized visual image of another person who *appears* to produce

Table 30.2 Chronology of Events Constituting an Autosensory Image

Stage	Event	Comments
Context	Lying down on L side, hand near forehead. L thumb, index and middle fingers next to forehead while falling asleep.	The fingers were not placed in this position intentionally, nor was I specifically aware of them there until the image occurred.
Ongoing cognitive activity	I had been imagining using my L hand to execute a difficult guitar chord (Em add G#), unsure of its order in a song.	This chord requires use of the L thumb, index and middle fingers in a pinching action similar to the squeezing necessary for removing a bottle cap. A difficult chord for me.
1. Original image	*I was using my L thumb, index and middle fingers to twist off the dark blue top of a blue plastic water bottle. I saw the cap between my fingers.*	I typically perform this movement with my R hand. I cannot recall having done it with my L hand.
2. Reflex/stimulus	While twisting the cap, I felt my actual L hand fingers twitch briefly and with the same direction of movement. I also felt a touch on my forehead.	The *image → movement → touch* sequence occurred very quickly. I realized almost immediately that the touch was self-produced.
3. Autosensory image (somatic)	*DZ was reaching her R arm in from my R side. It was grey and had very little form. I saw and felt her hand touch me at the same place my fingers were resting.*	The visual details were relatively indistinct but the arm's presence was very distinct. The image occurred as I woke up.
4. Wake up	The entire *image → movement → touch → image → wake up* sequence took less than a second.	The sequence was recalled rapidly in reverse order.

Source: Nielsen (2017). Sleep-onset imagery description is in italic.

the sensation. In other words, how does a cutaneous stimulus so immediately produce its own context-appropriate visual precursor? This puzzle may be viewed as a special case of conflict in multisensory temporal ordering and will be addressed more fully once we have considered other instances in which external sensory stimuli causally influence images (i.e., exosensory images).

Exosensory Imagery

I suggest the term *exosensory imagery* as a more inclusive category of Silberer's third type of autosymbolic imagery (somatic imagery), that is, an image influenced by external stimuli (sounds, lights, cutaneous contacts, imposed movements of the body, etc.). At present, examples of exosensory sleep-onset images are anecdotal and are based on fortuitous observations made under the different conditions itemized in Table 30.3. Here, external stimulations occurred unpredictably in locations as varied as an airplane during turbulence, a noisy park, and a quiet office. Discussion of these observations will include some phenomenological clarifications, followed by consideration of implications for image formation processes.

Brevity. The 18 images in Table 30.3 are all short-duration episodes—microdreams—despite their sometimes lengthy descriptions (M_{words} = 28.8±14.4; range: 12–75). Most (N = 14) consist of only a single part, usually a single dreamed movement of a limb, character or object, accompanied by some visual details. The other four images (#1, #3, #9, #10) consist of at most two parts: two consecutive actions or movements with visual details. In all but one of these (#3), some degree of coherence between the two parts is apparent. In image #3, the second part (cat's head emerges) seems tangential to the first part (hand puts file in box).

Eruptive quality. Most of the images possess an eruptive character in two separate but interrelated ways. First, they seem to erupt into awareness without warning, eliciting surprise and a quick return to consciousness. Second, the image's content hinges on an abrupt emphatic movement that seems to have been caught in mid-expression. Thus, for image #2, the multicolored clown is seen spinning with an energy and trajectory consistent with having just tripped violently or jumped off a trampoline. Similarly, in image #5, a young man vaults with such velocity that he seems to have just stumbled while running, and gives the image a "caricature-like" aspect. This eruptive quality is especially true for images affected by phasic stimuli, while for some images affected by tonic stimulation (e.g., #11–#13) an eruptive action is less apparent than its sudden appearance in awareness. For other tonic images (#15–#18) an eruptive action is, in fact, present.

Instability. Many of the images depict an instability theme: their primary constituent is a vigorous, even violent, movement in a downward or circular direction. These include an arm slapping down (#1); a clown somersaulting (#2); a door slamming (#4); a man tripping (#5); a girl falling (#7); a woman spilling a drink (#8); a bicycle collapsing and man falling on it (#9), a spinning ball sliding and falling (#10); and a page falling (#15). Image instability appears closely linked to the eruptive quality.[4]

Self versus non-self focus. The focus of images is sometimes the movements and sensations of the self (N = 7) and sometimes those of other characters or objects (N = 11). Accordingly, the effects of external stimuli are detected in modifications to either self (somatic) or non-self (visual, auditory) imagery attributes. In rare cases (#17), an apparent overlap between self and non-self attributes occurs such that the actions of another character are felt to be executed by the self.

Influence of External Stimuli

Several important relationships between image elements and their immediately preceding external stimuli are illustrated in this collection.

Multiple sensory modalities. Images are affected by stimuli from many sensory modalities, including vestibular, auditory, visual, and various somatic stimuli (cutaneous, thermal, pain). Visual stimuli are perhaps least reliably identified, with very few observations of this type having been made.[5] There is a fairly specific correspondence between stimulus modality and its influence on the image; in general, auditory stimuli affect sounds, vestibular stimuli affect balance, cutaneous stimuli affect touch, thermal stimuli affect perceived temperature, and so forth. Some exceptions to this general rule (e.g., #3, #18) point to a non-specific influence. For example, in image #18, pain and cutaneous sensations in a limb were associated with a visual image of an arm abruptly flailing. Additionally, cross-modality influences, especially an auditory stimulus effecting a visual change, are common.

Phasic versus tonic stimuli. Abrupt, short-lasting (phasic) stimuli and ongoing, longer-lasting (tonic) stimuli affect images in different ways. For images #1–#9, phasic influences, such as sudden sounds or airplane movements, result in equally abrupt changes in image content, most notably, in people

Table 30.3 Exosensory Images and the Sensory Stimuli Affecting Them, Categorized by Stimulus Modality and Type

	Image (#parts, #words)	External Stimulus	Stimulus Modality	Stimulus Type	Image Focus	Clarifications
1.	*A woman is holding her nose with her L hand, her R hand/arm sweeps down in front of her face. Suddenly, a hand (and arm) comes out of nowhere and slaps down on the bare forearm of another arm with a loud "whop." (2, 43)*	A "whop" sound coming from the tennis court near where I was lying in the grass woke me.	Auditory	Phasic	Other	The sound from the tennis shot matched precisely the timbre, timing and apparent direction of the sound in the image.
2.	*A bright, multicolored clown/jester suddenly somersaults with a snapping, elastic motion. His black suit had patches of red, yellow, green, blue, and other colors. (1, 24)*	Dozing while sitting on a couch near an IKEA cash register, which abruptly sounds with a loud clatter and wakes me.	Auditory	Phasic	Other	The somersault coincided with the noise. I was surrounded by brightly colored sofas, pillows and other furniture.[a]
3.	*A hand puts a file into a white box; a black cat's head suddenly emerges from behind the edge of a table. (2, 22)*	A stapler suddenly sounds in the next office.	Auditory	Phasic	Other	The cat's head emerges at the same time as the stapler sounds. The sound and the cat image seem strangely overlaid and incongruous.
4.	*A heavy door made of wood suddenly swings open to the R and slams against the corner of a countertop. (1, 21)*	The conference speaker had made a thudding sound by hitting the microphone	Auditory	Phasic	Other	The thud sound corresponded exactly with the door slam in the image. A slide on the screen just pre-image depicted a closed, large, brown wooden door.[a]
5.	*I see a young man's legs and feet as he trips over something and falls to the right in my visual field. Almost a caricature of a fall. (1, 28)*	A loud tearing sound, like Velcro ripping, from the seat behind me, woke me up. Airplane had been going through occasional turbulence.	Auditory/ Somatic	Phasic	Other	The fall coincided exactly with the ripping sound. Falling imagery is similar to other images observed during turbulence.
6.	*My upper body was in a seated, doubled over position, twisted toward the L and downward. I was in the act of pulling myself into an upright posture. (1, 28)*	Airplane dipped and rose quickly giving a feeling of "stomach rising" (like going over a hill in a car quickly).	Vestibular/ Somatic	Phasic	Self	The pulling up sensation coincided with the sudden dip/rise of the airplane.
7.	*A 5–6 year-old girl in an aisle—an airplane aisle perhaps—falls forward onto her hands and knees. She has brown, shoulder-length hair and a hair band. The aisle is reddish. (1, 33)*	The airplane made an unexpected "dip" during final descent that woke me up.	Vestibular/ Somatic	Phasic	Other	The girl's fall occurred at the instant the plane dipped.

Table 30.3 Continued

	Image (#parts, #words)	External Stimulus	Stimulus Modality	Stimulus Type	Image Focus	Clarifications
8.	*A woman (face indistinct) seated across from me suddenly spills red liquid from a glass onto her lap. I saw dark stains on her beige dress. (1, 26)*	The airplane made an unexpected "dip" during final descent that woke me up.	Vestibular/ Somatic	Phasic	Other	The spill coincided with the sudden dip. The woman seated to my R had a glass of wine served to her earlier in the flight.[a]
9.	*I felt some people pass very close by on my L, from back to front, as if on a sidewalk. Then a clear image of a bicycle collapsing in a pile on the ground, the driver falling to the L, face first on top of the bike. (2, 47)*	The airplane slowed abruptly, albeit very slightly, to begin final descent.	Vestibular/ Somatic	Phasic	Other	The bicycle collapse coincided with the sudden slowing of the airplane. Flight attendants passed close by on the L of my aisle seat (back to front) several times.[a]
10.	*I flip a volleyball onto my R finger and spin it clockwise for a bit. It flattens, bulges at the center, then deviates forward, then downward. I progressively lose control of it. It is twice as wide now and very flat as I grab for it with both hands. I feel it on my R fingers, which seems incongruous because it cannot be spinning on that part of my hand--as if on the backside. (2, 75)*	Hands holding open a glossy reprint article songbook style on stomach (lodged against R thumb mainly). In waking I felt it slowly slipping forward along the crook of the thumb and coming to rest on the fingers underneath it.	Cutaneous	Phasic/ Tonic	Self	The gradual slipping forward of the reprint coincided with the gradual slipping forward of the spinning ball; the ball and reprint were both felt to slide at the same locations on the hand.
11.	*I am climbing a stairwell that has freshly fallen snow scattered over the stairs. My L hand is holding a thick metal railing. (1, 23)*	Sitting in office, left hand holding right in lap, window to my L is open and cold air is blowing in.	Thermal	Tonic	Self	There were no abrupt movements or phasic stimulus.
12.	*In the same stairwell, about halfway up a flight of stairs. I have a cold feeling. I feel snow blowing up and enveloping me. The scene is largely dark. (1, 30)*	Sitting in office, left hand holding right in lap, window to my L is open and cold air is blowing in.	Thermal	Tonic	Self	There were no abrupt movements or phasic stimulus.
13.	*A man and boy are riding in a small motorcycle with a sidecar with bright red shiny fenders. (1, 18)*	Bright sunlight is coming in the windows of the office.	Visual	Tonic	Other	Sunlight may have shone red through my eyelids.
14.	*Seated in my chair I bend forward and place a medium-sized book on my desk, pressing against the book's bottom edge with my fingertips. (1, 24)*	Holding a heavy book open in my lap with R fingers bookmarking several pages; pressure on middle and ring fingertips.	Cutaneous	Tonic	Self	Correspondence is in the localized sensations in fingertips.

(*continued*)

Table 30.3 Continued

	Image (#parts, #words)	External Stimulus	Stimulus Modality	Stimulus Type	Image Focus	Clarifications
15.	*A grey cardboard page resting on my L thumb and index finger suddenly falls forward. (1, 15)*	My right thumb is pressing down on my left thumb and index.	Cutaneous	Tonic	Self	Correspondence is in the localized sensations in fingers.
16.	*I suddenly and vigorously slap a door with my open R palm. (1, 12)*	Seated in chair, my left elbow is pressing on my R palm.	Cutaneous	Tonic	Self	Only correspondence is a general increase in sensation in the R palm.
17.	*Someone is spinning an animal quickly around in circles with his R hand. It just seems stuck to his hand and turning around it. I feel as though I were making the movements myself. (1, 34)*	Sitting upright with both hands between my thighs palms facing out. A bit of paresthesia in both, more in R.	Cutaneous	Tonic	Other	Only correspondence is a general increase in sensation in the R hand.
18.	*An obese person or creature on my L suddenly flails his R arm forward toward me and growls. (1, 18)*	Sitting with book in lap, arms on armrests. R arm is pained and slightly paralyzed.	Pain/ Cutaneous	Tonic	Other	Only correspondence is between the flailing arm and the arm in pain and slightly paralyzed.

Source: Nielsen (2017).

or objects falling, appearing quickly, or being hit brusquely. Some changes suggest a direction integration of the stimulus into the core of the image; (e.g., in image #1, the sound of an arm being slapped directly reflects the sound of a tennis ball being hit; in image #4, the sound of a door slamming directly reflects the sound of a microphone being struck; and in image #6, the airplane's sudden rise during turbulence reflects a sense of pulling the bent-over self into an upright posture.

However, in several other images, a phasic stimulus appears to have only indirectly modified an image. In image #2, a vestibular stimulus is not incorporated directly as a self-feeling of falling or moving, but as a clown abruptly somersaulting. Similarly, in images #7 and #9, vestibular stimuli lead not to self-feelings of falling, but to other characters falling; in images #8 and #9, such stimuli lead to objects falling. Such indirect, "projected" incorporations have also been observed after somatosensory stimulation delivered during REM sleep (Dement & Wolpert, 1958; Koulack, 1969; Nielsen, 1993).

Curiously, tonic stimuli also sometimes lead to abrupt changes. Images #14, #15, and #17, in particular, demonstrate the eruptive quality familiar from phasic stimuli, even though in all three cases there was no sudden stimulus. Thus, although there is a fairly general correspondence between both the modality and the phasic or tonic nature of source stimulations, exceptions behoove us to seek explanations beyond a simple mechanism of "direct incorporation" or even "projected incorporation" (see later discussion).

The orderliness of imagery disruption. When phasic disruptions of image formation take place, the end-product of this disruption maintains a certain degree of orderliness. The integrity of objects and characters depicted is preserved to varying degrees, and the image contents almost inevitably adhere to the physical laws of classical mechanics for the real world. For example, images for which stimulation triggered a "falling" theme (#5, #7, #8, #9, #10, #15) all depict objects or characters that fall in a relatively orderly manner (i.e., downward in accordance with the influence of gravity, not up or sideways as might be expected if no sense of gravity was adhered to). Further, although some objects in these images do appear to lose their stability within the scene, they do not completely lose their internal structural integrity. For example, for the spinning ball in image #10 there is a progressive loss of stability both in balance control and in the ball's round shape, yet the ball changes shape in a plausible manner ("flattening") rather than falling apart entirely. Even so, there are again exceptions; in image #9, a bicycle collapses into a pile, losing its structure altogether. Overall, however, the maintenance of an image's stability, even in the face of disruption, points to degrees of interference with a basic *reality simulation* process and, more precisely, to disruption of multisensory integration of multimodal and self/non-self elements. Even as an image is disrupted, it improvises a solution within a context that obeys rules of classical mechanics for the real world. Further, the integration of real perceptual events in this manner implicates sensory systems in imagery formation, a notion that has been proposed both for waking imagery (Finke, 1980; Kosslyn, Behrmann, & Jeannerod, 1995; McNorgan, 2012) and dreaming (Windt, 2015).

Interpretation of Causal Factors: Multisensory Integration

In the preceding observations, I pointed out that sometimes an external stimulus is not only incorporated directly into an image, but it elicits details in other modalities that contextualize this incorporation. This takes place very quickly, from a few hundred milliseconds to, at most, a second or two, and before a full return to consciousness sets in. This rapid elicitation of both direct incorporation and apparent context poses a logical conundrum for a theory of image formation, but a conundrum whose resolution might help resolve how more complex dream imagery is produced. The conundrum hinges on the observation that an external stimulus so quickly elicits a set of image features, some of which seem to *precede* in time the incorporated stimulus. It is particularly clear in two images from Table 30.3 that appear after exposure to phasic sounds. For image #1, the sound of a tennis shot is not only incorporated directly as a hand slap sound, but visual details preceding the slap are also represented (i.e., the hand doing the slapping). For image #4, the sound of a microphone being struck is incorporated directly into the image as the sound of a door slamming, yet it also elicits the visual image of a swinging door that seems to precede the incorporated sound. The stimuli in both these cases presumably elicit—through some associative mechanism—visual details that are appropriate to, and thus help contextualize, the sound stimuli. The conundrum is in the perceived temporal ordering of events; an auditory event clearly leads to a visual event (A→V). Yet, the phenomenological chronology of the experience is that the visual event *precedes* the auditory event (a hand moves to cause a slap; a door moves to cause a slam) or V→A. What mechanism is responsible for rearranging the temporal order of events? Identifying this mechanism for simple exosensory images could illuminate basic mechanisms of production of more complex dream imagery.

One approach to solving this conundrum is to consider exosensory imagery as analogous to, or even as a special case of, *multisensory integration* (MSI; for reviews, see De Gelder & Bertelson, 2003; Talsma, 2015). Specifically, exosensory imagery could be studied as an MSI situation in which the sensory modalities of an external stimulus and an endogenous image feature are in conflict (e.g., auditory stimulus, visual image feature). A similar perspective has recently been validated for interactions between MSI and intentionally generated auditory and visual imagery (Berger & Ehrsson, 2013, 2014; Vetter, Smith, & Muckli, 2014) and allows us to consider how a number of findings from MSI studies parallel observations from the present inquiry in potentially clarifying ways. These include findings about (1) the *timing of percepts* in different sensory modalities, (2) the *perceived localization* of these percepts, (3) the *perceived intensity* of percepts, and (4) the *qualitative alteration* of visual percepts by auditory and somatic stimuli.

PERCEPT TIMING

During waking, information in different modalities reaches sense receptors at different speeds (e.g., light travels faster than sound) and is processed in sensory systems at different rates (e.g., hearing is processed more quickly than seeing). Thus, various mechanisms compensate for discrepancies in the timing, localization, and other stimulus features of multisensory stimuli. These mechanisms are thought to overcome intersensory conflicts to preserve the perception of unified objects and, ultimately, a unified stream of consciousness.

In the case of percept timing, much evidence indicates that the perceived onset of visual events can be temporally shifted by stimuli in other modalities—but especially in the auditory modality. Thus, when brief visual and auditory stimuli are presented consecutively, regardless of order, the perceived onset of the visual stimulus shifts toward that of the sound (Bertelson & Aschersleben, 2003; De Gelder & Bertelson, 2003; Fendrich & Corballis, 2001; Jaekl & Harris, 2007; Morein-Zamir, Soto-Faraco, & Kingstone, 2003). Tactile stimulation can force a time shift of visual events that is of equal magnitude to that induced by auditory stimulation (Keetels & Vroomen, 2008).

If the visual content of microdream imagery behaves like that of visual perception, then visual imagery, too, may be shifted temporally to appear closer in time to an external auditory stimulus. This one mechanism alone may account for how an actual A→V sequence of events is transformed into a virtual V→A sequence.

PERCEPT LOCALIZATION

Unlike percept timing, percept localization is more strongly influenced by visual stimuli. A sound's apparent location is likely to shift toward that of a visual event if the two occur close enough in time. The visual event is said to "capture" the sound's location as in the well-known spatial ventriloquist effect (Howard & Templeton, 1966): a visual stimulus (the dummy) captures the verbal stimulus (the ventriloquist's voice), forcing a multisensory illusion of spatial integration. Such an effect might underlie the production of exosensory imagery once a visual component has been elicited; the eliciting sound may be captured by the visual image and seem to arise from it, rather than from the real world. This is supported by experiments in which the classic ventriloquism effect occurred when subjects imagined the visual component of the illusion; an auditory stimulus was drawn toward the visual image's location, just as for an actual visual stimulus (Berger & Ehrsson, 2013). The authors conclude that "mental imagery is capable of integrating with perceptual stimuli of a different sensory modality" (p. 1369). A similar integrative mechanism could explain why incorporations of a sound stimulus into visual imagery usually do not preserve the original location of the stimulus. However, it is noteworthy that such a mechanism may also fail entirely, as suggested by image #1 in which the incorporated sound was perceived to originate exactly from its location in the real world.

PERCEPT INTENSITY

Sound stimuli may modify the apparent intensity of visual events (Stein, London, Wilkinson, & Price, 1996). For example, if an LED light is presented together with a brief, broad-band auditory stimulus, regardless of where the stimulus source is, the light will be rated as more intense than if it is presented alone—especially when the light is at a low visual intensity. Such auditory stimuli appear to facilitate early stage sensory processing of visual stimuli as suggested by, for example, reduced reaction times in a visual identification task (Doyle & Snowden, 2001) or improved detection of changes in visual motion (Staufenbiel, van der Lubbe, & Talsma, 2011). A similar facilitative mechanism may be implicated in the rapid production of visual imagery at sleep onset when a phasic noise elicits an abrupt facilitation of visual imagery, leading possibly to the "eruptive" quality of elicited images.

QUALITATIVE CHANGES IN VISUAL EVENTS

Auditory stimuli can alter visual perceptions in several qualitative respects that have implications for image-formation processes, including apparent motion and image segmentation. In the "bounce illusion," two small target discs moving in a straight line toward each other, coinciding, then continuing on can be made to seem to "bounce off" each other if a phasic sound burst is presented at or near the point of coincidence. Even a subliminal sound can induce this effect (Dufour, Touzalin, Moessinger, Brochard, & Despres, 2008). The pertinence for sleep-onset imagery is demonstrated by the fact that subjects merely imagining the phasic sound also experience the bounce illusion (Berger & Ehrsson, 2013). Additionally, brief sound stimuli can fragment a visual percept into two or more parts. With the sound-induced flash illusion, one phasic light flash accompanied by two rapid beeps will be perceived as two flashes of light; multiple beeps will elicit multiple apparent flashes of light (Shams, Kamitani, & Shimojo, 2002). Multiple tactile stimuli can also elicit this illusion (Violentyev, Shimojo, & Shams, 2005). For sleep-onset images, phasic stimuli might affect the apparent intensity and motion of visual images, possibly leading to their eruptive and kinetic qualities.

Conclusion

Traditional laboratory methods of assessing REM sleep dreaming have still not resolved key questions about the essential phenomenal ingredients of dreaming and the nature of its neurophysiological correlates. The typical sleep laboratory approach to studying such questions involves sampling long, multifaceted dream experiences and concurrent voluminous, polysomnographic signal arrays and has struggled to demonstrate clear relationships between such large sets of measures. This in turn has slowed the pace of discovery in dream science. I propose an alternative, simpler course that is consistent with developments in the microdynamic neurophenomenology of consciousness and that takes as its principal object of study the briefest episodes of imagery occurring at sleep onset—microdreams. Such images provide a fertile ground for assessing the details of oneiragogic phenomenology and the multiple memory sources contributing to them. The assessment of microdreaming also lends itself well to the development of theories of microdream formation and to experimental approaches for assessing how real and dreamed imagery constituents may be integrated. Two new types of microdream imagery—autosensory imagery and exosensory imagery—illustrate this potential. A concerted focus on, and alignment of, brief cognitive and neurophysiological events at sleep onset may reveal mechanisms of imagery structure and formation that are not possible with the complex measurements derived from traditional sleep laboratory approaches.

Notes

1. The neuro-centric method refers to the waking up of sleeping subjects when a particular configuration of polysomnographic events transpires (e.g., following 15 s of EEG-defined Stage 1 sleep or following 3 min of stage REM sleep). It differs from the phenomeno-centric method by which subjects themselves determine the moment of (self-) awakening after having just experienced an imagery event. Self-awakening methods have been described for sleep-onset (Nielsen, 1992, 1995) and NREM sleep (Brown & Cartwright, 1978).
2. Contrast this with Freud's analysis of the memory sources of his "Irma's Injection" dream; the dream was 332 words in length and required 4,130 words of terse prose to describe all its identified memory sources.
3. Episodic memory is defined in different ways (Cavallero, Foulkes, Hollifield, & Terry, 1990; Fosse, Fosse, Hobson, & Stickgold, 2003; Malinowski & Horton, 2014; Tulving, 2002). When defined as confidently remembered percepts of locations combined with objects, actions, or characters, they occur in <2% of home dreams (Fosse et al., 2003). However, elements of episodic memories are much more frequent, e.g., 28%–38% (Cavallero et al., 1990) or 65% (Fosse et al., 2003). Sometimes, such elements alone may constitute well-remembered episodic memories due to their substantial personal significance.
4. A sleep-onset image that commonly occurs after a day of vigorous sport such as skiing is of abruptly falling (cf. Wamsley, Perry, Djonlagic, Reaven, & Stickgold, 2010). Such images may be accompanied by an intense bodily jerk and an eruptive awakening.
5. One hypothesis is that image formation in a brightly lit room favors the influence of colors from the red end of the spectrum that are filtered by the closed eyelids. In one study conducted in bright light conditions (Nielsen, 1995), in 91 images there were 37 (41%) that contained a total of 69 color references. The most prevalent color—apart from black (31.9%)—was red, pink, or orange (24.6%), followed by white (15.9%), silver/grey (10.1%), green/blue (5.8%), brown/beige/gold (7.2%), and unspecified (4.4%).

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CHAPTER

31 Sleep Paralysis: Phenomenology, Neurophysiology, and Treatment

Elizaveta Solomonova

Abstract

Sleep paralysis is an experience of being temporarily unable to move or talk during the transitional periods between sleep and wakefulness: at sleep onset or upon awakening. The feeling of paralysis may be accompanied by a variety of vivid and intense sensory experiences, including mentation in visual, auditory, and tactile modalities, as well as a distinct feeling of presence. This chapter discusses a variety of sleep paralysis experiences from the perspective of enactive cognition and cultural neurophenomenology. Current knowledge of neurophysiology and associated conditions is presented, and some techniques for coping with sleep paralysis are proposed. As an experience characterized by a hybrid state of dreaming and waking, sleep paralysis offers a unique window into phenomenology of spontaneous thought in sleep.

Key Words: sleep paralysis, sleep, neurophenomenology, dreaming, neurophysiology, spontaneous thought

> I had a few terrifying experiences a few years ago. I awoke in the middle of the night. I was sleeping on my back, and couldn't move, but I had the sensation I could see around my room. There was a terrifying figure looming over me. Almost pressing on me. The best way I could describe it was that it was made of shadows. A deep rumbling or buzzing sound was present. It felt like I was in the presence of evil. . . . Which sounds so strange to say! (31-year-old man, United States)

Sleep paralysis (SP) is a transient and generally benign phenomenon occurring at sleep onset or upon awakening. Classified as a rapid-eye-movement (REM) sleep-related parasomnia, SP represents a psychophysiological state characterized simultaneously by qualities of both sleep and wakefulness, wherein the experiencer can open her eyes (Hishikawa & Kaneko, 1965) and can be aware of her physical environment, but is unable to move and may start seeing, hearing, feeling, or sensing something.

While documented instances of SP seem to be very consistent across cultures, SP's lived qualities, phenomenology, and interpretation as a meaningful experience vary depending on the cultural and religious background. Rooting SP in a particular belief system may either help the experiencer recognize that SP is common and transient, or amplify negative qualities of SP by giving more concrete shape to an already terrifying experience of a supernatural assault.

The emotional experience of SP is often one of fear, terror, and panic. Threatening presences, the vulnerability of being in a paralyzed state, uncontrollable visions—all these elements contribute to intense, predominantly dysphoric, negative affect. Some qualities of spontaneous thought associated with felt presence during SP can be seen as paranoid (Cheyne & Girard, 2007), spatial, or interpersonal/social (Nielsen, 2007; Solomonova, 2008).

The vast majority of SP experiences are associated with intense feelings of realism, and are most often characterized by fear and distress, which may carry over into wakefulness and create a vicious cycle of negative emotional association with sleep, including aversion to going to bed, and even, in extreme cases, can result in symptoms reminiscent of post-traumatic stress disorder (McNally & Clancy, 2005). Yet, some SP experiences are described in positive terms, especially vestibulo-motor phenomena that include out-of-body experiences (OBE), or sensations of flying or floating. While the intuitive and immediate reaction to SP is typically negative, as will be discussed in the section on practical considerations, there are numerous reports of neutral/positive SP. Furthermore, there is a possibility of harnessing the power and potential of the dissociative/overlapping state in order to take active charge of one's experience and to use the opportunity presented by the simultaneity of waking and sleeping cognition—a potential for entering into a lucid dream state or for contemplative self-observation.

Neurophysiologically, SP is currently understood as a state dissociation or a state overlap between REM sleep and wakefulness (American Academy of Sleep Medicine, 2014). During SP one can open her eyes, look around the room, become aware of her environment, and simultaneously experience REM sleep-related paralysis (muscle atonia) as well as intense and realistic imagery[1] of all sensory modalities—a nightmare spilling into the real world. Normally, during REM sleep, skeletal muscle atonia blocks most motor output, effectively preventing the sleeper from acting out her dreams (Peever, Luppi, & Montplaisir, 2014). Sleep paralysis can also occur in the context of narcolepsy (Sharpless & Barber, 2011; Terzaghi, Ratti, Manni, & Manni, 2012), but the majority of those who experience SP report it in its isolated form (often referred to as *isolated sleep paralysis*), without known medical or neurological association.

In current medical and neuroscientific literature, SP is discussed in terms of its presentation and negative factors: SP-associated mentation is generally seen as a non-desirable effect of REM sleep intrusion into waking. In this chapter I propose that situating SP experiences as a dream phenomenon within the framework of embodied mind and enactive cognitive science, including contemplative approaches to consciousness, is an alternative that accounts for the phenomenology of SP as a lived experience, allows for rich and detailed cultural framing of the experience, and offers avenues for a cross-cultural social neurophenomenology of SP.

First, I will discuss the phenomenology and neurophysiology of SP experiences. I will present SP in general, without distinguishing between its isolated and narcolepsy-related form, unless such a separation is warranted. I will start by presenting the current state of knowledge of SP prevalence, as well as the varieties of imagery accompanying SP and their cultural significance. I will then discuss SP in terms of a REM sleep parasomnia and outline its precipitating and enabling factors, as well as sleep and dream characteristics of those who experience SP. Finally, I will examine SP in light of various cultural and shared practices, including preventive measures and practices aimed at interrupting and transforming SP experiences.

The experiential examples of SP used in the present chapter are all derived from an Internet-based study of SP (Solomonova et al., 2008). Our research group collected 193 responses from people with recurrent SP experiences, using a modified version of the Waterloo Unusual Sleep Experiences Questionnaire (Cheyne, Newby-Clark, & Rueffer, 1999). Our participants were recruited online, using word of mouth, and via advertising on SP-related forums, information, and support.

Definitions and Prevalence

Idiopathic SP (SP not associated with narcolepsy, and without known cause) is a benign and transient parasomnia (Howell, 2012), occurring during transitions between wake and sleep: at sleep onset or upon awakening. The *Diagnostic and Statistical Manual of Mental Disorders* (5th edition; DSM-5) classifies isolated SP accompanied by fearful mentation as an instance of a nightmare disorder (American Psychiatric Association, 2013). During an episode of SP, characteristics of REM sleep intrude upon seemingly awake consciousness: thus the person experiencing SP, while having an impression of being awake and aware of her environment, is unable to initiate voluntary movements (i.e., experiences REM sleep muscle atonia/paralysis), and may also experience intense and realistic sensations in any sensory modality—REM sleep-related mentation (American Academy of Sleep Medicine, 2014). SP should be distinguished from night terrors—early night awakenings with feelings of panic/terror, typically associated with somnambulism-spectrum arousal from slow wave (Stages 3 and 4) non-REM (NREM) sleep. Night terrors are characterized by sudden awakening in an agitated state, anxiety, body motility, and general amnesia with regard to underlying cognitive experience (Szelenberger, Niemcewicz, & Dabrowska, 2005).

Prevalence estimates of SP range widely, and may depend on geographic and cultural factors. A systematic review of SP prevalence has revealed that studies report SP lifetime prevalence from as low as 1.5% to possibly 100% in the general population (Sharpless & Barber, 2011). The authors indicated that about one in five individuals may have experienced SP at least once in their lifetime (of 36,533 persons in their review). Prevalence estimation of SP is difficult due to numerous factors such as ethnicity and cultural background, including variable familiarity with the phenomenon and in the wording of questions (Fukuda, 1993). For example, in a cross-cultural study, Fukuda and colleagues (2000) reported that while it is unclear whether SP is equally prevalent in Canada and Japan, the lack of familiarity and of a normative cultural framework for SP in Canada may contribute to the fact that many Canadian, but not Japanese, respondents qualified SP as a kind of a dream, and would not have, therefore, readily recognized SP in a prevalence study. An additional reason for under-diagnosis of SP in the West may be the fact that those who experience SP may be misdiagnosed as having psychiatric disturbances (Hufford, 2005). The developmental trajectory of SP is traditionally associated with an onset during adolescence, which may indicate a process associated with sleep architecture maturation (Wing, Lee, & Chen, 1994). However, in one study of older adults, a bimodal onset pattern was reported, with a second pattern of onset of SP episodes after the age of 60 years (Wing, Chiu, Leung, & Ng, 1999), suggesting a possibility that SP may have a variety of onset conditions.

Neurologically and phenomenologically, SP is situated on the REM-sleep based dream/nightmare continuum. In this chapter, I will approach SP experiences as a variant of intensified or disturbed dreaming, and will situate them within a framework of embodiment and enactivism.

The 4EA Cognition and Oneiric Mentation

Recent years have seen the development of a paradigm shift from a strictly neurocentric view of the mind, a position that can be stated as "embrained" (Morris, 2010), to a diverse family of approaches that consider the mind embodied (Varela, Thompson & Rosch, 1991; Gallagher, 2005), enactive (Noe, 2004; Thompson, 2005; Stewart, Gapenne & Di Paolo, 2010), extended into and embedded in the physical and social world (Clark & Chalmers, 1998; Menary, 2010), and affective (Colombetti, 2013; Pessoa, 2013). While these approaches are in many respects quite different, they have sometimes been labeled as 4EA (embodied, embedded, extended, enactive, affective) cognition, with a common theme of offering a robust alternative to computational, connectionist, and neuro-reductionist views of the mind (Protevi, 2012; Wheeler, 2005). These theories attempt to situate cognition, brain activity, and psychophysiology within the larger contexts of lived subjective experience, by emphasizing the roles of developmental sensorimotor attunement to the world, as well as of the active and motivated processes of perception and sense-making, the importance of the social and cultural milieu, and the role of emotion and affect.

Sleep and dreaming phenomena have been only rarely addressed by 4EA theorists (with the exception of Thompson 2014, 2015a, 2015b), and the prevailing view of the sleeping mind today situates sleep mentation as being firmly constrained within the brain (Hobson, Pace-Schott & Stickgold, 2000; Rechtschaffen, 1978; Revonsuo, 2006). As Revonsuo states, "The conscious experiences we have during dreaming are isolated from behavioral and perceptual interactions with the environment, which refutes any theory that states that organism-environment interaction or other external relationships are constitutive of the existence of consciousness" (Revonsuo et al., 2015, p. 3). Alternatively, situating dream mentation within a framework of 4EA approaches implies that the dreaming subject is not entirely isolated or disconnected from environmental and somatic stimuli, and that her experiential self retains affective, social, sensorimotor, and sense-making qualities. Dreaming then is not passively lived as a purely mental simulation (Revonsuo et al., 2015), but can be seen as a process of active imagination (Thompson, 2014) rooted in the dreamer's physical, social, and affective world (Solomonova & Sha, 2016). I propose that SP experiences, by virtue of their special kind of overlap between and simultaneous presence of both waking and dreaming cognition, are perfect candidates for neurophenomenological research on spontaneous thought in sleep, which would help illuminate particular qualities of dreaming cognition that may otherwise be inaccessible to reflective consciousness upon awakening from a dream.

Phenomenology of Sleep Paralysis Experiences

In addition to transient experience of muscle paralysis (Figure 31.1),[2] the most dramatic quality of SP is its sensory content, characterized by vivid, intrusive audiovisual and somatosensory imagery. The experience of SP can be extremely realistic, may have a quasi-perceptual and wake-like quality, and may be accompanied by tactile and kinesthetic sensations. Reflective thought processes, self-awareness, and metacognitive abilities seem to be relatively preserved during SP experiences, and people who have had multiple SP experiences may develop a "feel" for recognizing SP imagery.

SP-associated experiences are typically referred to as hallucinations (hypnagogic, when occurring at sleep onset, or hypnopompic, when happening upon awakening), since these occur during otherwise seemingly awake consciousness (American Academy of Sleep Medicine, 2014; Liddon, 1967). This entails that a person who experiences SP sees something that is not there, something that is distorted or false. Such a view presupposes that during SP one is effectively awake and is misinterpreting her experience. Another way of looking at SP is to situate it within the spectrum of dream mentation and dreaming imagination. While dreaming also has been seen as a delusional/hallucinatory activity, an alternative view, in line with embodied mind theories and enactive approach, has also been proposed: "When you hallucinate, you seem to perceive what is not there. [. . .] When you imagine, you evoke something absent and make it mentally present to your attention" (Thompson, 2014, p. 179). In this chapter I adopt this latter view and will refer to SP experiences as a variant of spontaneous thought/mentation or mental imagery, rather than hallucinations or delusions.

Kinds of Sleep Paralysis Experience

A factor analysis by Cheyne and colleagues (1999) showed that SP mentation typically falls into three general categories. The first category is *intruder,* and it is characterized by a felt presence and fear, as well as auditory and visual imagery. The person who experiences SP feels that someone is in the house or in their room. This experience is sometimes accompanied by seeing or hearing someone or something sentient move around the house. The second category of SP experiences is known as *incubus*, in which the felt presence is interpreted as a supernatural assault and is often accompanied by a sensation of shallow breathing, a feeling of being smothered, pressure on the chest, or pain. In this

Figure 31.1. (See Color Insert) A representation of sleep paralysis experience. The sleeper is awakened suddenly and sees a menacing shadowy creature on top of him. He experiences the sensation of being pushed into the bed, while the bed itself is swirling in a sort of a tornado. The two faces of the dreamer represent the "double" consciousness during sleep paralysis: he is simultaneously terrified of the supernatural attacker and also knows that if he does not resist the experience and allows himself to drift back into sleep he may have a lucid dream (this lucid consciousness is represented as a sleeping face with a detailed brain, denoting vibrant possibilities of lucidity). Artist: Benjamen Samaha, Montreal, Canada, 2016. Reproduced with the artist's permission.

case, the sleeper often sees and feels the maleficent being on top of her. The third category, *unusual bodily experiences*, appears to be a separate, less well-known, and a qualitatively different kind of SP experience: these are often described as positive events, such as sensations of floating, out-of-body experiences (OBEs), and feelings of bliss. Both *intruder* and *incubus* categories typically include the experience of felt presence—a distinct sensation that someone sentient is in the immediate vicinity of the sleeper (Cheyne, 2005).

Most literature on SP focuses almost exclusively on the first two kinds, *intruder* and *incubus*, possibly due to their particularly intensified felt presence imagery, which contributes to distressing SP experiences (Cheyne & Pennycook, 2013; Solomonova et al., 2008). However, neutral and positive instances of SP have also been described, and the third category, *unusual body experiences*, or vestibulo-motor experiences, is often characterized by pleasant sensations and a spirit of exploration, accompanying sensations of flying, out-of-body experiences, or autoscopy (observation of one's own body from an unusual/novel point of view) (Brugger, Regard & Landis, 1997).

Felt Presence

> Just before going to sleep or if awoken suddenly I feel as though a presence, usually a dark shadow figure is standing over the bed staring down at me, or pacing back and forth. (22-year-old, gender not reported, United States)

Among all SP experiences, felt presence, the distinct sensation that another sentient being, human or not, is present in the extracorporeal space of the experiencer, is arguably the most salient, terrifying, and rich. Felt presence is consistently reported as the most common SP-associated experience—about 80% of episodes (Cheyne et al., 1999)—which produces the most fear and SP-related state of distress (Solomonova et al., 2008). One salient feature of felt presence experiences during SP is the fact that it is a distinct sensation, and may occur in the absence of visual, auditory, or tactile imagery. Felt presence experiences during SP have been classified as a paranoid delusion (Cheyne & Girard, 2007), an expression of spatial social imagery (Nielsen, 2007), and as a variant of basic intersubjective experience of the world (Solomonova, Frantova, & Nielsen, 2010).

Felt presence experiences are often interpreted within the cultural framework available to the experiencer (see the following section on the cultural neurophenomenology of SP), but some basic characteristics seem to be common across cultures and ages (Cheyne, 2001): (1) felt presence often manifests from ambiguous stimuli: it is often described as "shadowy," and its physical characteristics are often unclear; (2) the experiencer may report a distinct sensation of being watched, and that the presence has some intentions toward the dreamer; these range from some vague interest to full-blown assault; (3) felt presence is usually accompanied by intense emotions (often fear when the presence is interpreted as threatening), sometimes to the point of a distinct feeling of dread, imminent death, or being in the presence of evil. Positive emotions, however, are also possible, especially when the experience is understood as visitations by deceased relatives or visions of the divine.

Intruder

Consider the following examples of felt presence experiences of the *intruder* type: A 26-year-old man from the United States reports: "It felt as if someone was watching me but silently standing behind me." In this example the presence is felt in a distinct and clear way, but is not seen or heard, yet the experiencer knows where in space the presence is located. Similarly, a 29-year-old woman from the United States regularly experiences the malevolent presence without ever seeing it: ". . . feeling of evil that is watching or monitoring; never able to actually see this 'evil entity.' " Even in the absence of direct visual, auditory, or tactile imagery, she feels that she is observed and that the presence is "evil." The ambiguous qualities of the physical attributes of SP visitors can be illustrated by the following two examples. A 39-year-old man from the United States writes, "The 'presence' is a tall black/darkest grey shadow of a human form without any features. It stands in the doorway to my bedroom waiting to be 'noticed.' " Likewise, a 30-year-old woman experienced various ways in which the presence was manifesting during her SP attacks: "Once it seemed a shadow was leaving the room. One other time the shadow seemed to have 'wild' hair or if it doesn't have hair at all, it looked as some sort of black something."

Incubus

The *incubus* experience happens when the *intruder* physically oppresses the sleeper, sometimes in a rather dramatic way. In words of a 52-year-old man from the United States: "My worst experience was being choked by a man who burst into my bedroom. The experience was so real and frightening that I was very afraid of my SP for many months after." The *incubus* takes many forms, including human, supernatural, and, more rarely, animal: "I often hallucinate creatures like large cats—lions or tigers, . . . wrapping themselves firmly around me and crushing my body" writes a 20-year-old woman from England.

Some of the most dramatic and potentially traumatic SP *incubus* experiences are instances that are lived as sexual assault or alien abduction (McNally & Clancy, 2005b; McNally, 2011). Consider the following example, reported by a 40-year-old man from the United States: "When it is a 'Dark Man' episode, he most likely touches me. Either by laying across my body, in a sexual way or in the beginning, he would grab me and drag me. I always felt that if I let go, he would pull me out of my body." Similarly, a 29-year-old woman from Spain describes her distressing SP experience: ". . . extreme terror, the feeling that air is dense and darker, that shadows boil and take shape. . . . I hear some low tone noises, voices, tactile feeling of grabbing, of naked cold skin, and, very rarely, a presence. Very dark with round eyes, spider-like fingers, that laughs, messes up the bed, and makes me feel terror, with some sexual approaches. . . ." In a study linking reports of space alien abduction to SP episodes, McNally and Clancy present this case: ". . . female abductee . . . was completely paralyzed, and felt electrical vibrations throughout her body. She was sweating, struggling to breathe, and felt her heart pounding in terror. When she opened her eyes, she saw an insect-like alien being on top of her bed" (McNally & Clancy, 2005, p. 116).

Positive Felt Presence Experiences and Doubling

While most easily recognizable and most commonly documented cases of felt presence during SP have to do with a threatening and ominous "visitor," some evidence suggests, however, that the presence is not always understood as hostile. Such experiences include perception of friends and family; visitation from deceased relatives or benevolent spirits; and erotic encounters where the sense of presence is comforting. A 20-year-old SP sufferer from the United States writes, "Once or twice I have thought that my friend or roommate was standing over me. I was confused but not afraid." Similarly, encountering deceased family members in visions or in dreams can be experienced as a positive spiritual event, and possibly play a healing role in processes of bereavement (Belicki, Gulko, Ruzycki, & Aristotle, 2003; Garfield, 1996).

Finally, another rare kind of SP-related felt presence episode involves first an experience of "someone there," and then a doubling of the dreamer's own body, a self-projection into the extracorporeal space. Some individuals report that the felt presence entities are becoming an externalized view of themselves: "Sometimes I feel that the presence is myself, that I can watch myself," reports a 21-year-old man from Jamaica; "I switch to another world and I myself become a presence," writes a 19-year-old man from Russia.

Body Experiences in Sleep Paralysis

Most (if not all) SP episodes are defined by an altered experience of the body. These include simple experiences of muscle paralysis; sensations associated with supernatural assault, including touch, pressure on the chest, or even choking; feelings of unusual vibrations or falling into a vortex; and out-of-body experiences, including flying, falling, or moving around one's house.

One of the most salient features of SP is the REM sleep–related muscle atonia. The inability to move is a striking and unusual experience for most individuals, and the mismatch between sensing the body and the loss of voluntary control over the body's movements may contribute to a range of somatosensory experiences. As discussed earlier, some of the most intense SP episodes may involve a feeling of being assaulted or touched by a supernatural entity. For instance, a 34-year-old man from the United States describes the following experience: "Felt my arms pinned across my chest in a strait jacket hold, felt hands on my chest pinning me against a wall." Perception of not being able to fully breathe, often accompanied by feeling of pressure on the chest, may be prevalent in as much as 57% of SP episodes (Sharpless et al., 2010).

Although most accounts of and research on SP experience have centered on paralysis accompanied by terrifying mentation and by felt presence, not all SP experiences are characterized by imagery and many are simply experiences of transient body paralysis during the transition between sleep and wakefulness, without any other accompanying mental activity (American Academy of Sleep Medicine, 2014). Additionally, SP episodes may be predominantly somatosensory in nature: Cheyne (1999) characterizes these experiences as *vestibulo-motor* mentation.

Autoscopy, out-of-body experiences, vibrations, floating, falling, and body-doubling experiences (Cheyne, 2002) are all possible within the SP framework due to its reliance on dream-supporting REM sleep mechanisms. During a dream, especially a lucid dream (wherein one is aware of the fact that she is dreaming), it is possible to have a simultaneous experience of one's dream body and real body at the same time. Thompson (2014) distinguishes between the dreaming self ("I" the dreamer) and the dream ego ("I" as dreamed) as two coinciding modes of self-experience, which may sometimes be experienced in parallel. The dreaming self is the sleeping self; it is the "I" of the waking life, now engaging in the practice of sleep and dreaming. The dream ego, on the other hand, is the experiential self, immersed in the dream scenario. The "I" as dreamed is the temporary "I" that takes on the first-person perspective as a subject (and sometimes an object) of the dream world. Seen from this point of view, SP episodes may represent an intense experience of the dreaming ego, lacking a dream body and temporarily "stuck" within her immobilized sleeping body of the dreaming self/"I" the dreamer while experiencing dream-like mentation. This feeling of being stuck, coupled with awareness of the overlap between states of vigilance, may then transform itself into a situation of perceptual doubling of body imagery.

Contrary to most SP episodes with a felt presence component, some bodily experiences are described in quite positive terms. For instance, a 20-year-old woman from England describes this characteristic of her typical SP episode: "Generally, the experiences start with a low, pleasant vibration that moves through my body in defined waves, from the feet up. I feel them most strongly in the throat and in my eardrums."

Out-of-body experiences are also relatively common in SP—as much as 39% of SP experiencers have had one at some point (Cheyne, 2002). A 39-year-old woman from the United States writes, "I floated out of my bed into the kitchen. But, as I floated over my bed, I saw like this beast figure crouched over on the front of my bed. I floated over it down to the kitchen. That is where I saw this [*sic*] beautiful kaleidoscope-like leaves. They were so vibrant . . . I then floated back to my room into my body." In this example there is a combination of various SP characteristics: dream-like mentation superimposed onto the environment, a nocturnal visitor, and an altered sense of the body.

SP experiences are also sometimes accompanied by false awakenings—dreams where one has a vivid and realistic feeling of waking up in one's own bed and engaging in usual activities, only to realize that one is still asleep (Buzzi, 2011). While false awakenings are typically characterized as dream experiences, their phenomenology in terms of realism and possible state overlap is to a degree similar to SP. In Cheyne's report (2002), 58% of people who experience SP also experienced false awakenings at least occasionally. Additionally, false awakenings are often associated with feelings of dread, anxiety, and oppression (Green & McCreery, 1994; Nielsen & Zadra, 2011), similarly to SP. The following two examples from our Internet-based sample illustrate such cases: a 24-year old man from the United States reports: ". . . sometimes I think I have moved . . . sometimes even gotten up and walked around only to find that I never got up at all." In a similar vein, a 21-year old man from Jamaica describes his experience: "I will wake up into another dream inside my bedroom and think I am awake and realize I am still sleeping minutes later and the same procedure repeats several times."

Emotions

> . . . Extreme anxiety and fear, mind is awake, but body is asleep. I feel as though I am trapped and cannot communicate with those around me. (23-year-old woman, United States)

The most prevalent emotion associated with SP experiences is fear. Indeed, the most natural reaction to waking up unable to move is panic, and the sensation of constricted breathing (consistent with REM sleep physiology) may increase the state of distress. Sharpless and colleagues (2010) introduced the term *fearful isolated sleep paralysis* to denote SP experiences characterized by an intense state of distress.

As much as 90% of reported SP episodes are described as fearful (Cheyne, Rueffer, & Newby-Clark, 1999). Similarly, in an sample of Irish university students, fear was found to be the most prevalent emotion, with 82% of respondents stating that they have experienced fear at some point during an SP episode (O'Hanlon, Murphy, & Di Blasi, 2011). Moreover, nightmare frequency was previously reported as a predictor of SP occurrence (Liskova, Janeckova, Kluzova Kracmarova, Mlada, & Buskova, 2016). This data suggests that SP, or at least the *fearful* form of SP, can be seen as an intensified form of a nightmare: A recent study by Robert and Zadra (2014) reported that about 65% of nightmares and 45% of bad dreams are characterized by fear.

One approach to classify the affective and personal impact of SP experiences is to assess not only the frequency or intensity of SP episodes, but also *distress* associated with SP experiences (Solomonova et al., 2008; Cheyne & Pennycook, 2013). To what extent is the individual affected by SP? To what extent do negative emotions carry over from an SP episode into waking life? Do SP experiences promote a negative relationship with sleep? These questions have been successfully examined in previous research on nightmares (Belicki, 1992; Blagrove, Farmer, & Williams, 2004), showing that the individual impact of negative and intense dream experiences depends more on a trait-like reactivity, sometimes referred to as *affect distress* (Nielsen & Levine, 2007). This trait is thought to represent a general dysfunction of affect regulation network, and it has been shown to be a better measure of how much nightmares influence waking life emotional well-being than the frequency or intensity of self-reported nightmare occurrence. Furthermore, affect distress mediates reactivity, negative interpretation, and degree of negative reaction to nightmares (Belicki, 1992; Levin & Fireman, 2002). According to Nielsen and Levin (2007; Levin & Nielsen, 2009), dreaming helps regulate emotional memory consolidation and emotional reactivity via fear extinction. Nightmares, therefore, represent a case of problematic/dysfunctional processes of fear extinction. In combination with other factors, affect distress is likely to play a role in the formation, experience, and interpretation of SP.

Positive emotions associated with SP are much less studied, and it is not possible to accurately estimate their prevalence. One possible reason for this is lack of appropriate screening (SP is often diagnosed as an unpleasant phenomenon) and lack of medical/psychiatric concern: Patients are not very likely to describe such experiences to their health practitioner, since they are not bothered by them. In addition, the current diagnostic criteria for a recurrent isolated SP as listed in the latest edition of the *International Classification of Sleep Disorders* (3rd edition; American Academy of Sleep Medicine, 2014), include that the episodes must cause "clinically significant distress including bedtime anxiety or fear of sleep." Such a provision would effectively exclude all possible positive and non-distressing SP phenomena from investigation and/or diagnosis. Nonetheless, in a web-based SP study Cheyne (2002) reports that in addition to anger (30% of respondents) and sadness (23%), bliss (17%) and erotic sensations (17%) are also sometimes present in SP.

Visual and Auditory Experiences

Felt presence is the most prevalent, the most emotionally disturbing, and the most salient SP-related experience. Therefore, it is unsurprising that most visual and auditory mentation during SP usually has something to do with these unwelcome visitors. The entities, however, while *felt* in a very distinctive and concrete way, are often described visually as rather general and vague shadowy beings. Visual experiences are reported to occur in 54%–56% and auditory experiences in 55%–60% (Cheyne, 2002; Solomonova et al., 2008) of SP sufferers.

SP may be accompanied by auditory experiences, ranging from abstract and mechanical sounds, such as electric sounds and sounds of buzzing, to vivid auditory imagery, consistent with SP experience of an *intruder* or an *incubus*. Sounds of footsteps and of voices are often reported (Cheyne, 2002; Cheyne, Rueffer, & Newby-Clark, 1999; Solomonova et al., 2008).

Cultural Grounding of Sleep Paralysis

While SP is a lesser-known sleep phenomenon in the West, it is quite prevalent and is well described in many other cultures. Due to the lack of general awareness of SP in the West, it is rarely discussed in the context of family medicine or psychology. Cross-cultural work on SP revealed that it is rooted in a variety of religious beliefs and cultural schemas, including interpretations of the experience and techniques to engage with the nocturnal visitors. Some of the common qualities of SP across cultures (Adler, 2011) include the following: (1) sensation of being awake; (2) perception of the environment; (3) paralysis; (4) feeling of fear and dread; (5) felt presence; (6) chest pressure/breathing difficulties; (7) supine position; and (8) various unusual body sensations. These apparently culturally invariant qualities of SP-related occurrences of the experience of a supernatural attack have been at the center of the phenomenological and cross-cultural cognitive research on SP.

Figure 31.2 is a reproduction of an eighteenth-century work by Henri Fuseli entitled *The Nightmare*. It represents a sleeping woman in a supine position being oppressed by a maleficent creature sitting on her chest and with an ominous presence of the *nightmare*. It is likely that the early use of the English term *nightmare* was to describe intense SP (Orly & Haines, 2014). Culture-specific presentations of SP-related felt presence experiences typically involve a maleficent supernatural being, such as a witch or an

Figure 31.2. (See Color Insert) Henry Fuseli, *The Nightmare* (1781). Detroit Institute of Art. Public Domain image: https://commons.wikimedia.org/w/index.php?curid=15453518.

evil spirit. Some examples found across cultures include the *kanashibari* demon in Japan (Arikawa, Templer, & Brown, 1999; Fukuda et al., 1987); *kokma* in the West Indies (Ness, 1983); "old hag" in Newfoundland (Hufford, 1989); *pandafeche* in Italy (Jalal, Romanelli, & Hinton, 2015); *uqumangirniq* among the Inuit of Baffin Island (Bloom & Gelardin, 1983; Law & Kirmayer, 2005); and many others (for a comprehensive list of terms for SP experiences, see Adler, 2011). Figure 31.3 illustrates a possible SP representation (Olry & Haines, 2014): a Japanese demon *Yamachichi* oppresses and inhales the breath of the sleeper.

The first systematic cultural exploration of SP was done by Hufford (1989): He described a phenomenon specific to Newfoundland—the "old hag" witch attack. In his book Hufford discusses the tension in situating SP experiences somewhere between the "cultural source hypothesis," wherein cultural interpretations and framing influence how an experience unfolds, and the "experiential source hypothesis," in which some invariant lived experiences, such as SP, may influence the development of a spiritual interpretation and formation of cultural beliefs (Hufford 1989, 2005). Similar to this notion, McNamara and Bulkeley (2015) proposed an experiential hypothesis to describe how dreams and other dream-associated experiences, including visions and transcendental experiences, can be seen as a cornerstone and a source of religious belief (McNamara & Bulkeley, 2015). According to this view, a number of cultural, religious, and paranormal beliefs are shaped primarily by direct experience and then framed within a particular tradition, which imbues them with existential and metaphysical meaning, a notion that is reminiscent of William James's grounding of mystical experience in the phenomenology of lived experience (James, 1985).

The effect of framing such intense subjective experiences within a cultural tradition can have at least two kinds of potentially opposing effects. On the one hand, many cultures provide not only supernatural explanations of SP, but also remedies and protective rituals against it (some of which are described later in this chapter), thus rooting the SP in a framework that allows for shared narrative and for practical interventions. On the other hand, intense and fearful SP, when interpreted as supernatural assault, has a potential for traumatizing the sleeper, thus creating a vicious circle of anxiety, aversion to sleep, facilitation of future SP episodes (Hinton et al., 2005b; Sharpless et al., 2010), and increasing the level of distress via "cultural fear priming" (Jalal, Romanelli, & Hinton, 2015;

Figure 31.3. (See Color Insert) Takehara Shunsen, *Yamachichi* (1841). Public domain image: https://commons.wikimedia.org/w/index.php?curid=2074508.

Ohayon, Zulley, Guilleminault, & Smirne, 1999). For instance, the *incubus* experience, when seen as part of the Christian tradition starting with the late Antique period, according to Gordon (2015), gained additional stigmatizing power, with a connotation of an illicit supernatural sexual experience. Not only were SP victims living through a waking nightmare of an encounter with a demonic assailant, they were also seen as responsible for having summoned it due to their own sinful predisposition/thoughts/impurities.

It is important to note that while SP can include a range of experiences, such as positive experiences, neutral emotions, vestibulo-motor phenomena, out-of-body experiences, and others, most cultural interpretations of SP deal specifically with overlapping aspects of *intruder* and *incubus*.

Neural Basis, Associated Conditions, and Precipitating Factors

Human sleep is typically divided into two kinds: REM sleep and NREM sleep. Healthy adults alternate between NREM and REM in cycles lasting about 90 minutes, for a total of 5–6 cycles over a night of sleep. While it is possible to experience dreaming in all stages of sleep, REM sleep is typically characterized by the most vivid, realistic, bizarre, and emotionally intense sleep mentation (Nielsen, 2000). Other vivid dream experiences, such as nightmares (Nielsen & Levin, 2007) and lucid dreams (LaBerge, Levitan & Dement, 1986), are also typically associated with REM sleep.

Within the context of narcolepsy, sleep paralysis is a part of the diagnostic tetrad, alongside daytime sleepiness, cataplexy, and hypnagogic hallucinations (Thorpy, 2016). There is not sufficient data to assess whether there are significant differences in phenomenology between narcolepsy-associated SP and the isolated form.

SP episodes are characterized by the simultaneous presence of waking thought and of REM sleep psychophysiology (Mahowald & Schenck, 1991, 2005; Terzaghi et al., 2012), and the sleeper can often open her eyes and become relatively aware of her environment, while REM sleep–related spontaneous mentation—vivid dreaming—superimposes onto otherwise awake consciousness. This imagery may occur at sleep onset (hypnagogic) or upon awakening (hypnopompic). Other characteristics of REM sleep, such as airway occlusion and rapid shallow respiration (Gould et al., 1988), may contribute to the feeling of being suffocated or the perception of shortness of breath often reported by SP sufferers. Additionally, in one study, obstructive sleep apnea was found to be a possible precipitating factor for SP (Hsieh, Lai, Liu, Lan, & Hsu, 2010).

Little research has been done on the sleep characteristics of SP sufferers. Some preliminary data suggest that the SP sleep profile may be similar to that of frequent nightmare sufferers (Nielsen et al., 2010), in that SP participants appear, paradoxically, to exhibit less REM sleep pressure, have more "skipped" REM sleep periods, and show no increase in eye movement density (as opposed to healthy controls) throughout the night (Solomonova, Nielsen, Takeuchi, Bezinger, & Carr, 2012). SP participants also show higher delta power during sleep than non-SP controls (Marquis et al., 2015), which suggests alteration of the processes of wake-NREM-REM regulation.

Some of the vestibulo-motor characteristics, such as autoscopy, out-of-body experiences, and feelings of physical transformation, may stem from disturbances in right parietal regions (Jalal & Ramachandran, 2014): The mismatch between intended motor movement and inability to move may contribute to unusual physical sensations.

SP may be experimentally elicited in laboratory settings, but only using an arduous protocol of repeated sleep interruption. For example, SP episodes were experimentally induced by letting participants sleep uninterrupted for the first NREM period, thus eliminating most of the slow-wave sleep pressure (a tendency of slow-wave NREM sleep to take precedence and occupy a large proportion of early night sleep), and then repeatedly awakening participants after 5 minutes of REM sleep have elapsed, thus augmenting REM sleep pressure and facilitating sleep-onset REM periods (SOREMPs). SOREMPs may be seen as a facilitating factor in a REM-wake state dissociation thought to characterize SP experiences. It should be noted, however, that even within such controlled settings and demanding protocols, rates of SP were relatively low: 6 episodes total in 16 participants who already had a tendency toward recurrent isolated SP (Takeuchi, Miyasita, Sasaki, & Inugami, 1992), and 8 episodes from 184 sleep interruptions in 13 SP sufferers (Takeuchi, Fukuda, Sasaki, Inugami, & Murphy, 2002). These results suggest that the incidence of SP at sleep onset may signify an individual's propensity to enter into REM sleep directly upon falling asleep. This further supports the idea that SP may result from alterations in wake-REM-NREM regulation patterns, resulting in state overlap.

Associated Conditions

Little is known about the epidemiology of SP, but growing evidence points to a combination of genetic and experiential factors. The only study to date to examine genetic factors associated with SP has reported moderate heritability, and that this effect was associated with factors known to contribute to disrupted sleep cycles (Denis et al., 2015). Sleep fragmentation and disruption in wake-NREM-REM regulation are an important factor facilitating SP occurrence, but it is uncertain whether all types of SP can be explained by a propensity for sleep fragmentation. Some ethnic groups seem to be more likely to experience SP than others. The Hmong population in Wisconsin, for instance, had a significantly higher incidence of SP than a non-Hmong cohort (Young et al., 2013), with as much as 31% of interviewed Hmong participant reporting at least weekly occurrence of SP episodes. Individuals of African descent also seem to have elevated rates of SP (Bell et al., 1984; Friedman & Paradis, 2002).

Links between affective disorders, especially depression and anxiety, and SP have also been reported. A relationships have been found between SP and depression magnitude and anxiety (Szklo-Coxe, Young, Finn, & Mignot, 2007), social phobia and panic disorder (Otto et al., 2006; Paradis & Friedman, 2005; Sharpless et al., 2010) and social anxiety (Simard & Nielsen, 2005), especially with the sensation of being observed (Solomonova et al., 2008). Changes in REM sleep regulation are often found in mood disorders, especially in depression (Arargun & Cartwright, 2003; Nofzinger et al., 1994).

The relationship between trauma, especially post-traumatic stress disorder (PTSD), and SP has been noted by a number of researchers. McNally and Clancy found that there was a higher proportion of SP reports in participants with a history of childhood sexual abuse (McNally & Clancy, 2005a), and Abrams and colleagues (2008) reported that sexual abuse survivors report more distressing and more frequent SP incidence. In addition, higher rates of SP were found in Hmong population in relation to traumatic Vietnam War experiences (Young et al., 2013), as well as in Khmer (Hinton, Pich, Chhean, & Pollack, 2005a) and Cambodian refugees (Hinton, Pich, Chhean, Pollack, & McNally, 2005b). Similarly, Sharpless and Grom (2013) report that some cases of SP onset in adolescents begin after the loss of a family member. Considering that SP may be conceptualized as a nightmare spectrum experience, this relationship may represent the same dysfunction in the affect regulation network (Levin & Nielsen, 2007; Nielsen & Levin, 2007) as the one that has been proposed to be involved in nightmare production. PTSD-related sleep disturbances have been extensively documented (Germain, Buysse, & Nofzinger, 2008; Spoormaker & Montgomery, 2008), including REM sleep dysregulation and increased nightmares (Germain, 2013; Mellman et al., 2002), which in itself may contribute to altered REM sleep pressure, in turn facilitating the occurrence of SP episodes.

Since SP is often associated with intense, detailed, and troubling visions, a link between SP and psychiatric disorders has been hypothesized. Research, however, shows no consistent relationship between psychiatric conditions and SP, with the exceptions of PTSD, panic disorder, and social anxiety. In one study, a number of links between SP and psychiatric conditions were found (Ohayon et al., 1999); these findings were challenged, however, by an Internet-based study (Solomonova et al., 2008) with a larger sample size, in which no strong links between psychopathology and SP were described. However, while isolated SP often presents itself in the absence of psychopathology, higher rates of hypnagogic and hypnopompic experiences (dream experiences occurring during the transition between sleep and wake, at sleep onset or upon awakenings, respectively), some of which may be associated with SP, are often found in psychosis (Plante & Winkelman, 2008).

Precipitating Factors

In their recent book, Sharpless and Doghramji (2015) list a number of plausible precipitating factors for SP occurrence in susceptible individuals. Sleep fragmentation and insufficient sleep are among the most obvious factors. REM sleep deprivation has been shown to increase REM sleep pressure, contributing to REM rebound effect and intensified dreams at sleep onset (Nielsen et al., 2005). Poor sleep quality with frequent awakenings and disruptions may also facilitate REM-wake overlap, creating fruitful conditions for the occurrence of SOREMPs (Takeuchi et al., 1992; Takeuchi et al., 2002; Spanos, McNulty, DuBreuil, Pires, & Burgess, 1995). Shift work, jet-lag, use of sleep-disrupting medication, stress, anxiety—all these factors affect sleep and may facilitate an SP episode. Alcohol consumption was also reported to promote SP (Golzari & Ghabili, 2013; Munezawa et al., 2011), probably due to its effect on altering sleep architecture (Roehrs & Roth, 2001). Sleeping in a supine position also appears to enhance the risk of an SP episode (Sharpless et al., 2010).

Neurocognitive Considerations

A Return to Felt Presence

While undoubtedly felt presences are a hallmark of SP, especially of the intense and frightening episodes, presence experiences are not restricted to this parasomnia and are reported in a variety of conditions, thus possibly representing a more general and basic social imagery process (Nielsen, 2007; Solomonova, Frantova, & Nielsen, 2011). Arguably, the most salient and compelling felt presence occurs in the context of mystical and spiritual experiences. Otto (1958) introduced the idea of the *numinous* as a cornerstone of religious mystical experiences. Some of the recent work comes from anthropology: The ecstatic presence of God is manifested in the community of Evangelical Christians in the United States (Luhrmann, 2012). Other examples of felt presence have been documented in situations that are physically and emotionally straining or novel. Some examples of these experiences include high-altitude climbing (Brugger, Regard, Landis, & Oelz, 1999); feeling the presence of a baby in postpartum mothers (Nielsen & Paquette, 2007); the presence of deceased relatives in the context of bereavement (Keen, Murray, & Payne, 2013; Simon-Buller, Christopherson, & Jones, 1989; Taylor, 2005); in extreme environments, such as solitary sailing (see also Suedfeld, Rank, & Malůš, Chapter 40 in this volume) and surviving in remote and hostile environments (Suedfeld & Mocellin, 1987); and others. While in most cases felt presence is experienced spontaneously, in some cases it may be a product of sustained mental practices (as in prayer and some forms of meditation). One contemporary non-religious phenomenon is *tulpamancy* (Veissiere, 2016)—a long-term practice of conjuring up imaginary companions, that, over time, may be experienced as almost as real as other people.

Additionally, being able to have a felt sense of others may be seen as a prerequisite for the development of subjectivity. Recent work in phenomenology and enactivism suggests that the development of sense of self depends crucially on sensing others, as early as in utero (Ammaniti & Gallese, 2014; Gallagher, 2005), that the sense of one's own body depends on the sense of others (Maclaren, 2008), and that the self-other dynamic is a necessary condition for the sense of self (Zahavi, 2014). Evidence from dream research also suggests that dream processes are relational and intersubjective. The fact that dreams are most often about other people has been conceptualized as simulations of social interaction (Revonsuo, 2015) and as representations of individual attachment styles (McNamara, Andresen, Clark, Zborowski, & Duffy, 2001). Additionally, dreams, similarly to waking, can be seen as a dynamic interaction between the "self"-related and "non-self" elements of dream content (everything extraneous to the dreamer). These non-self elements (non-human characters, dream environment, even dream objects) can be seen as a "dream other" due to their inherent relational property (Solomonova et al., 2015), as the dream environment in its entirety affectively motivates the dreamer to engage with it.

Toward a Cultural Neurophenomenology of Sleep Paralysis

SP has often been characterized as dissociative (Terzaghi et al., 2012) state, since it effectively combines characteristics of "waking" consciousness (self-awareness, access to autobiographical memory, ability to open eyes and perceive the environment) with REM-sleep phenomena, specifically muscle atonia/paralysis and mentation/dreams. This notion of SP as dissociative has been at the heart of the previous neurobiological work on the link between dreaming and REM sleep. The relative deactivation of the dorsolateral prefrontal cortex characteristic of REM sleep (Hobson, Stickgold, & Pace-Schott, 1988; Maquet, 2000) has been long hypothesized to be at the root of the loss of autobiographic memory and of the inability to appreciate the contents of the dream as "bizarre" or implausible in relation to reality. This has led to the hypothesis that in REM sleep dreaming one is effectively delusional and in a state of a transient psychosis (Hobson, 2004). In SP, similarly, there is often incomplete autobiographical access. This association between SP and REM sleep has also displaced the experience of SP from the psycho-spiritual domain of meaningful encounters with menacing/unreal/supernatural others, into a more reductionist account of uncontrollable and inescapable REM-initiated hallucinations.

In contrast, an account of SP in the context of an oneiric phenomenology and in a 4EA perspective may allow for a more nuanced reading of these experiences. An emerging neurophenomenological framework of sleep challenges the strict distinctions between wake, NREM, and REM sleep. Indeed, while SP is one of the examples of simultaneous presence of REM sleep and wake processes, it is not the only phenomenon that attests to the fluidity and interpermeability of states of consciousness. Lucid dreaming is another example of REM-wake co-occurrence (LaBerge, 1986); REM sleep behavior disorder is characterized by preserved motor output during REM dreaming (Peever, Luppi, & Montplaisir, 2014); somnambulism episodes combine NREM and wake physiology and phenomenology (Zadra, Pilon, Joncas, Rompré, & Montplaisir, 2004); and a variety of dream-enacting behaviors, such as laughing, simple movement, crying, and looking for a baby in bed, are prevalent in normal populations (Nielsen & Paquette, 2007; Nielsen, Svob, & Kuiken, 2010).

A more continuous view of mentation in sleep includes viewing SP as a form of oneiric experience: as a process of intensified mind-wandering (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013), as a process of creativity (Hartmann & Kunzendorf, 2013), or as enactive imagination (Thompson, 2014), a process of sense-making in a rich, embodied, and intersubjective world (Solomonova & Sha, 2016). In his discussion of lucid dreaming, Thompson (2014) proposes that in addition to seeing this state as a dissociative superimposition of two distinct states of consciousness, it may be simultaneously approached as an integrative state, thus allowing for an integration of two different yet related ways of self-experience.

While SP sufferers feel awake and in their own bed, the realism of the experience and the quality of total immersion are completely overpowering to the dreamer, so that she is unable to appreciate the dreamlike quality or the unreality of the SP episode. The high prevalence of tactile and physical sensations probably contributes to this effect. There are, however, numerous accounts of long-time SP experiencers that are characterized by a certain "feel" for the experience as somewhere between real and unreal. SP-related experiences may have a very compelling and realistic quality, but they are usually lived differently from waking experiences, as a kind of a liminal state.

Consider the following example: While the participant is experiencing intense emotion and is quite absorbed in the unfolding on the SP, he seems to have a kind of a dual awareness regarding the nature of his SP:

> . . . Can't. Move. Not a muscle. Not an eyelash. It's often accompanied by hallucinations. So this bizarre

> or terrifying event is happening all around me, and I am completely unable to respond or defend myself. Sometimes I know it's not real, somewhere in my mind, but it looks real, and it sounds real, and I'm terrified or revolted (or maybe just bemused), but I cannot wake myself up to stop it. (30-year-old man, United States)

Similarly, in another example, the experiencer is also hesitant to ascribe any particular state to her experience:

> . . . I might be answering wrong, because I see the beings in my dream-state immediately before waking. But their presence seems so real, I would compare the experience to having them accompanying me in the room. (48-year-old woman, United States)

Grounding SP in its cultural context allows us to appreciate the variety of factors contributing to qualities of the lived experience, and it may not be possible to dissect the relative contribution of the multitude of neural, phenomenological, and cultural narrative factors (Kirmayer, 2009). Importantly, in the current medical context, reducing SP to a dysfunction of REM psychophysiology may also have an important effect on reducing the potential for a deeper exploration of SP as a spiritual experience (Hufford, 2005).

The cultural neurophenomenology of SP is a powerful tool for investigating SP from the 4EA cognition perspective. As neurophysiological, experiential accounts of SP show, the dreamer is in fact embodied—the oneiric scenario is dependent on the dreamer's state of consciousness (REM intrusion) and on the dreamer's physiological state (atonia, shallow rapid breathing). She is embedded in a physical (interprets ambiguous stimuli around her) and in a cultural world (these ambiguous stimuli take on a familiar shape and are infused with a deeper cultural and interpersonal signification). The sleeper is also extended into the world—the whole environment, both dreamed and real, is part of her ongoing experience; and her experience is enactive—there is a relational quality: She is not a passive observer of the oneiric drama unfolding before her eyes, but rather, she is deeply engaged (Solomonova & Sha, 2016).

In order to elucidate neurophenomenological qualities of SP in greater detail, future work may use microdynamic phenomenology/elicitation interviews, aimed at uncovering the fine-grained temporal and structural qualities of lived experience (Nielsen, Chapter 30 in this volume; Petitmengin, 2006; Petitmengin & Lachaux, 2013), in addition to neurophysiological data and deep awareness of the cultural, religious, and spiritual context of the experiencer.

Sleep Paralysis Practices: Prevention, Disruption, Treatment, and Exploration

While SP remains a relatively unknown phenomenon in much of Europe and America, a number of practical culture-specific practices have been developed to protect the sleeper from the negative influence of presumed supernatural forces. While some of these methods have deep roots in their respective metaphysical contexts, and therefore need to be grounded in existing religious and mystical practices, a number of practical and conceptually neutral recommendations have emerged, and seem beneficial for most SP sufferers, regardless of background.

No established treatment for SP currently exists; its clinical management is instead often focused on treating comorbid problems. According to a review by Sharpless and Doghramji (2015), psychoanalysis, cognitive-behavioral therapy (CBT), hypnosis, and education in sleep hygiene have been investigated in relation to SP, but no empirical consensus on the efficacy of such interventions is currently available. Based on the available evidence on SP and cognitive-behavioral approaches to treatment of sleep disorders, especially insomnia, the authors propose a manual for CBT-ISP. This is a promising first step toward finding a systematic method of dealing with SP. Sparse evidence for pharmacological interventions for SP also exists: in one study it was suggested that REM sleep-suppressing antidepressants may provide temporary relief (Plante & Winkelman, 2008), and treatment of narcolepsy may reduce SP frequency (Mamelak, Black, Montplaisir, & Ristanovic, 2004). Antidepressants and anxiolytics were also used in severe cases (Hsieh et al., 2010). Terrillon and Marques-Bonham (2001) proposed that management of SP might benefit from the administration of melatonin, which would help normalize the circadian rhythm. The cost of side effects associated with these treatments, however, may outweigh the benefit, and Shapless and Doghramji (2015) argue for a cautious approach, tailored to each individual situation.

While methods for dealing with sleep paralysis have not been systematically explored by empirical psychology or cognitive science, the contemporary context of Internet-facilitated support groups and information-sharing practices are changing the solitary and culture-bound nature of SP attacks. Furthermore, a number of methods, which have been anecdotally reported and documented online and in print, see SP experiences as an opportunity rather than a nuisance, and promote exploration of one's own consciousness via SP-supported lucid dreaming or even contemplative approaches to SP (Hurd, 2010). One popular support group–mailing list is known as "Awareness during sleep paralysis" (ASP), and a reddit group on SP counts over 4,000 users, sharing information on the phenomenology of their experiences and methods of overcoming them.

Cultural and clinical practices associated with SP can be roughly separated into three kinds: (1) preventive practices, focused on avoiding SP-enabling circumstances; (2) disruptive practices, designed to stop SP in the middle of the experience; and (3) observational/explorative practices, aiming at observing SP and possibly transforming it into a positive event, such as a lucid dream or an out-of-body experience.

Raising awareness of SP-associated phenomena itself may be one of the most important factors in reducing fear and distress before, during, and after SP occurrence (Otto et al., 2006; Sharpless et al., 2010). Indeed, knowing that the experience is transient (will not last), benign (does not contain any real danger), and common (is shared with many individuals across the world) are powerful tools for psychological distancing and for facilitating an eventual observational, as opposed to fully immersive and fatalistic, attitude toward SP. Knowing about SP phenomenology and neurophysiology and having access to cultural grounding with available symbolic gestures helps prevent, disrupt, and transform a negative experience into a tool for self-exploration. Figure 31.4 summarizes the intricate links between precipitating factors and effects of SP experiences in light of disruptive and observational/transformational practices.

Methods for Preventing Sleep Paralysis

While undoubtedly helpful, simply knowing the basis of SP may not be enough to alleviate terror and distress associated with the experiences, and disruption techniques are clearly warranted. A 25-year-old man from the United States reports, "This happens sometimes every night, sometimes only once every few weeks. Even though I 'know' what is happening, and that I am in no danger, it is always terrifying." The first study to systematically assess prevention strategies for SP by Sharpless and Grom (2014) has suggested that while no foolproof method for preventing SP is yet known, some strategies, such as avoiding sleeping on one's back (supine position), maintaining optimal sleep hygiene (avoiding stimulants, noise, irregular sleep patterns, and anything that contributes to sleep fragmentation), and pre-sleep relaxation practices may help in preventing SP.

A number of culture-specific preventive ritualistic measures to prevent SP exist. These include placing a variety of defensive objects in the room or in the bed before going to sleep, such as a variety of knives (Hufford, 1982, Law & Kirmayer, 2005); sprinkling salt (a common anti-witch remedy) (Roberts, 1998); putting a broom bottom-up (Paradis & Friedman, 2005) or a pile of sand at the

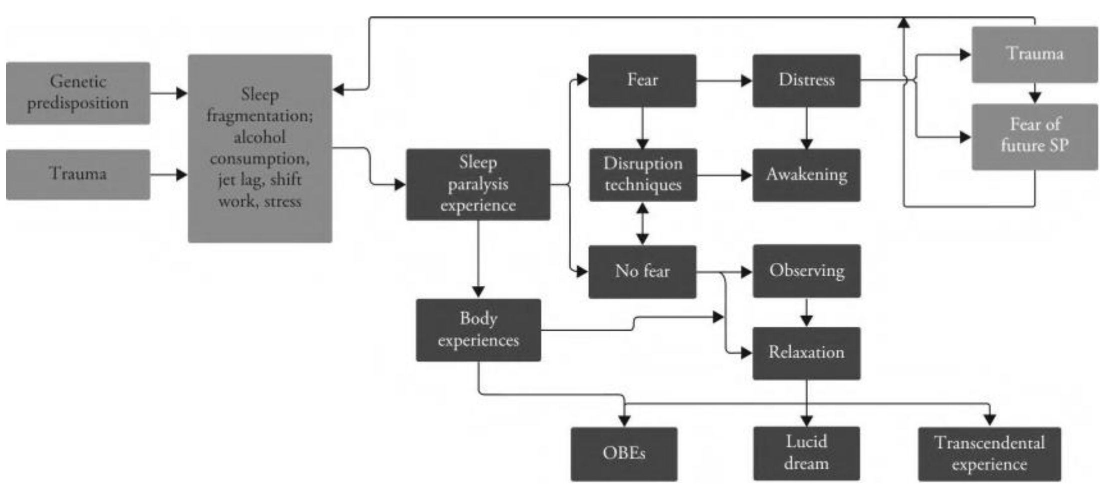

Figure 31.4. (See Color Insert) Predisposing, precipitating factors and experience and outcome of sleep paralysis episodes. Note: OBE = out-of-body experience; SP = sleep paralysis.

bedroom door (Jalal, Romanelli, & Hinton, 2015); and many others. Putting a Bible in the room (Hufford, 1982) and saying a protective prayer before bedtime are also thought of as effective deterrents. Other ritualistic actions, designed to deter, divert, and chase away unwelcome supernatural visitors, were also documented in a variety of contexts (Sharpless & Doghramji, 2015).

Techniques for Disrupting Sleep Paralysis

While preventive measures, whether culturally embedded or aimed at increased awareness and promotion of sleep hygiene, may be effective in reducing the frequency of SP episodes, many methods for dealing with an ongoing SP experience also exist. Considering that most SP experiences are characterized by fear and other unpleasant sensations, it is not surprising that in one study the majority of participants reported having attempted to disrupt the ongoing SP experience. Moving the extremities and self-monitoring (raising awareness, promoting calm) may be helpful during the SP episode (Sharpless & Grom, 2014). Not all attempts or all strategies are equally successful, but it seems that attempting micro movements, instead of trying to get up or to scream, are most effective. Culture-bound rituals include saying a prayer (Hufford, 1989), making a sign of a cross with one's tongue (Davies, 2010), and asking someone to physically shake the oppressed sleeper (Law & Kirmayer, 2005).

Observational/Transformational Practices

One may argue that ISP and lucid dreaming are polar opposites. However, they share the same underlying psychophysiology and seem to involve similar mechanisms: Both are dependent upon REM sleep mechanisms; both are characterized by the simultaneous presence of the dream state and by the feeling of being awake, including activation of higher order metacognitive functions indicative of some degree of waking thought processes (Dresler et al., 2012; Filevich, Dresler, Brick, and Kühn, 2015; LaBerge, Levitan, & Dement, 1986; Voss, Holzmann, Tuin, & Hobson, 2009); and in both cases, muscle atonia is present. The crucial difference between the two states is the quality and the focus of awareness and metacognition: In lucid dreaming, one is aware of the illusory nature of the dream scenario, whereas in SP the dreamer is often absorbed by the vision, not always fully realizing that it is dreamlike, and, in case of fearful SP, is too absorbed in the panicky state of perceived imminent danger.

The link between SP and lucid dreaming has not been systematically investigated in empirical research, but two studies report a positive correlation between frequency of lucid dreaming and SP (Denis & Poerio, 2016; Solomonova, Nielsen, & Stenstrom, 2009), suggesting that the REM-wake intertwined state, characterizing SP, may be a trait-like phenomenon predisposing individuals to SP, on the one hand, and facilitating lucidity in REM sleep dreams, on the other.

Transforming SP into a positive experience, such as an OBE or a lucid dream, or utilizing SP experiences as a means of contemplative insight into one's own mind, may become a practice in itself, since not only techniques for disrupting and preventing SP exist in the contemporary digital culture, but also techniques for inducing SP, with the hope that the experience will function as a portal to a desirable altered state of consciousness (Hurd, 2010). The following two reports illustrate the transformative potential of SP:

> I have woken up from dreaming and found I can't move or open my eyes. I get the feeling of lemonade bubbling in my body, especially my head. It is very frightening. But since I have been having OBEs[3] I now relax and go with the flow of sleep paralysis and sometimes I actually achieve an OBE. (40-year-old man, Australia)

> At first I was very frightened until I found the ASP email group and found that I was not the only one being "visited" by this being during sleep paralysis. . . . When it first started happening it was more of an assault and I had to fight terribly to escape. But after years, I learned to ignore and now I've been trying to communicate with the presence. (40-year-old man, United States)

Further Considerations and Future Directions

In terms of possible avenues for treatment, since SP can be conceptualized as a form of nightmare occurring in a mixed state of consciousness, nightmare treatment techniques could be useful in approaching SP. Currently, the most used and recommended technique for treating chronic nightmares is *imagery rehearsal therapy* (Krakow, Kellner, Pathak, & Lambert, 1995; Krakow & Zadra, 2006), which consists of "rehearsing" and transforming dysphoric oneiric imagery in a safe context. This method has been effective in treating PTSD-related nightmares (Cook et al., 2010; Casement & Swanson, 2012; Germain et al., 2004;

Krakow et al., 2001), which seems particularly appropriate for intense and trauma-related SP experiences. Similarly, treatment of nightmares by lucid dreaming is a promising avenue (LaBerge, 2009; Spoormaker & Van Den Bout, 2006; Zadra & Pihl, 1997). Considering that neurophysiologically both states are characterized by an overlap between REM sleep and wakefulness, and that a number of folk approaches treating SP as a portal to lucid dreams already exist, mastering lucid dreaming could be an effective approach to the transformation of an ongoing SP episode. Such a strategy may also be highly effective in de-stigmatizing and desensitizing the experiencer, especially in increasing her mastery and agency over her spontaneous oneiric experiences.

Contemplative practices, such as meditation or *pranayama* (yogic breathing), may also be useful in dealing with recurring SP episodes. There is currently no empirical evidence for contemplative techniques and SP management, with the exception of a case study by Jalal (2016), but anecdotal evidence from practitioners, as well as growing empirical literature linking contemplative practices with stress management, emotion regulation, and increased self-awareness, provides grounds for future research.

Recent years have seen an important increase in empirical studies on the effects of meditation and meditation-based mindfulness interventions. There are documented benefits of contemplative practice in clinical populations, including positive effects in mood disorders such as anxiety and depression (Goyal et al., 2014; Hofmann et al., 2010), social anxiety (Goldin & Gross, 2010), and PTSD (Kearney et al., 2013). At least four kinds of meditation are currently investigated in relation to mental health: focused attention, open monitoring (Lutz, Slagter, Dunne, & Davidson, 2008), self-transcendence (Travis & Shear, 2010), and loving-kindness meditation (Hofmann, Grossman, & Hinton, 2011). Different kinds of meditation practices may recruit different neural networks (Fox et al., 2016), and particular psychological and neuroplastic changes, associated with meditation practice, likely depend on the kind and duration of meditation experience (Lutz, Jha, Dunne, & Saron, 2015). These different kinds of contemplative practice may be helpful in targeting different kinds of recurrent SP experiences, promoting de-automatization (Kang, Gruber, & Gray, 2013) and deconstructing patterns of behavior/reactivity. Meditation may be effective in SP management as a way of cultivating a non-judgmental or "non-sticky" observational attitude to arising imagery, sensations, and emotions, and in letting the experience unfold. In addition, one important feature of most mindfulness-related practices is the focus on the experience of the body (Kerr, Sacchet, Lazar, Moore, & Jones, 2013), and some evidence suggests that meditation practice may improve awareness of one's own body states (Solomonova et al., 2016) and increase introspective accuracy for somatic experience (Fox et al., 2012). Breathing practices, such as *pranayama*, may be particularly effective in transforming SP as it is happening due to the fact that many SP episodes are characterized by a feeling of disordered/insufficient breathing. A recent study (Seppälä et al., 2014) reported that breathing exercises were effective in decreasing PTSD symptoms in war veterans. This implies that practicing techniques that improve awareness of body sensations may lower the reactivity to SP episodes, thus lowering the distressing quality of the experience, and increasing the potential for disrupting or transforming SP.

Acknowledgments

The author was supported by Social Sciences and Humanities Research Council (SSHRC) of Canada and by a J.-A. DeSèves Sacre-Coeur Hospital Foundation doctoral scholarship. Thanks are due to Tore Nielsen, Philippe Stenstrom, and Michelle Carr for numerous conversations on sleep paralysis and its interpretation, and to the members of the Dream and Nightmare Laboratory at the Center for Advanced Research in Sleep Medicine. Additional thanks are due to Don Donderi and Elena Frantova, as well as to all participants who have consented to share their experiences with us. Special thanks to Benjamen Samaha (artist) and to the anonymous SP sufferer for generously offering the narrative and the drawing of a sleep paralysis episode.

Notes

1. In this chapter I will use the terms "imagery" and "mentation" interchangeably to refer to visual, auditory, somatosensory, and even social experiences during SP. The term "imagery" here is therefore not restricted to the visual domain. I prefer "imagery" and "mentation" to "hallucination; in order to emphasize the dream-like process of spontaneous imagination that takes place during SP, and to de-emphasize the association with delusional thought and pathologies, associated with the term "hallucination."
2. Excerpt from the dreamer's account: "The transition between wake and sleep is a crucial moment to enter into the world of dreams. During this transition on countless occasions I would awaken suddenly not being able to move. During this experience it seems that the very essence of fear permeates my consciousness. Eeriness goes through my soul, freezes my blood and interrupts all substantial notion of my being.

No words can describe that visceral sensation, and in parallel, no words can come out of my mouth. Aware of the lack of muscle tonus, I try to escape this inevitable Machiavellian *black beast*, that materializes in my head before my eyes and on my chest, slowing down my breathing. Moreover, my senses are grabbed by an impression of fighting a hurricane that may drag me out of my body. This cyclone, that has a black hole in lieu of an eye, forces me to fight it, and this fight seems crucial to my survival [. . .]. In addition, there are auditory experiences, an amalgam of petrifying words and vibrations that feel like sudden gusts of wind in the eardrums. All this happens when by body feels like a statue, without a possibility of screaming.

[. . .] On occasion, with determination and *lucidity*, I can have power over this swirl of stillness. [. . .] I take back some control of my imaginary hands, and then I hold them out to *Morpheus* for a dazzling and colorful dance in a deep and enlightened night." (Male SP sufferer, also diagnosed with narcolepsy. Montreal, Canada. Account translated from French).

3. OBE = out-of-body experience

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CHAPTER

32

Dreaming and Waking Thought as a Reflection of Memory Consolidation

Erin J. Wamsley

Abstract

Dreaming has often been viewed as a "mysterious" experience entirely distinct from waking cognition. An alternative view proposes that dreams are generated by the same fundamental processes that give rise to spontaneous thought during wakefulness. New evidence suggests that these processes include activity of the brain's memory systems, supporting consolidation of newly encoded experience. During both sleep and wakefulness, fragments of recently encoded memory are recombined with related remote memory and semantic information to create novel scenarios. This is an adaptive process that contributes to the "consolidation" of memory and is reflected in the phenomenology of both our nightly dreams and waking daydreams.

Key Words: dreaming, sleep, spontaneous thought, memory, semantic, daydream

Introduction and Historical Notes

What are dreams made of? For millennia, humans have sought to answer this question. Today, converging lines of evidence point to a surprisingly simple possibility: Dreams, like spontaneous thought in wakefulness, are made of *memory*.

The general notion that dreams arise from memory stretches back more than a century, with the most influential models describing dream construction as a process categorically distinct from that which gives rise to waking cognition. Freud, for example, saw sleep as a time when the "unconscious" mind was uniquely enabled to influence mental imagery, in a manner unlike any waking experience (Freud, 1913). The appearance of memory in dreams was recognized, but considered of secondary importance to discovering latent "meaning" hidden in dreams. Over 70 years later, Hobson and McCarley proposed the first neuroscientific theory of dreaming (Hobson & McCarley, 1977). Ostensibly a stark departure from Freud, the "Activation-Synthesis" hypothesis proposed that dreams are constructed via a bottom-up process initiated by essentially random brainstem impulses during REM (rapid eye movement) sleep (Hobson & McCarley, 1977), devoid of the sort of intentionally disguised meaning championed by psychoanalysts. Yet like psychoanalysis, Activation-Synthesis[1] still described dreaming as a category of cognition entirely distinct from waking thought—dreams were a unique form of visual hallucination characterized by heightened emotion, uncritical acceptance of bizarre events, and a breakdown of higher-order cognitive functions (Hobson & McCarley, 1977; Hobson, Pace-Schott, & Stickgold, 2000). Memory networks might have been among those randomly activated during dreaming, but the chaotic process by which this occurred bore little resemblance to waking cognition. In short, for the last hundred years, dreaming has most often been considered a process entirely distinct from that which gives rise to waking thought.

An alternative view proposes that dreams are generated by the same fundamental processes that give rise to spontaneous thought during wakefulness (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Domhoff, 2011; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; Wamsley & Stickgold, 2010). Grounded in the work of cognitive theorists including Calvin Hall (1953) and John Antrobus (1983, 1991), new observations of offline memory processing during both sleep and rest lend increasing support to this conceptualization. Certainly, the cessation of sensory input and altered neurochemical milieu during sleep render dream cognition partially dissimilar from waking thought. Yet the fundamental brain processes that give rise to spontaneous thought may remain constant across states of consciousness. Here, we argue that these fundamental processes are rooted in the brain's memory systems, which initiate the reactivation and consolidation of recently formed memory across both sleep and resting wake states. In the following, we describe evidence that during both sleep and wakefulness, fragments of recently encoded memory are recombined with related remote memory and semantic information to create novel scenarios. This is an adaptive process that contributes to the "consolidation" of memory and is reflected in the phenomenology of our dreams and daydreams.

Dreaming and Memory

The Incorporation of Memory into Dreams

There is a long history of evidence that dream content is composed, at least in part, of both recent and remote memories. Even prior to Freud's concept of "day residue" (Freud, 1913), early experimentalists were testing the effect of pre-sleep experience on subsequent dream content. Norwegian psychologist J. Mourly Vold, for example, conducted extensive experimentation on the relationship between visual experiences introduced during the evening and the content of dreams the following night (Warren, 1897). Following the discovery of REM sleep in the early 1950s, this question received renewed attention as researchers attempted to trace the incorporation of pre-sleep experiences into dreaming by exposing participants to videos, images, or other stimuli prior to sleep (Breger, Hunter, & Lane, 1971; Cartwright, Bernick, & Borowitz, 1969; Foulkes & Rechtschaffen, 1964; Witkin & Lewis, 1967). Yet despite the large amount of research effort devoted to this question, laboratory studies using appropriate controls (such as independent raters blinded to experimental condition) largely failed to demonstrate significant effects of experimental stimuli on subsequent dreaming (Wamsley & Stickgold, 2009).

A notable exception was the discovery that research participants incorporate the experience of visiting the sleep laboratory into their dreams at high rates (Dement, Kahn, & Roffwarg, 1965). The laboratory environment, electroencephalograph (EEG) equipment, and experimenters encountered the previous night are consistently among the most common features of laboratory-collected dream reports (Dement et al., 1965). Thus, despite the difficulty of experimentally influencing dreams using images and videos, certain recent episodic memories do clearly influence subsequent dream content. The precise features of a memory that render it more or less likely to be reactivated during sleep and incorporated into dreaming are not well understood. However, the salience of sleeping in a laboratory while attached to EEG recording equipment and being observed by strangers might cause this novel experience to have an outsize influence on dream content. Indeed, recent studies of memory consolidation during sleep suggest that salient information that is emotional (Payne, Stickgold, Swanberg, & Kensinger, 2008), rewarded (Fischer & Born, 2009), or known to be relevant to a future test (van Dongen, Thielen, Takashima, Barth, & Fernández, 2012; Wilhelm et al., 2011) is preferentially processed in the sleeping brain.

Further supporting the notion that more salient waking experiences are preferentially incorporated into dreams, subsequent research has demonstrated that, unlike passive viewing of images and videos, emotionally engaging, interactive video-game tasks have a consistently strong effect on subsequent dream content. In one series of studies using the downhill skiing arcade game *Alpine Racer II*, we found that 30% of subsequent sleep-onset dream reports were related to the game. Other studies have demonstrated clear incorporation of the video game Tetris (Kusse, Shaffii-LE Bourdiec, Schrouff, Matarazzo, & Maquet, 2011; Stickgold, Malia, Maguire, Roddenberry, & O'Connor, 2000), virtual maze navigation tasks (Solomonova, Stenstrom, Paquette, & Nielsen, 2015; Wamsley, Tucker, Payne, Benavides, & Stickgold, 2010), and other video-game experiences (Gackenbach, Rosie, Bown, & Sample, 2011) into dreams. Taken together, these observations suggest that while not all experimental tasks show a definite impact on dream content, engaging, interactive pre-sleep learning experiences have a high probability of influencing subsequent dream experience. Taken together, these observations offer an unequivocal demonstration that memory of recent learning experiences forms a major component of subjective experience during sleep.

However, episodic memories are rarely "replayed" in dreams in their entire, original form (Fosse, Fosse, Hobson, & Stickgold, 2003; Malinowski & Horton, 2014). For example, a 2003 study by Fosse and colleagues analyzed the waking-memory sources of 299 home-collected dream reports, finding that although recent memories were frequently identified as the *source* of the dream (51% of reports), less than 2% included all of the key elements of the original memory, including the setting, characters, objects, and actions of the waking experience (Fosse et al., 2003). Instead, dreams identified as "related" to a recent memory typically incorporate only fragments of the source episode, perhaps intermingled with other recent memories, remote memories, and semantic knowledge.

In our studies of the *Alpine Racer* skiing game, for example, the reports that judges (blind to condition) scored as related to the game were never a complete and faithful reiteration of the learning experience (Wamsley, Perry, Djonlagic, Reaven, & Stickgold, 2010). At times, participants reported isolated elements that closely mirrored the waking experience, such as this participant, who imagined a specific point on the skiing course, reporting that he dreamed

> . . . about that skiing game and how just the first really big turn I didn't know it was coming around the corner. I just felt that like I continually was doing that turn. (Wamsley, Perry, et al., 2010)

Yet in other instances, related experiences appeared in the dream, rather than a direct representation of the learning experience itself. For example, one participant reported a dream that clearly referenced a remote memory related to the learning task:

> I was picturing stacking wood this time . . . I felt like I was doing it at. . . at a ski resort that I had been to before, like five years ago maybe. (Wamsley, Perry, et al., 2010)

In other cases, the memory of a recent learning experience might be combined with semantically related remote memories from the more distant past. For example, after training on a virtual maze navigation-learning task, a participant in another study reported

> thinking about the maze and kinda having people as check points . . . that led me to think about when I went on this trip a few years ago and we went to see a bat cave, and they're kind of like, maze-like. (Wamsley, Tucker, Payne, Benavides, et al., 2010)

Although dream reports in the preceding studies were restricted to early NREM (non-rapid eye movement) sleep,[2] in other recent work we have observed that dream reports from all sleep stages at times combined elements of waking episodes from different points in the past (Wamsley, Hamilton, Graveline, Manceor, & Parr, 2016; Figure 32.1). This feature of dreaming, in which fragments of multiple episodes are simultaneously activated and combined into a novel form, echoes recent observations from the rodent memory reactivation literature, showing that the "replay" of memory during sleep is not really a direct reiteration of a single waking experience, but instead combines features of multiple waking episodes, at times resulting in the "replay" of novel, never-before-experienced spatial trajectories (Gupta, van der Meer, Touretzky, & Redish, 2010; Kudrimoti, Barnes, & McNaughton, 1999). While it may at first seem that the activation of multiple memory fragments in combination would lead to memory distortions, such a mechanism could actually be ideally suited to the gradual integration of newly learned information with related memory networks in the neocortex via hippocampal replay, for example as described by the *complementary learning systems* model (Kumaran, Hassabis, & McClelland, 2016; McClelland & O'Reilly, 1995; see also Mills, Herrerra-Bennett, Faber, & Christoff, Chapter 2 in this volume), or to the extraction of commonalities across multiple waking experiences, a process that is also facilitated by sleep (Durrant, Taylor, Cairney, & Lewis, 2011; Ellenbogen, Hu, Payne, Titone, & Walker, 2007; Lau, Tucker, & Fishbein, 2010).

Future Simulation in Dreams

Dream experience may also serve to simulate possible future events. Recent advances in cognitive neuroscience have led to the notion that human memory functions not to help us remember the past per se, but rather to prepare us for the future (Schacter, Addis, & Buckner, 2007). Thus, a growing field has begun to examine waking thought, imagery, and daydreaming as the product of a "prospective brain" (Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis, Wong, & Schacter, 2007; Schacter et al., 2007) that is constantly using past experience to predict and prepare for possible future events. The notion that our brains use memory to construct episodic simulations of potential futures is strongly in line with the long-standing "threat simulation" hypothesis of dreaming proposed by Antti Revonsuo (Valli & Revonsuo, 2009), which focuses

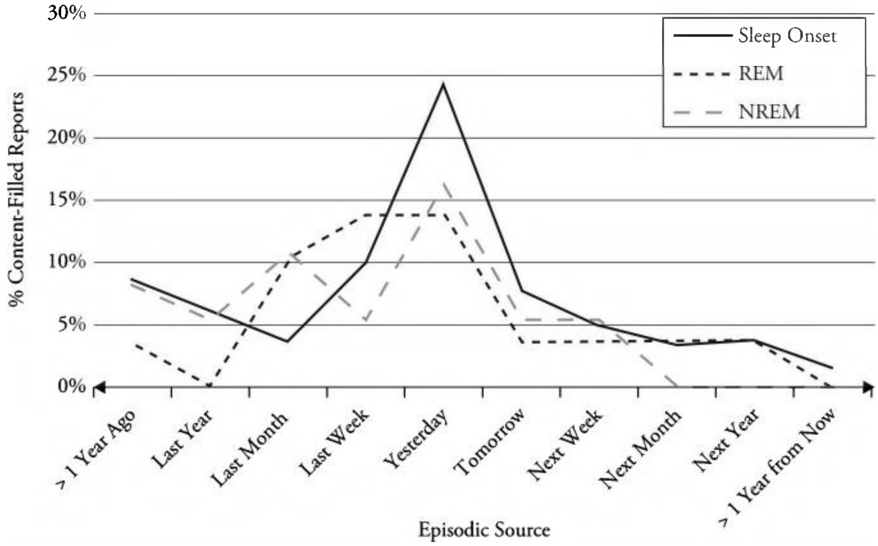

Figure 32.1. The incorporation of past and anticipated future episodes into dream content. Participants commonly identify their dreams as originating from specific past events, or from specific impending future events. Dream reports most commonly reference the recent past or near future, rather than more distant time points. In all sleep stages, single reports may combine multiple past and future sources.

on dreaming as a rehearsal for threatening events that could occur in the future, triggered by negative emotional experiences in the past. Our own observations also support the notion that future-oriented imagery forms a major component of dream experience (Wamsley et al., 2016). In one recent study, participants spent the night in the sleep laboratory and were awakened to provide multiple dream reports from both NREM and REM sleep stages. During a morning interview, participants listened to recordings of all of their reports from the previous night, identifying whether the experience incorporated an event from the *past*, an event that will be experienced in the *future*, or both. Participants frequently identified anticipated future events as the source of their dream content. Although past experience was most frequently identified as the source of the dream (49% of reports), a full 30% of dream reports were identified as stemming from an impending future event (Figure 32.1) (Wamsley et al., 2016).

Neurophysiological Evidence of Memory Processing During Sleep

Related evidence suggests that not only are recent memories incorporated into dreaming, but the activation of memory networks during sleep is actually *functional.* In humans, behavioral studies have established that sleep following learning leads to improved memory. Across a wide variety of domains, including verbal (Ellenbogen, Hulbert, Stickgold, Dinges, & Thompson-Schill, 2006; Payne et al., 2012; Plihal & Born, 1997; Tucker et al., 2006), perceptual (Mednick, Nakayama, & Stickgold, 2003; Stickgold, James, & Hobson, 2000), motor (Nishida & Walker, 2007; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002), and spatial (Nguyen, Tucker, Stickgold, & Wamsley, 2013; Wamsley, Tucker, Payne, & Stickgold, 2010) memory, obtaining sleep following learning leads to superior memory performance at a delayed test, relative to an equivalent duration of active wakefulness. This memory benefit is thought to derive from a process of systems-level memory consolidation unfolding in sleep, during which the repeated reactivation of recent memory traces facilitates gradual updating of cortical networks encoding experience (Diekelmann & Born, 2010; Frankland & Bontempi, 2005).

This model is supported by neurophysiological evidence that memory networks are activated during sleep at both the cellular and systems levels. First, studies using single-unit recordings in the rodent hippocampus and neocortex have described the phenomenon of memory "reactivation," in which patterns of place for cell activity, first established when rats are exploring a spatial environment during wakefulness, are later repeated during sleep

(Ji & Wilson, 2006; Lee & Wilson, 2002; Wilson & McNaughton, 1994). This offline "replay" of ensemble activity is thought to contribute to memory consolidation—as hippocampal networks repeatedly trigger the cortical activity patterns representing experience, cortical connections are strengthened, which eventually allows the memory to be retrieved without the aid of the hippocampus (Frankland & Bontempi, 2005; O'Neill, Pleydell-Bouverie, Dupret, & Csicsvari, 2010). Indeed, hippocampal oscillations during which these reactivation events occur ("sharp-wave ripples") increase following learning (Eschenko, Ramadan, Molle, Born, & Sara, 2008), and conversely, their disruption impairs memory (Ego-Stengel & Wilson, 2010; Girardeau, Benchenane, Wiener, Buzsáki, & Zugaro, 2009). While these cellular-level "replay" events are not definitively associated with dreaming, their occurrence clearly demonstrates that memory-related neural activity is occurring during sleep.

The effect of sleep on human memory has similarly been linked to sharp-wave ripple oscillations during NREM sleep (Axmacher, Elger, & Fell, 2008), and to the activity of memory-related brain regions as identified in neuroimaging studies. Beginning in the 1990s, neuroimaging studies of human sleep have consistently demonstrated that memory-related brain regions, including the hippocampus and medial prefrontal cortex, are among those that remain active in sleep (Braun et al., 1997; Maquet et al., 2000; Nofzinger et al., 2002; Peigneux et al., 2004). Even during NREM sleep, some medial temporal and medial prefrontal regions remain relatively active, when adjusting for the large global reductions in signal that occur brain-wide (Nofzinger et al., 2002; Peigneux et al., 2004). Meanwhile, several imaging studies have also demonstrated experience-induced patterns of brain activation during human sleep (Maquet et al., 2000; Peigneux et al., 2003; Peigneux et al., 2004), and in one case, learning-related hippocampal activation during slow-wave sleep was found to predict next-morning memory performance on a virtual navigation task (Peigneux et al., 2004).

Dreaming Is Associated with Improved Memory

Further evidence that memory consolidation contributes to dreaming comes from studies showing that when recent learning experiences are incorporated into dream content, memory for that information is enhanced. Fiss and colleagues (1977) reported the first observation of this phenomenon, finding that after reading a short story, participants who reported dreams related to the story exhibited superior memory for the text the following morning (Fiss, Kremer, & Litchman, 1977). De Koninck et al. followed this work by examining the correlation between dream content and language learning in an academic setting. Among students enrolled in a French-immersion class, those with the strongest language acquisition incorporated French into their dreams more frequently than students who were less successful in the class (De Koninck, Christ, Hébert, & Rinfret, 1990). Most recently, our laboratory has demonstrated that dreaming of a virtual maze-navigation task is associated with enhanced consolidation of spatial memory both across a nap (Wamsley, Tucker, Payne, Benavides, et al., 2010) and across a full night of sleep (Wamsley, Nguyen, Tucker, Olsen, & Stickgold, 2012) (Figure 32.2). Although the hypothesis that dreaming of a learning task is associated with improved memory has not been universally supported (Schredl & Erlacher, 2010), these studies suggest that the processes that cause sleep to benefit human memory may be at least reflected in concomitant dream experience.

Which Memories Appear in Spontaneous Cognition and Why?

But supposing that the preceding account proves to be true—what controls *which* memories are reactivated during sleep, and how they are combined together? A memory consolidation account of dreaming suggests that there is likely to exist some organized set of principles governing which memory networks become active during sleep, and thus appear in the content of dreams (Wamsley, 2014). For example, recent work on sleep-dependent memory consolidation has proposed that the salience of a learning experience (variously defined as reward value [Fischer & Born, 2009], emotional intensity [Payne et al., 2008], or future relevance [Wilhelm et al., 2011]) mediates its reactivation and consolidation in the sleeping brain. However, this hypothesis remains largely untested when it comes to dreams. In one recent study, informing participants that they would be tested on what they were learning the next morning (a manipulation previously reported to enhance memory consolidation in sleep [Fischer & Born, 2009]) did not affect the incorporation of the learning experience into dreaming (Wamsley et al., 2016). Similarly, although there is a long-standing hypothesis that highly emotional waking experiences are most likely to influence

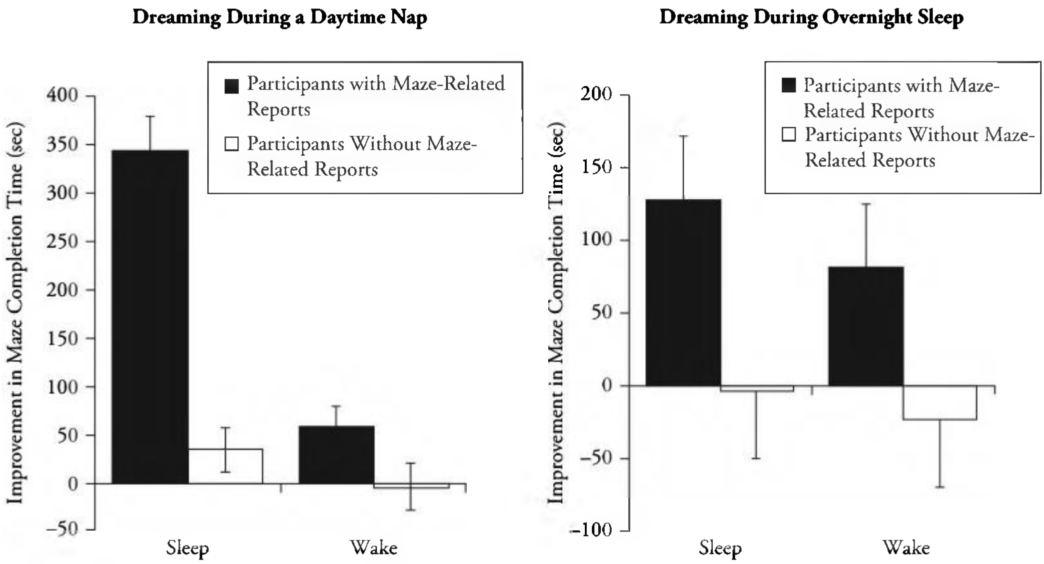

Figure 32.2. Dreaming of a learning task is associated with enhanced memory consolidation. During both a daytime nap (left) and a night of sleep (right), participants who reported dreaming about the experimental learning task (Virtual Maze Navigation Task) showed enhanced memory performance at later test. Reports of spontaneous thoughts about the task during wakefulness were not significantly associated with performance.

dream content, there remains little experimental work that directly supports this hypothesis.

Still, there are a few robustly established observations about the rules governing the incorporation of memories into dream content. First, we know that waking experiences are not incorporated into dreaming as a simple function of the amount of time that we spend engaged in these activities during wakefulness—routine activities such as reading, writing, and working on a computer, for example, comprise a large portion of participants' daytime activities, but are rarely incorporated into subsequent dreams (Hartmann, 2000; Michael Schredl & Hofmann, 2003). Second, waking memories are especially likely to be incorporated into dreaming at specific time points following the experience, with memory incorporation showing an initial peak during the first one to two nights following encoding, and a secondary peak approximately a week later (Blagrove, Fouquet, et al., 2011; Blagrove, Henley-Einion, Barnett, Edwards, & Heidi Seage, 2011; Nielsen, Kuiken, Alain, Stenstrom, & Powell, 2004; van Rijn et al., 2015). Finally, it appears that dreams during NREM sleep are more easily traced to specific waking episodes at a particular time and place, relative to REM dreams (Baylor & Cavallero, 2001). As described earlier, however, these waking episodes typically appear in dreams in an abstracted form in which only fragments of recent experience are interleaved with other content. Although the neurophysiological mechanisms underlying these phenomenological observations remain unknown, the incorporation of select waking experience features into NREM dreaming at specific points following encoding could reflect the time course of memory consolidation for select experiences during NREM sleep.

If the content of dreams even partially reflects memory consolidation in the sleeping brain, then observing the manner in which memories appear in dreaming could help us to better understand the process of consolidation in general. Certainly, the cognitive-level activation of memory in dreams provides information about the specific memory networks that are active in the sleeping brain at a level of detail currently unavailable in humans by other means (Wamsley, 2013). It follows that using subjective reports as an indicator of activated memory networks during sleep could provide useful information about underlying memory processes.

For example, the *complementary learning systems* model (Kumaran et al., 2016; McClelland & O'Reilly, 1995) suggests that in order to optimally integrate new memories into cortical networks, representations of recent experience must be repeatedly reactivated during offline states. But this repeated reactivation must be interleaved with the activation of other related memories, so that new experiences are gradually integrated into cortical networks in a way that avoids catastrophic inference amounting to the "overwriting" of older information with the newest learning (Kumaran et al., 2016; McClelland & O'Reilly, 1995). The manner in which new memories are interleaved with other memory traces remains unknown. There are several possibilities, including that (1) recent memories stored in the hippocampus are reactivated interleaved with all other recently encoded hippocampal memories; (2) recent memories stored in the hippocampus are reactivated interleaved only with related recent memories, for example via a process of spreading activation that biases memory networks with overlapping features to become active, or (3) recent memories stored in the hippocampus are reactivated interleaved with related cortical memory networks (Kumaran et al., 2016). In any of these scenarios, different memories might be reactivated sequentially (either within the same sleep stage or across the night in different sleep stages), or they might be reactivated *simultaneously*, as suggested by recent observations of hippocampal replay events, in which elements of multiple experiences are simultaneously expressed at the ensemble level (Gupta et al., 2010; Kudrimoti et al., 1999). Subjective reports revealing *which* recent and remote memory traces are active during sleep could help us to distinguish between competing models of how different memories are reactivated offline in an "interleaved" manner. Ongoing work in our laboratory seeks to achieve this by describing the manner in which multiple episodes from different temporal sources are combined to create novel imagery in both dreaming and waking thought.

Memory and Spontaneous Cognition in Waking

In the preceding, we have suggested that dreaming is constructed from fragments of memory as recent episodes are reactivated and interleaved together during sleep. However, this process is very likely not unique to sleep. On the contrary, the incorporation of waking memory fragments into dream scenarios may be only a special case of a more general process by which spontaneous cognition is constructed across all states of consciousness. Indeed, these observations about dreaming closely mirror the concept of "constructive episodic simulation," proposed by Schacter and others as a central feature of waking cognition (Addis et al., 2009; Schacter & Addis, 2007; Schacter, Guerin, & St. Jacques, 2011).

Certainly, memories of the past are a major component of waking daydreams and "mind-wandering," as are mental simulations of possible futures and imagined scenarios (Andrews-Hanna, 2011; Smallwood & Schooler, 2015). While from one perspective, these latter forms of experience may seem to fall outside the realm of "memory," future-oriented cognition and imagination in fact also draw on memory representations and are associated with the activation of many of the same brain regions engaged when recalling past experiences (Addis et al., 2009; Addis et al., 2007; Schacter et al., 2007). Meanwhile, these and other brain regions recruited during spontaneous waking thought (Fox et al., 2013; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015) overlap significantly with those that remain active during REM sleep (Fox et al., 2013; Fox et al., 2015) and some that remain relatively active into NREM sleep, when adjusting for the overall reduced level of activity (Nofzinger et al., 2002; Peigneux et al., 2004). A recent meta-analysis directly addressed this point by quantitatively demonstrating that brain activation patterns during REM sleep show a high degree of overlap with the "default network" during off-task rest, and that simultaneously, the features of dream cognition mirror reports of spontaneous thought sampled during the resting wakefulness of default mode studies (Fox et al., 2013; see also Domhoff, 2011). Thus, in both sleep and wakefulness, the construction of spontaneous thought engages memory systems, as evidenced through both reports of phenomenology and neuroimaging observations.

At the same time, many of the neurophysiological processes thought to promote memory consolidation during sleep are also engaged during resting wakefulness. Most obviously, both sleep and resting wakefulness are characterized by a precipitous decrease in external sensory input, relative to active waking states. And although the "reactivation" of recent memory traces in the rodent hippocampus and cortex was first described during slow-wave sleep, it is now well documented that this same replay of waking experience is also expressed during quiet waking rest (Carr, Jadhav, & Frank, 2011; Davidson, Kloosterman, & Wilson, 2009; Foster & Wilson, 2006; Karlsson & Frank, 2009). The hippocampal "sharp-wave ripples" during which memory reactivation occurs are also prevalent during resting wakefulness, in humans as well as animals (Axmacher et al., 2008; Clemens et al., 2011). And while low-frequency EEG activity is clearly most prominent during sleep, slow EEG oscillations and the cortical "up-" and "down-states" associated with these oscillations are also present during resting wakefulness (Crochet, 2006; Kirov, Weiss, Siebner, Born, & Marshall, 2009; Vyazovskiy et al., 2011). Finally, consolidation-promoting neurochemical features of sleep are also partially replicated during eyes-closed rest—decreased acetylcholine levels during quiet resting wakefulness (Marrosu et al., 1995) may facilitate hippocampal-cortical communication that favors consolidation, rather than encoding (Hasselmo, 1999; Hasselmo & McGaughy, 2004). Thus, many mechanisms proposed to account for the effect of sleep on memory consolidation are also present during waking rest.

Non-sleep resting states may also behaviorally benefit memory consolidation in humans. Recent work from our laboratory and others has demonstrated that obtaining a brief period of eyes-closed rest following learning benefits memory for at least a week (Dewar, Alber, Butler, Cowan, & Della Sala, 2012), and that the memory benefit of rest is linked to the same slow-frequency EEG oscillations implicated in memory consolidation during sleep (Brokaw et al., 2016). In our studies of dreaming and memory consolidation described earlier, spontaneous thoughts about the learning task during *waking* were not significantly predictive of later memory performance, but there were trends in this direction (Figure 32.2).

Taken together, these observations suggest that during both sleep and resting wakefulness, the construction of spontaneous cognition is supported by a similar brain process. At the regional level, the network of brain areas involved overlaps with (but is not identical to) the described "default mode" network engaged during periods of reduced task demand, especially including medial prefrontal and medial temporal areas, which also remain relatively active during sleep (Domhoff, 2011; Fox et al., 2013; Fox et al., 2015). On a cellular level, recent episodic memories are reactivated in the hippocampus and cortex, perhaps with multiple related experiences being reactivated in tandem. On a phenomenological level, across all states of consciousness, we experience a continuous stream of spontaneous thoughts and images that are at once novel and built from fragments of specific past episodes.

Future Directions

The preceding account remains speculative on many fronts, and a number of key questions remain unanswered. Chief among these is the question of how directly subjective experience maps onto the neurophysiology of memory consolidation, in any state of consciousness. The evidence presented here establishes that this is at least a hypothesis worth pursuing—there appears to be a relationship between the offline reactivation and consolidation of memory, on the one hand, and the subjective experiences of dreaming and imagining, on the other. It is the nature of this relationship that remains obscure. There is a spectrum of possibilities here—at one extreme, it could be that although offline memory processing has some minor influence on subjective experience, the proximal neural processes that generate conscious experience are far removed from those supporting any memory function. In this scenario, the study of subjective experience would reveal little useful information about the brain basis of memory, and conversely, any memory-based model would be insufficient to explain the construction of spontaneous cognition. At the other extreme, spontaneous cognition in sleep and wakefulness could be a direct subjective-level instantiation of neurobiological processes that function to reactivate, consolidate, and integrate memory following encoding. In this latter case, the study of spontaneous subjective experience would emerge as a key method of describing the brain processes of memory consolidation, and conversely, a memory-based model would provide the optimal description of how spontaneous cognition is constructed. Because the resting brain is likely engaged in a multiplicity of processes, some of which are related to offline memory processing and some not, the truth likely lies somewhere between these extremes. Moving into the future, these questions can be answered by new studies that integrate high-resolution neural decoding techniques with correspondingly detailed analyses of the subjective experience (as in Horikawa, Tamaki, Miyawaki, & Kamitani, 2013), along with methods of experimentally manipulating these processes.

Acknowledgments

The research described herein was funded in part by Bursaries award 83/12 from the BIAL Foundation and by R21MH098171 from the National Institute of Mental Health.

Notes

1. These comments apply also to more recent iterations of the theory, i.e. the "Activation-Input-Modulation" (AIM) model (Hobson, Pace-Schott, & Stickgold, 2000).
2. Contrary to some popular notions, complex, visually vivid mental experiences are actually common during all stages of sleep. Overall, research participants recall a mental experience from REM sleep about 80% of the time, as compared to about 50% of the time from NREM sleep (Nielsen,

2000; Wamsley, Hirota, Tucker, Smith, & Antrobus, 2007). Although REM sleep dreams do tend to be longer, more visually vivid, and more bizarre, this is not an absolute categorical distinction—late-night NREM dreams, for example, can be just as vivid and complex as the typical REM dream (Antrobus, Kondo, Reinsel, & Fein, 1995; Wamsley et al., 2007).

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CHAPTER

33 Involuntary Autobiographical Memories: Spontaneous Recollections of the Past

John H. Mace

Abstract

Spontaneous recollections of the past are a common and salient part of everyday mental life. However, memory researchers have only recently (i.e. within the past twenty years) turned their attention to the study of this memory phenomenon. While research in this area has answered a number of pressing questions about the nature of involuntary memories, answers to some questions remain elusive (e.g. determining their functional nature). This chapter reviews the main body of this work. In addition, the chapter looks to the future of involuntary memory research, highlighting its promise in a number of regards (e.g. its potential role in informing an understanding of autobiographical memory retrieval).

Key Words: spontaneous memories, spontaneous recollections, involuntary memories, involuntary remembering, involuntary autobiographical memories

Ebbinghaus (1885/1964) appears to be the first memory researcher to formally define involuntary memories:

> Often, even after years, mental states once present in consciousness return to it with apparent spontaneity and without any act of the will; that is, they are reproduced *involuntarily*. Here, also, in the majority of cases we at once recognize the returned mental state as one that has already been experienced; that is, we remember it. (p. 2)

In the modern era, we define involuntary memories in much the same way. For example, involuntary memories have been described in the modern literature as instances in which memories of past events come to mind spontaneously, unintentionally, automatically, without effort, and so forth (e.g., Ball & Little, 2006; Berntsen, 1996, 2009; Conway & Pleydell-Pearce, 2000; Kvavilashvili & Mandler, 2004; Mace, 2004; Mace, 2007b, 2010; Richardson-Klavehn, Gardiner & Java, 1996; Schacter, 1987). As salient today as they were in Ebbinghaus's generation, this memory phenomenon is quite common and well-known to individuals, as spontaneous memories of the past appear to intrude into conversation and thought, and to occur while driving, walking, and running; in short, we experience them in all aspects of our waking mental life. Despite their well-known status, it was not until late in the twentieth century that the first empirical study of involuntary memories appeared in the literature (Berntsen, 1996), and not until this century that one could describe involuntary memory research as a collective effort that makes up an important part of autobiographical memory research (e.g., Ball & Little, 2006; Barzykowski & Staugaard, 2015; Berntsen & Hall, 2004; Kvavilashvili & Mandler, 2004; Mace, 2004; Schlagman, Schulz, & Kvavilashvili, 2006).

This chapter reviews the major findings and questions posed by involuntary memory research. While the study of involuntary memories actually began with word-list memory tasks (i.e., studies examining the influence of spontaneous word recollection on implicit memory measures, e.g., Bowers & Schacter, 1990), most of the research to date has focused on spontaneous recollection in everyday life (e.g., Berntsen, 1996), that is, spontaneous memories of one's past. The focus in this chapter is on this latter body of work.

Terminology, Classification, and Methods of Study

As with most other areas in cognitive psychology, there is no shortage of labels for spontaneous recollections of the past. Although traditionally, and perhaps typically, called *involuntary memory*, this memorial phenomenon is variously called *involuntary explicit memory* (e.g., Bowers & Schacter, 1990; Schacter, 1987), *involuntary conscious memory* (e.g., Mace, 2005a; Richardson-Klavehn, Gardiner, & Java, 1994), *involuntary autobiographical memory* (e.g., Ball & Little, 2006; Berntsen, 1996, 2009; Kvavilashvili & Mandler, 2004; Mace, 2004, 2007b, 2007c, 2010a), and *involuntary aware memory* (e.g., Kinoshita, 2001; Mace, 2003a, 2003b). While the terms *involuntary explicit memory, involuntary conscious memory*, and *involuntary aware memory* have been generally used for the word-list manifestation of this phenomenon (i.e., spontaneous word recollection, e.g., Bowers & Schacter, 1990; Kinoshita, 2001; Mace, 2003a, 2003b; Schacter, 1987), the terms *involuntary memory* and *involuntary autobiographical memory* have been used to denote spontaneous recollections of one's past in everyday life (e.g., Ball & Little, 2006; Berntsen, 1996; Kvavilashvili & Mandler, 2004; Mace, 2004).

In further delineation of involuntary memories, I have argued that they can be divided into three separate phenomenological categories: *direct involuntary memories, chained involuntary memories*, and *traumatic involuntary memories* (Mace, 2007a, 2010a, 2010b).

Direct involuntary memories refer to everyday situations in which cues in one's internal or external environment (e.g., thoughts or percepts) lead to memories of the past (e.g., Ball & little, 2006; Berntsen, 1996, 1998; Mace, 2004). This type of involuntary remembering is probably the most common and frequently experienced form of involuntary remembering. In contrast, chained involuntary memories appear to be less common. Here, involuntary memories appear to be activated by other involuntary memories, as well as voluntary memories (e.g., Mace, 2005b, 2006; Mace, Clevinger, & Martin, 2010). For example, when one experiences an involuntary memory in everyday life, occasionally (some 15% of the time) the involuntary memory immediately leads to the production of another involuntary memory, which may in turn produce another, and so forth until the process appears to terminate, at least consciously (e.g., Mace, 2005b, 2007a; Mace et al., 2010). These chained involuntary memories also occur as a result of voluntary remembering (i.e., a deliberately retrieved memory causes one or more involuntary memories, e.g., Mace, 2006). The third category of involuntary remembering involves the production of traumatic memories. Here, individuals experience traumatic involuntary memories concerning some past traumatic experience (e.g., Berntsen, 2001). These memories occur repetitively, and this form of spontaneous remembering is a defining characteristic of post-traumatic stress disorder.

Concerning methodology, the most common approach used to study involuntary memories is the naturalistic diary method. This approach requires subjects to keep a diary of the involuntary memories that they experience in everyday life. While the diary method used by involuntary memory researchers has been fairly uniform, it has also varied in a number of ways. For example, some researchers ask their subjects to record all of their involuntary memories for a one- or two-week period (e.g., Mace, 2004; Mace, 2005b; Mace, et al., 2010; Schlagman, Schulz, & Kvavilashvili, 2006), while others ask them to record only two per day until they reach a total of 50 (e.g., Berntsen, 1996; Berntsen & Hall, 2004). While the diary method has provided quite a lot of useful information about involuntary memories, it also has some serious limitations. Perhaps its biggest drawback concerns its inability to control and manipulate involuntary memories. However, involuntary memory researchers have found a number of ways around this problem.

For example, Mace (2005b) combined the diary method with a laboratory manipulation (i.e., temporal priming), thereby introducing elements of laboratory control into a naturalistic diary design. Mace (2006) measured involuntary memory chains with a standard autobiographical memory task in the laboratory, comparing the results from this task with the results from a more conventional laboratory task, event-cuing (Brown & Schopflocher, 1998). Similarly, Ball (2007) used a free-association task to elicit involuntary memories in the laboratory while simultaneously manipulating attention on the task. In perhaps the most ingenious method to date, Schlagman and Kvavilashvili (2008) devised a unique laboratory task with the express purpose of eliciting and manipulating involuntary memories. They had subjects perform a menial vigilance task while they were simultaneously exposed to word cues. The task required subjects to view slides of horizontal or vertical lines with individual word phrases embedded in them (e.g., "relaxing on the beach"). They were to indicate when the slides had vertical lines, and also to report any spontaneous thoughts (or memories) that might have been triggered by the textual content of the slides. The results showed that subjects had reported that word cues had triggered involuntary memories, and when these memories were compared to similarly elicited voluntary memories, they dissociated from one another on a number of independent measures, thereby verifying the reliability of the task to elicit involuntary memories.

Involuntary Memories in Everyday Life

Prior to the advent of involuntary memory research, there remained a number of open questions and misconceptions about involuntary memories. For example, are involuntary memories strictly random memories in that they have no relationship with previous or ongoing thought? Are they primarily elicited by simple sensory experiences, such as taste or smell? A lot of the early research was able to answer many questions like these, while the answers to some other questions remain elusive (e.g., the question of functionality). I highlight the main points in the following.

Cuing Characteristics

Involuntary memory researchers have found that involuntary memories are not random in the strictest sense of the word (i.e., occurring without any prior input), but are instead cued by a variety of different experiences (e.g., thoughts; visual and auditory percepts, and other sensory experiences; conversation; bodily states, such as pain; activities; and other involuntary memories; see Berntsen, 1996; Berntsen & Hall, 2004; Mace, 2004, 2005b, 2007a; Mace, Bernas, & Clevinger, 2015; Schlagman, Kvavilashvili, & Schulz, 2007). Despite the type of cuing experience, most of the cues have been shown to relate to the original event in a central rather than a peripheral manner (see further details in Berntsen, 1996, 1998). Thus, these findings have shown that involuntary memories are not entirely random, and they are not solely elicited by basic sensory experiences, as common misconceptions had suggested. Indeed, it turned out that very few of them are actually triggered by tastes or smells (some 3% or less; see Ball & Little, 2006; Berntsen, 1996; Mace, 2005b; Mace et al., 2015).

While these early studies have answered some basic questions concerning the nature of involuntary memory cuing, there still remains a number of open questions in this area. For example, some 10% of all involuntary memories do not have identifiable cues (e.g., Berntsen, 1996; Mace, 2004). Whether these are actually un-cued involuntary memories (an interesting prospect in its own right) or failures to recognize cues remains a mystery (Mace et al., 2015).

Frequency of Occurrence and Mental State

Diary studies of everyday involuntary memories have estimated that individuals experience some 3-5 involuntary memories per day (e.g., Berntsen, 1996; Mace, 2004, 2005b; Mace et al., 2015). Informal reports from involuntary memory researchers suggest that there is a small subset of individuals who experience many more than 3–5 per day, perhaps in the range of 50–100. Research attempting to explain definitively the cause of this vast individual difference has yet to be undertaken. However, there is one report that suggests that these individuals may have disorders of attention (Verwoerd & Wessel, 2007), and thus there is the suggestion that these individuals may experience a large number of involuntary memories because of their inability to focus attention or suppress irrelevant information.

Consistent with the possibility that attention may play a role in the production of involuntary memories, early diary studies have shown that involuntary memories were more likely to occur in relaxed or non-focused states of attention, rather than focused states (e.g., Berntsen, 1998; Kvavilashvili & Mandler, 2004). For example, Berntsen (1998) reported that some two-thirds of all involuntary memories had occurred when subjects reported being in a non-focused or diffuse state of attention. Thus, involuntary memories are more likely to occur when one is daydreaming, or otherwise in a non-focused state of attention, as opposed to when one is engaged in focused attention. This aspect of involuntary memory research is interesting because it suggests that involuntary memories might be failures of cognitive control, at least part of the time (Kamiya, 2014).

How Random Are Involuntary Memories?

Are involuntary memories simply random mental events, or are they more organized mental events in that they are influenced by prior cognitive activities, such as brooding or reminiscing over the past, and so forth? Mace (2005b) tested the idea that involuntary memories might by primed by everyday cognitive activities like thinking or reminiscing about the past. In the first study of this report, subjects participated in a two-week diary study that concluded with a questionnaire that asked them to report on what had been on their minds for the previous two weeks coinciding with the diary-recording period. The results showed a correlation between the contents of the questionnaire and the contents of the diary, suggesting that the content of the involuntary memories had tracked (or had been primed by) subjects' preoccupations. However, as one cannot be sure of the direction of causality with such data, studies two and three used the same diary recording procedure, but in these studies subjects additionally came into the laboratory at various intervals to engage in an autobiographical memory task that had them recalling memories from different periods of their lives (e.g., from high school, from the past year, etc.). When the involuntary memories recorded in their diaries were compared to relevant control subjects, a significant proportion of them were related to the time period that they were asked to recall in the laboratory, suggesting that the recall sessions had primed their involuntary memories.

Thus, the results of the Mace (2005b) study suggest that involuntary memories are primed by one's daily cognitive activity. One way to interpret these results is to see involuntary memories as relevant, at least in the sense that they may track and coincide with one's ongoing thoughts and preoccupations. Whether or not all involuntary memories can fit into this category remains an open question, and thus it is still possible that involuntary memories can be seen as somewhat random mental events, with unknown functionality to the individual. We will return to the concept of involuntary memory functions in a later section.

Chained Involuntary Memories

As discussed earlier, involuntary memories sometimes lead to the immediate production of one or more additional involuntary memories (e.g., Mace, 2005b, 2006; Mace et al., 2010; Mace, Clevinger, & Bernas, 2013). Such activations, or involuntary memory chains, also follow from voluntary memories (Mace, 2006). Apart from being a unique instance of involuntary remembering (i.e., memories causing other memories), these involuntary memories appear to be important for two main reasons. First, they occur during the act of voluntary remembering, and second, they appear to be telling us something about the organizational nature of autobiographical memory.

Concerning voluntary recall, Mace (2006) reported that some 40% of voluntary retrievals on an autobiographical memory task had led to the production of one or more involuntary memories (see also Mace, 2009). Given this very high rate of involuntary remembering, it seems likely that involuntary memory recall is a routine part of the voluntary recall process. And, given that the involuntary memories emanating from the voluntary memories have been shown to be related in content, and frequently from the same time period, it is plausible to imagine that this form of involuntary remembering, involuntary memory chaining, is especially functional to voluntary recall (for more details, see Mace, 2007a).

Whether involuntary memory chains come from voluntary memories or involuntary memories, they have been consistently observed to be related to one another. For example, one might involuntarily remember seeing mummies in the British Museum, and this memory could in turn trigger a memory of seeing the Egyptian collection at the natural history museum in New York City (for more on the nature of the associations, see Mace et al., 2013; Mace, 2014). I have argued that these characteristics of involuntary memory chains make it likely that they are spreading activations that surface into consciousness (Mace, 2007a, 2010b; Mace et al., 2010; Mace et al., 2013). It is for this reason that I have further argued that the associations seen in involuntary memory chains are reflective of the underlying associative structure of autobiographical memory (see full details in Mace, 2010b, 2014; Mace et al., 2010; Mace et al., 2013). This is at least one aspect of involuntary memory research that has had implications beyond the study of involuntary memories per se.

Involuntary Memories Versus Voluntary Memories

In addition to examining involuntary memories in everyday life, involuntary memory researchers have also directly compared involuntary memories to voluntary memories. Most of this work involved comparing involuntary memories recorded in diaries to voluntary memories collected in the laboratory using standard or slightly modified autobiographical memory tasks (e.g., Berntsen, 1998; Berntsen & Hall, 2004; Mace, Atkinson, Moeckel, & Torres, 2011). The goal of most studies was straightforward: to document similarities and differences.

Concerning differences between involuntary memories and voluntary memories, they have been few in number, and perhaps not always noteworthy or of significance. For example, involuntary memories have been shown to differ from voluntary memories in emotional and physiological impact (Berntsen & Hall, 2004). Involuntary memories are also more likely to be experienced from a first-person perspective (as opposed to a third-person perspective; Nigro & Neisser, 1983), as well as having higher feelings of reliving the original event (Mace et al., 2011). However, these differences have only pertained to remote memories (i.e., memories greater than 10 years old), and the emotional and physiological findings have not always been obtained (e.g., Mace et al., 2011).

The most consistent difference between involuntary and voluntary memories concerns the specificity of the events recalled (i.e., generating memories of specific past events, or episodic memories, as opposed to more general autobiographical memories, e.g., remembering that I took a trip to London in 2005 without recalling any specific episode or details). Involuntary memories are more likely to pertain to specific past events than voluntary memories, which tend to feature more general event memories (e.g., Berntsen, 1998; Mace et al., 2010; Mace et al., 2011). However, this difference may not be of particular theoretical relevance, as it may simply be a measurement error of sorts; that is, it may not be fair to compare naturally occurring involuntary memories to laboratory-generated voluntary memories on this measure, as the latter category uses somewhat artificial and arbitrary cues to elicit memories. Under these circumstances, one may not always be able to retrieve a specific memory for preselected and often vague retrieval cues (e.g., remember a time from your past involving the word *steam*). Indeed, we recently found that in cases where subjects had only produced a general memory on an autobiographical memory task, they frequently were able to come up with a specific episode when they were prompted to keep trying (Mace, Clevinger, Delaney, Mendez, & Simpson, 2017). Whether specific versus general memory production differences are merely a function of task differences, or something more theoretically interesting, remains a topic for future research.

Concerning similarities between involuntary and voluntary memories, there are many more of these than there are differences. For example, involuntary and voluntary memories are equally vivid, are both judged as veridical, each show the classic reminiscence bump (Rubin, Wetzler, & Nebes, 1986), and so forth (e.g., Berntsen, 1998; Berntsen & Hall, 2004; Mace et al., 2011; see detailed reviews in Berntsen, 2009; Mace, 2010a). Thus, taken together, these findings argue that the main difference between involuntary and voluntary memories lies on the retrieval intention dimension. While the obvious difference between them is that one is intentional while the other is unintentional, their retrieval differences seem to be far more elaborate and complex than this.

For example, involuntary memory retrieval might simply be explained in terms of priming and spreading activation (Berntsen, 2009; Mace, 2010b; Mandler, 2007). In contrast, voluntary memory retrieval appears to be more complicated, as it may involve many more processes. Studies that have examined voluntary recall processes in autobiographical memory have found that subjects use more than one retrieval strategy to recall the past (Haque & Conway, 2001; Mace et al., 2016). Indeed, at least one study (Mace et al., 2016) has shown that subjects use a multitude of strategies (some four or five), each distinctly different from one another. In addition to this, one could argue that voluntary retrieval also utilizes different involuntary retrieval processes (i.e., using both direct retrieval and involuntary chaining; Conway & Pleydell-Pearce, 2000; Mace, 2007a, 2010a). Thus, in sharp contrast to involuntary retrieval, voluntary retrieval appears to involve quite a number of different retrieval processes, each potentially having a different underlying mechanism.

Involuntary Memories: A Question of Function

As spontaneous, seemingly random mental events, perhaps one of the more important questions concerning involuntary memories is their functional relevance. Do they serve the classic three functions that have been postulated for autobiographical memories (i.e., directive, self, and social functions; Baddeley, 1988; Bluck & Alea, 2002)?[1] Or, in stark contrast, are they entirely non-functional, simply a vestige of primordial cognition? A handful of studies have sought answers to questions concerning the utility of involuntary remembering.

Mace and Atkinson (2009) examined this question directly in a diary study that asked subjects to report how involuntary memories were useful to the situation in which they occurred. They report that approximately one-third of all involuntary memories recorded by diary participants were judged to be functional to one's immediate situation, suggesting that involuntary memories may typically be of little relevance in one's everyday life, as they typically do not provide any useful information or utility to one's situation. Adding to these results, Rasmussen and Berntsen (2011) report that voluntary memories were more likely to be judged as fitting directive, self, or social functions than involuntary memories, while the latter were more likely to be associated with daydreaming, periods of boredom, and to occur during non-focused attention (see also Rasmussen, Johannessen, & Berntsen, 2014; Rasmussen, Ramsgaard, & Berntsen, 2015). Thus, their results suggest that involuntary remembering is functionally inferior to voluntary remembering, while they highlight the fact that involuntary memories most typically occur at times when they can have little or no task relevance (i.e., when one is daydreaming or otherwise in a non-focused state of attention).

While there are probably a number of ways in which the results of these studies can be interpreted, I put forth two possibilities, one, a negative or skeptical account, the other, not so negative and non-skeptical.

The skeptical account asserts the non-functional nature of involuntary memories. This view sees involuntary remembering as entirely non-functional, a vestige of a primordial cognition that does little more than provide us with irreverent and unneeded memories. This view would argue that reports of involuntary memory function (e.g., Mace & Atkinson, 2009) are either spurious, or coincidental at best, as the data supporting some function comes via means of questionnaires, rather than through experimental procedures. In support of this view, all one need do is look at the data, which show that involuntary memories occur during non-focused states of attention, and occur more frequently in individuals who have disorders of attention (i.e., problems focusing and inhibiting irrelevant information). Such data suggest that these mental events are normally (or should normally be) inhibited, and when they are not, they are simply another class of cognitive failures.

The more positive account of involuntary memory functions acknowledges some of this argument; that is, it accepts the fact that involuntary remembering is perhaps an archaic mode of cognition, but not necessarily a non-functional one. Here, involuntary memories are seen as having limited utility, in that they are not always functional. Sometimes they may be functional, and sometimes not, in which case they may simply be cognitive failures. Thus, in this view, involuntary remembering is seen as a somewhat imperfect functional mechanism, one that sometimes works haphazardly, and sometimes with purpose. This view would also caution against making functional contrasts with voluntary remembering, as involuntary remembering may often be cast in a negative light, as the former is a more recent, more perfect cognitive device. In general support of this view, all one need do is examine diary entries that subjects mark as functional. While it is possible that some of these entries may be spurious, some also make a compelling case, as there are some instances where involuntary memories were undoubtedly functional in a classic manner (i.e., showed clear directive functions). For example, one participant indicated that seeing a set of steps had triggered a memory of having tripped on them a couple of days ago. Another participant noted that when approaching an intersection while bicycling, the sight of that intersection had triggered a memory of narrowly missing a car that pulled out in front of him while bicycling in that spot a couple of weeks earlier.

Conclusion: The Promise of Involuntary Memory Research

Shrouded in mystery for over a century, research on involuntary memories has provided answers to quite a number of basic questions. In this chapter I have highlighted the main areas of this research. All of these areas have informed the study of involuntary memory, and many of them have the potential to contribute to our understanding of other areas of memory and cognition. I conclude this chapter by highlighting three areas of study that hold such promise.

The first concerns the question of involuntary memory functions. One could argue that this is perhaps the most important question to involuntary memory research and to the study of cognition. Should the answer turn out to be one of the two possibilities that I laid out in the preceding, each would have profound implications. For example, if the non-functional argument were to prove true, this clearly would answer an important question about involuntary remembering per se, and it would also potentially give us insight into other forms of spontaneous cognition, informing the science of cognition generally. One could see similar implications for the alternative, imperfect functional mechanism account.

The second area of promise concerns the retrieval characteristics of involuntary memories. Here, one could argue that the study of involuntary memory activations has and should continue to give us insights into involuntary memory retrieval, but perhaps more important, involuntary memory research has forced direct comparisons between involuntary and voluntary recall. As noted earlier, this research has highlighted the complexities of involuntary and voluntary retrieval by showing that they have many and varied forms. This type of research is just the beginning of what should eventually lead to a full, or at least better, understanding of autobiographical memory retrieval, which should have ramifications for the understanding of retrieval processes in general, as well as other areas of cognition.

Finally, the third area of promise concerns the study of autobiographical memory organization. As noted earlier, the study of involuntary memory chains has provided some insights into the area of autobiographical memory organization, specifically the organizational relationships found among episodic memories. Elsewhere (Mace et al., 2010; Mace et al., 2013; Mace, 2014), I have argued that as vehicles of spreading activations within the autobiographical memory system, the associations found in involuntary memory chains are giving us rare insights into the basic associative nature of episodic memories, insights that pure laboratory approaches did not appear to provide. I believe that this type of involuntary memory research is a prime example of how involuntary memory research can have broader relevance.

Note

1. In the directive function, autobiographical memories are seen as guides to current and future behavior. In the social function, the sharing of autobiographical memories among individuals is viewed as important to social bonding. In the self-function, autobiographical memories are seen as the database on which the notion of the self is formed (for more details, see Baddeley, 1988; Bluck & Alea, 2002).

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PART VII

Clinical Contexts, Contemplative Traditions, and Altered States of Consciousness

CHAPTER

34

Potential Clinical Benefits and Risks of Spontaneous Thought: Unconstrained Attention as a Way into and a Way out of Psychological Disharmony

Dylan Stan *and* Kalina Christoff

Abstract

Spontaneous thought has recently been defined as a state of reduced constraints on the mind, and it encompasses a range of experiences such as mind-wandering, day and night dreaming, creative idea generation, and others. While its day-to-day benefits have been explored for some time, its clinical implications have been understudied, and for the most part have been limited to potential detrimental effects on mood. We propose that spontaneous thought has a wider variety of clinical effects, as well as a number of potential therapeutic benefits—affording the opportunity to address suppressed or repressed material, facilitating therapeutic insights, and promoting general relaxation. Its unconstrained mode may not be without clinical risks, however. Within literature discussing meditation, sleep, relaxation, and sensory deprivation—activities that promote unconstrained attention—evidence suggests that some individuals may become destabilized, or face a worsening of symptoms in some circumstances. More research needs to be done to clarify the mediating factors that could result in these divergent outcomes.

Key Words: spontaneous thought, unconstrained attention, clinical risks, therapeutic benefits, meditation, sleep, sensory deprivation, relaxation

The open mental mode of spontaneous thought has been described as being an avenue leading toward creativity, insight, future planning, and meaning-making (Christoff, Gordon, & Smith, 2011; Fox & Christoff, 2014; Klinger, 2014; Smallwood & Schooler, 2015). At the same time, it has been associated with possible detriments to ongoing task performance, and the capacity to foster depressive or ruminative symptomatologies (Killingsworth & Gilbert, 2010; Marchetti, Koster, Klinger, & Alloy, 2016; Smallwood, O'Connor, Sudbery, & Obonsawin, 2007). While the majority of the clinically oriented discussions have been largely limited to its connection with dysphoria and depression, there is evidence to suggest that spontaneous thought has a much greater scope of clinical influence—both in its potential to propagate different maladaptive thought patterns in at-risk populations, and in its capacity to offer therapeutic benefits and healing.

The first part of this chapter describes possible sources of therapeutic benefit from a spontaneous mode of thought, and suggests that it might already be playing a significant role in a number of commonly used psychological therapies. We then move on to provide some evidence that suggests that spontaneous thought is not always without risk for some individuals—making a preliminary case for how, under certain conditions, it might also have the capacity to exacerbate symptoms in a variety of clinical conditions. Spontaneous thought, it appears, can be both a way into and a way out of psychological disharmony, depending on how carefully its open-ended terrain is navigated.

This free-flowing mode of mind has often been associated with the act of mind-wandering (Christoff, 2012; Christoff et al., 2011; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016)—the effortless shifting between unrelated or loosely related thoughts—but spontaneous thought can also be implicated in an array of other contexts. Daydreaming is perhaps a more absorbed form it can take, where one finds oneself immersed in fantasy and naturally unfolding mental imagery (Singer, 1974). The generative mode of creativity (in contrast with evaluative modes), as in brainstorming, for example, is yet another type of spontaneous thought (Beaty, Benedek, Silvia, & Schacter, 2016; Ellamil, Dobson, Beeman, & Christoff, 2012; see also Dobson, Chapter 23 in this volume); the relative lack of restrictions seems to open the mind up to distantly connected concepts, enabling indirect problem-solving and lateral thinking to take place. A theoretical perspective on the origins and nature of this range in thinking will be briefly outlined before delving into the clinical topics.

A recent neuroscientific framework (Christoff et al., 2016) aims to account for spontaneous thought's dynamic nature by proposing possible patterns of activity between large-scale brain networks. The default network (DN) has popularly been associated with task-unrelated mind-wandering states (Callard, Smallwood, Golchert, & Margulies, 2014; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007) and is composed of a set of regions that are often recruited during memory retrieval, prospective thinking, and mentalizing (inferring the mental states of others) (Andrews-Hanna, 2012; Buckner, Andrews-Hanna, & Schacter, 2008; Spreng, Mar, & Kim, 2009). What sets this framework apart are its novel interpretations of certain subdivisions within the DN, and the implications those might hold for how spontaneous thought develops. It differentiates between subsystems that appear to contribute in two distinct ways to the stream of thought: those that are primarily sources of variability in thought content, and those that primarily constrain or limit the way thought unfolds over time (Christoff et al., 2016).

Spontaneous thought can occur both in brief, momentary incidents and over extended timescales. In this framework, it is defined as "a mental state, or a sequence of mental states, that arises relatively freely due to an absence of strong constraints on the contents of each state and on the transitions from one mental state to another" (Christoff et al., 2016, p. 719). Simply put, the fewer restrictions there are on thought-flow, the more it is able to move about naturally. The question becomes: what does it mean for thoughts to move about naturally or freely?

One of the DN subsystems, centered around the medial temporal lobes (DN_{MTL}), is suggested to be a significant source of variability in thought content, and also appears to be recruited just before the arising of spontaneous thoughts (Fox, Andrews-Hanna, & Christoff, 2016; Selimbeyoglu & Parvizi, 2010). A region within it, the hippocampus, has been linked to functions of memory retrieval and episodic simulation (the generation of imagined future events) (Moscovitch, Cabeza, Winocur, & Nadel, 2016; Squire, Stark, & Clark, 2004), and has been proposed to act as an index for previous experiences (Teyler & DiScenna, 1986). Separate features of each experience may be encoded together in hippocampal representations, capable of triggering a constellation of neurons to evoke a unified memory (Moscovitch, 2008). Neurons shared by other memory constellations may cue them to become reactivated as well (Moscovitch, 2008), leading to a cascade of closely or distantly related experiences flowing through the mind. Perhaps the free motion of spontaneously arising thoughts can be attributed, in part, to these associative processes in the DN_{MTL} occurring in a relatively uninhibited way.

Constraints on this spontaneous thought activity can arise in a number of ways, temporarily narrowing the stream of attention, and creating stability for a period of time (Christoff et al., 2016). Most notably, externally oriented, sensory-dependent attention seems to inhibit DN activity (Shulman, Fiez, Corbetta, & Buckner, 1997; Toro, Fox, & Paus, 2008) and keep us rooted in perceptual foci (Corbetta, Patel, & Shulman, 2008). When directed internally, however, another DN subsystem (DN_{CORE}), with one of its main hubs located in the medial prefrontal cortex, appears to play a role in constraining attention in a relatively automatic way (Christoff et al., 2016). The DN_{CORE} might couple with the DN_{MTL} to allow for the automatic processing of recent events and the meaning-making often observed in mind-wandering (Christoff et al., 2016). In addition, the frontoparietal control network—a wide-reaching network, closely linked with cognitive control—might impose further constraints on these regions, narrowing their range of possible activity to facilitate deliberate thinking about our goals, reasoning about the past, and planning for the future (Andrews-Hanna, Smallwood, & Spreng, 2014; Christoff et al., 2016).

What might be most significant to our discussion, moving forward, is the potential for spontaneous DN_{MTL} activity to cue responses in affective salience networks, triggering automatic or deliberate cognitive control (Christoff et al., 2016). Stumbling upon emotionally unresolved memories, for example, might cause us to either ruminate unintentionally, or to consciously seek out possible remedies. What is important to note here is that, while the origins of a thought might be spontaneous, if it becomes constrained this spontaneity would cease or be diminished. It therefore seems that spontaneous thought flow can frequently give rise to conditions that restrict further spontaneous thought—for whatever length of time, short or long. We expect this to happen regularly, as our day-to-day lives see no shortage of goals or concerns (Klinger, 1971).

Motivational intensity may be a significant factor contributing to the strength of constraints and reductions in spontaneity (Stan & Christoff, Chapter 5 in this volume). As the motivational intensity behind some mental act increases, we expect constraints to become more extensive and restrictive. Constraints, however, will likely always be present in our mental activity, even during spontaneous thought, in subtle ways. An additional factor to consider might be their tendency to persist over time: While *enduring constraints*, such as worry states, for example, might be more restrictive on the flow of thought, more *transient constraints*, even strong ones, might still provide sufficient gaps for the mind to move about freely. Salient cues in the environment that come and go might be an everyday example of this—noises, lights, passing faces—consuming our attention for moments so brief that loose trains of thought can still continue around them.

Potential Clinical Benefits of Spontaneous Thought

The day-to-day benefits of spontaneous thought are commonly discussed in the literature, mostly in the context of memory consolidation, prospection, creativity, and meaning-making (Baars, 2010; Baird, Smallwood, & Schooler, 2011; Christoff et al., 2011; Franklin et al., 2013; McMillan, Kaufman, & Singer, 2013; Mooneyham & Schooler, 2013; Smallwood & Andrews-Hanna, 2013). A state of loosened restrictions has been seen to facilitate the arising of current topics of concern, enabling the reassessment and restructuring of one's goals (Klinger, 1971). Recent experiences can be learned from, and new meaning can be made as old events are revisited. Spontaneous thought also seems to provide a wellspring for creative and divergent thinking (Baird et al., 2011; Smallwood & Andrews-Hanna, 2013)—a state of mind that may be associated with attitudes of openness and flexibility in daily life (Cropley, 2009; McCrae, 1987). Spontaneous thought, it appears, is an important contributor to our general wellbeing (Smallwood & Andrews-Hanna, 2013).

In the clinical realm, we propose, spontaneous thought might also be a common source of therapeutic benefit—in both indirect and direct ways—working off mechanisms similar to those described in the preceding. Individuals may be guided through an evocation of this open mode of mind in a structured setting, facilitating the reordering of troubling material and enabling a process of sense-making and healing to take place (Klinger, 1977). Spontaneous thought, we will also argue, may even sometimes be therapeutic by its very nature. Some general contexts and examples will be explored here; while there will be clear conceptual overlaps, a few broad groupings will, nevertheless, be teased apart.

The first grouping of benefits has to do with the surfacing of suppressed or repressed material. In the therapeutic setting, an individual may be provided with a safe context in which he or she can set aside defense mechanisms (constraints) and explore or encounter thoughts, emotions, or memories that spontaneously arise. Various thought control strategies have been seen to be commonly used by both clinical and non-clinical populations to contain unwanted or unpleasant thoughts (Wells & Davies, 1994). Distraction, reappraisal (changing one's interpretation), punishment (of oneself, for having the thought), and worry are all significant examples (Wells & Davies, 1994)—the latter two being linked with emotional vulnerability and psychopathology (Abramowitz, Whiteside, Kalsy, & Tolin, 2003; Amir, Cashman, & Foa, 1997; Morrison & Wells, 2000; Warda & Bryant, 1998; Wells & Davies, 1994). Such methods of control all seem to be different ways of using heightened levels of constraints to restrict one's mental experience. While *worry* might seem counterintuitive as a control strategy, it is proposed to involve the engagement of more thought-like processes to mask underlying emotional discomfort or troubling mental imagery (Borkovec & Inz, 1990). Similarly, *punishment* can sometimes be a strategy for blocking the arising of unwanted thoughts, with some measures on a punishment rating scale being "I get angry at myself for having the thought," or "I slap or pinch myself to stop the thought" (Wells & Davies, 1994, p. 872).

As deliberate constraints on attention (such as the active suppression of unwanted thoughts or concerns) are relaxed, neglected needs or emotions, previously ignored, may be allowed to surface. This surfacing itself may be therapeutic, and might enable an individual to plan steps that can be taken to address his or her situation. Not only has the creation of narratives around emotionally valenced material been shown to have positive effects on well-being (Lepore, 1997; Pennebaker, 1993; Pennebaker & Seagal, 1999; Smyth, 1998), but some research also has found that the suppression of emotional reactions can have a range of negative health implications (Butler et al., 2003; Gross & John, 2003; Petrie, Booth, & Pennebaker, 1998). Also, the suppression of thoughts has been seen to result in a paradoxical increasing of their frequency (Wegner, Schneider, Carter, & White, 1987)—a factor that has been found, in chronic cases, to maintain or worsen obsessions, anxiety, and depression (Purdon & Clark, 1994; Wegner & Zanakos, 1994).

The relaxing of more automatic constraints on the mind might enable similar effects—for example, in cases where one is not even aware of the suppression. In this case, however, an extra dimension of *learning* (about one's self or situation) could also result. In a clinical setting, natural patterns of thought and affective responses can be observed by both practitioner and client, providing clues about hidden concerns or needs (Klinger, 1977). The repetitive, spontaneous emergence of one's favorite pastimes or leisure activities, for example, might cue the recognition that too much time has been spent on work lately, and not enough on play. Or, a sudden flash of anger might uncover feelings of being unheard or ignored in some recent interactions. Two mechanisms of action may feature into these types of cases: First, relaxing constraints may enable the release of affective reactions being actively suppressed in that moment. Second, the heightened variability in thought content, associated with more spontaneous modes of mind, might increase the probability for latent affect-laden memories to be cued and triggered.

In more severe cases, such conditions may cause the re-experiencing of traumatic memories. Individuals with post-traumatic stress disorder sometimes engage in what appears to be a more drastic form of constraining the mind: dissociation (van Der Kolk & Fisler, 1995). Dissociation from memories of traumatic experiences appears to be "an attempt to maintain mental control [when] physical control [had been] lost," involving detachment from the experience, and deep absorption in other thoughts or sensations (Spiegel, 1997, p. 227). The relaxation of such constraints, however, under safe circumstances, appears to be beneficial for well-being; with the right preparation and context, exposure to traumatic memories has been demonstrated to be effective in treatment (Paunovic & Öst, 2001; Rauch, Eftekhari, & Ruzek, 2012; Taylor et al., 2003) and to facilitate a habituation effect (Jaycox, Foa, & Morral, 1998)—gradually reducing their emotional charge, and disconfirming related negative cognitions. Re-evoking traumas in a controlled manner also gives individuals the opportunity to have conversations around the troubling topics, integrating them into a more complete worldview, and making meaning from them (Greenberg, 1995).

The mechanisms behind this group of benefits all appear to be working by indirect therapeutic means. For example, the emotional liberation granted by spontaneous thought occurs by virtue of the surfacing and expression of affective reactions. Likewise, the illumination of suppressed or repressed material, facilitated by heightened levels of thought variability, seems most beneficial because of the decision-making and learning opportunities it provides. Another group also involving indirect mechanisms will be examined next.

The second grouping of benefits are expected to come from the broader modes of processing made accessible through spontaneous thought (Christoff et al., 2011). The more tangential associations in undirected fantasy have also been suggested to be a possible source of clinically beneficial insights (Klinger, 1977). Loosening one's frame of mind may enable alternate perspectives on a situation to emerge and be considered. Similarly, stepping outside ordinary, repetitive thinking may facilitate a person's insight into patterns of dysfunction he or she has been prolonging over time. For example, an individual might be granted access to a series of memories in which a certain addictive behavior is made suddenly apparent. The acquiring of insight or awareness has been one commonly proposed mechanism of change in psychotherapy (Gelso & Harbin, 2015; Grosse Holtforth et al., 2015; Hobbs, 1962; Messer & McWilliams, 2015). It has also been suggested that implementing certain behavioral changes in therapy without such awareness may be less efficacious in the long term (Prochaska, DiClemente, & Norcross, 1992).

Spontaneous thought may also enable an expansion in the range of options and possibilities one can perceive. A similar proposition has been made in relation to depression (Hecker & Meiser, 2005)—aspects of which share similarities with the undirected and unfocused qualities of spontaneous thought. Despite its negative nature, it has been suggested to have adaptive origins: The expanding of attentional focus might provide the opportunity for an individual to separate from unachievable goals, and begin to become aware of other possible sources of pleasure and fulfillment (Hecker & Meiser, 2005).

These broader modes of processing seem to be enabled by a couple of factors. First, heightened levels of thought variability could provide a wider range of memories and ideas (Klinger, 1977), increasing the material available for one to work with. Second, it is possible that the relaxing of constraints could also free up attentional resources, allowing one to sustain more distant connections and thus perceive the wider patterns that are occurring. Again, this second group of benefits, just like the first, is proposed to work primarily in an indirect way: It is what the spontaneous mind *brings forth* that provides the therapeutic effect.

Finally, a third grouping can be made around the relaxed conditions that enable spontaneous thought in the first place. This is perhaps the most *direct* source of therapeutic benefit, as it is the nature of spontaneous thought, itself, that is the origin of these proposed effects. In order to access this mode of thought, perceptual constraints must be minimal, and strong salient activity in the environment absent. Individuals must also relinquish control of their mind for a period of time; the loosening of deliberate cognitive constraints on mental activity might contribute to a reduction in felt effort, and a general sense of allowing one's experiences to unfold.

Mindfulness is a type of meditation that has become increasingly popular in the Western world (Williams & Kabat-Zinn, 2011). Although it has been used, at times, as a contrast to mind-wandering and spontaneous thought (Smallwood & Schooler, 2015), they may be more related than might first appear. Although some focused meditations clearly rely on the implementation of constraints to keep one centered on some object or mental image, *open monitoring*—a general category to which mindfulness belongs—uses a much less constrained approach (Lutz, Slagter, Dunne, & Davidson, 2008; see also Eifring, Chapter 38 in this volume). It involves the non-judgmental observation of all aspects of one's experience, internal or external (Lutz et al., 2008). Since it entails the maintenance of a monitoring state, it must utilize some degree of constraints, but the non-judging attitude that meditators are instructed to take allows their thoughts to move in a largely free way. This is evidenced by the finding that open monitoring promotes divergent thinking and creative idea generation (Colzato, Ozturk, & Hommel, 2012), and also insight problem solving (Ostafin & Kassman, 2012). It is also possible that the deliberate constraints that exist on attention are subtler and more transient in nature—appearing only for brief moments to gently steer the mind away from arising thoughts that draw it in. This appears to be the case, as individuals are instructed to *bring the mind back* with gentleness when it has strayed (Hölzel et al., 2011), not forcibly hold attention still.

In addition to possible reductions in felt effort, the loosening of deliberate constraints on attention might also result in a gradual relaxing of more automatic reactivity, as one begins to "unwind." Some research is supportive of this, showing reductions in affective reactions after mindfulness training (Hoge, Bui, Marques, & Metcalf, 2013), as well as the attenuation of bottom-up processing of startle cues in experienced mindfulness meditators (van den Hurk, Janssen, Giommi, Barendregt, & Gielen, 2010). It would be understandable, then, how, over time, practicing techniques that foster such states has been shown to be effective in the treatment of anxiety and for stress management in general (Chiesa & Serretti, 2009; Grossman, Niemann, Schmidt, & Walach, 2004; Hoge et al., 2013; Kabat-Zinn et al., 1992). Similar beneficial effects have also been reported for the use of other relaxation-based interventions in general anxiety disorder (Borkovec & Costello, 1993; Manzoni, Pagnini, Castelnuovo, & Molinari, 2008). In addition, some have suggested that the practice of mindfulness might also result in the development of more adaptive and flexible attitudes (Fox, Kang, Lifshitz, & Christoff, 2016; Shapiro, Carlson, Astin, & Freedman, 2006), effects which, if true, may add even more implications for the influence of spontaneous thought on well-being.

While we expect a wide variety of clinical therapies and self-management techniques to employ the preceding mechanisms through the encouragement of spontaneous thought, only a few will be touched upon here, to illustrate the point. The use of free association in psychoanalysis, for example, is aimed at revealing the subconscious workings of a client's mind, through a non-judgmental and open-ended exploration (Klinger, 1977). An individual is told to "put himself into a condition of calm self-observation" and to report whatever memories or thoughts come freely to mind (Freud, 1920, Nineteenth Lecture, para. 3). He is instructed to "skim only across the surface of his consciousness and must drop the last vestige of a critical attitude toward that which he finds" (Freud, 1920, Nineteenth Lecture, para. 3). Hypnotherapy is another therapeutic technique that uses the spontaneous mode of thought to deliver positive suggestions and evoke change in an individual. It is described as involving the "quieting of the mind" and "the induction of a state . . . in which a person's normal critical or skeptical nature is bypassed, allowing for [the] acceptance of suggestions" (Stewart, 2005, p. 511). Mindfulness-Based Stress Reduction, finally, is a particular implementation of mindfulness meditation in combination with other cognitive therapies that has recently become a popular clinical choice, often in structured group programs (Kabat-Zinn, 2003). Again, the complete acceptance of one's moment-to-moment experience in mindfulness (Keng, Smoski, & Robins, 2011) likely results in an overall loosening of constraints on the mind.

Potential Clinical Risks of Spontaneous Thought

Although the benefits of spontaneous thought seem to predominate, there is some evidence that suggests that an unconstrained mind may not be favorable in all circumstances. It may be the case that prolonged periods of unusually low levels of constraints on mental activity might be destabilizing for individuals already struggling with emotional or cognitive disturbances. Likewise, the sudden encountering of repressed or suppressed material might be overwhelming, potentially leading to heightened levels of anxiety, or, worse, further traumatization, dissociation, or psychosis. Case reports related to different activities that greatly facilitate spontaneous thought can reveal certain recurring types of complications that bear resemblance to these. Literature related to *meditative states, sleep and relaxation-related states*, and *states of reduced sensory stimulation*—all associated with considerable and sometimes sudden reductions in mental constraints—will initially be explored. A brief proposal of possible mechanisms and risk factors will follow.

A connection has already been drawn, in the preceding, between open-monitoring forms of meditation and spontaneous thought. Another general category of meditations has been distinguished as involving not only the absence of focus, but also the absence of control and effort altogether—as observed in aspects of Transcendental Meditation (Travis & Shear, 2010). These styles are said to overlap frequently, in practice and across traditions (Travis & Shear, 2010), and will be hard to fully distinguish, but the meditation literature presented here does refer often to the use of this less constrained type.

Case reports of psychiatric problems being precipitated by meditation have been cited for decades in psychiatric and psychological journals (Epstein & Lieff, 1981; Lazarus, 1976; Walsh & Roche, 1979; West, 1979). Depersonalization, altered capacity to differentiate between one's internal world and the external world, and the emergence of highly charged, repressed memories have all been reported (Castillo, 1990; Walsh & Roche, 1979). Hallucinations, delusions, and other psychotic experiences (Sethi & Bhargava, 2003; Sharma, Singh, Gnanavel, & Kumar, 2016; Walsh & Roche, 1979) have been cited as well, with a limited amount of evidence suggesting that mania can also be precipitated (Yorston, 2001). A meta-analysis of case reports on meditation-induced psychosis found that only about half of the incidents involved a prior psychiatric history (Kuijpers, van der Heijden, Tuinier, & Verhoeven, 2007), which may suggest that prolonged periods of unconstrained cognition might have the capacity to evoke first episodes in those at risk. It is important to note, however, that the investigation also found that almost all individuals had a rapid recovery (Kuijpers et al., 2007).

There are obvious major methodological limitations to the preceding findings, as they are limited to case studies, lack control groups, and are not always explicit about the types of meditation practiced. It is also hard to know to what extent meditation itself was responsible for the reported symptoms, and to what degree other factors, such as sleep deprivation and fasting—common to many of the cases—had a role (Kuijpers et al., 2007). One study, in fact, analyzed three case studies and found sleep deprivation and drug withdrawal, respectively, to be principal influences in two of them (Chan-Ob & Boonyanaruthee, 1999). Nevertheless, abnormal experiences do seem to be generally associated with meditation; a phenomenological study found that "unusual experiences, visual or auditory aberrations, 'hallucinations,' unusual somatic experiences and so on, are the norm among practiced meditation students," and, in many cases, do not pose problems (Kornfield, 1979, p. 51). For individuals on the verge of psychosis, however, such experiences would likely be further destabilizing.

Sleep-related states, on the other hand, have long been compared with other forms of unconstrained cognition (Klinger, 1971). The dynamic qualities of dreaming have been likened to those of mind-wandering and spontaneous thought—both tending to unfold in a highly unrestricted and associative way (Christoff et al., 2016; Domhoff & Fox, 2015; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; see also Domhoff, Chapter 27, and Fox & Girn, Chapter 28, both in this volume). In sleep, the emergence of nightmares, or frightening or disturbing dreams, are commonly seen in post-traumatic stress disorder (American Psychiatric Association, 2013; Benca, 1996; Ross, Ball, Sullivan, & Caroff, 1989), panic disorder (Benca, 1996), and schizophrenia (Benca, 1996; Claridge, Clark, & Davis, 1997). In fact, the re-experiencing of traumatic events in dreams is said to be one of post-traumatic stress disorder's cardinal manifestations (Ross et al., 1989). Also, in panic disorder, surveys suggest that 44%–71% of affected individuals have, at least once, experienced waking from sleep in a state of panic (Craske & Tsao, 2005). Another paper found that schizotypy was positively related to, and even predicted, the strength of nightmare experiences (Claridge et al., 1997). These frightening sleep-related experiences often cause individuals to develop fears about going to bed and even to become avoidant of it (Benca, 1996)—probably only making matters worse.

In addition to sleep itself, the pre-sleep or sleep-onset ("hypnagogic") phase can also be considered spontaneous in nature (for a detailed review, see Nielsen, Chapter 30 in this volume). Individuals with obsessive-compulsive disorder can have trouble falling asleep, as obsessions—intrusive and distressing thoughts—can interfere with normal sleep onset (Benca, 1996). People with insomnia similarly report pre-sleep ideation or imagery that is intrusive and upsetting, and focused on worries (Harvey, 2000; Sanavio, 1988). In a clinician-administered interview comparing 30 individuals with insomnia to 30 with regular sleep, the insomniacs described their pre-sleep mental activity as being less intentional, and including more distressing imagery (Harvey, 2000).

In non-sleep relaxation, similar findings have been reported. Panic attacks, paradoxically, have been found to be frequently induced during easeful mental states (Cohen, Barlow, & Blanchard, 1985; Heide & Borkovec, 1983; 1984; Wells, 1990). While symptoms in panic disorder are often provoked by overt, anxiety-causing situations, "many patients [also] report that their attacks occur in the absence of anticipatory anxiety or distressing cognitions, or in some cases, when they feel the least apprehensive and most relaxed" (Cohen et al., 1985, p. 96). Hypnotherapy—the relaxation-based technique mentioned earlier—has also been accompanied, at times, by a variety of adverse psychological reactions (Auerback, 1962; Mott, 1987). Anxiety, dissociation, the surfacing of traumatic memories, and schizophrenic episodes have all been reported in case studies (Gruzelier, 2000); a manic episode was also apparently precipitated by the practice of self-hypnosis (Suresh & Srinivasan, 1994). While the evidence is far from clear, sleep and relaxation-related states seem to possess the capacity to uncover and sometimes exacerbate fragile psychological conditions.

Finally, spontaneous thought has also been seen to be evoked readily in conditions of isolation and reduced sensory input—often causing memories, mental imagery, voices, and other experiences to emerge (Suedfeld, Rank, & Malůš, Chapter 40 in this volume). Abnormal effects, such as depersonalization and hallucinations of various kinds, have been reported in both natural and experimental settings (Flynn, 1962; Leiderman, Mendelson, Wexler, & Solomon, 1958; Solomon, Leiderman, Mendelson, & Wexler, 1957). In one study, it was found that "after several hours, directed and organized thinking became progressively more difficult . . . subjects who remained [in sensory deprivation] longer than 72 hours usually developed overt hallucinations and delusions . . . similar to those reported with mescaline and LSD" (Solomon et al., 1957, p. 361). Sensory deprivation has even been used as a non-pharmacological model for psychosis, mimicking its effects in the unaffected population for scientific purposes (Daniel & Mason, 2015; Daniel, Lovatt, & Mason, 2014; Luby, Gottlieb, & Cohen, 1962). Enabled, supposedly, by a near-complete removal of external constraints, the plummeting into a groundless spontaneous mode of mind might worsen matters for those already experiencing or prone to psychosis. Indeed, sensory deprivation has been shown to cause significantly stronger psychosis-like symptoms in hallucination-prone individuals

(Daniel et al., 2014). These examples suggest that caution should sometimes be used in more sensitive cases, when a sudden loosening of constraints is to be initiated.

Although direct research is lacking on this topic, some general patterns do seem to be emerging that may indicate the need for further investigating the effects of unconstrained cognition in vulnerable populations. An interesting point to note is the differing severity and range of symptoms across the various situations described in the preceding: The sleep and relaxation literature tended to report anxiety-related symptoms more often, while cases associated with meditation, hypnosis, and sensory deprivation seemed to include more psychosis-like symptoms. This may be due to a selection effect, or biases in reporting—with more severe cases, such as psychosis, taking precedence whenever present. Another possibility, however, is that meditation, hypnosis, and sensory deprivation do, in fact, lead to more extensive reductions in constraints, and perhaps in ways that are more foreign to ordinary experience, or more forced, at times. We will very briefly propose a few factors that may make the difference between spontaneous thought's potentially beneficial nature, discussed earlier, and the cautionary accounts just outlined.

First, some individuals may become unsettled by the unconstrained nature of spontaneous thought. Some have theorized that the need to remain in control, and the discomfort around relaxing that control, may play a role in instigating panic attacks (Heide & Borkovec, 1984)—or that perceived uncontrollability and unpredictability of one's experiences are factors in the etiology of post-traumatic stress disorder (Ehlers & Steil, 1995; Foa, Steketee, & Rothbaum, 1989). Similarly, obsessive-compulsive disorder is characterized by the strong need to control one's thoughts and outcomes in the world through rituals and compulsions (Moulding & Kyrios, 2006) and other neutralizing behaviors (Rachman, 1997; 1998)—acts hypothesized to counteract the high degree of intolerance of uncertainty that typically comes with the condition (Tolin, Abramowitz, Brigidi, & Foa, 2003). Uncertainty, incidentally, is a prominent feature of the experience of letting go into the unguided territory of spontaneous thought.

Second, while the release of suppressed or repressed material may be liberating in many instances, it may also prove harmful in some conditions, especially since significant reductions on mental constraints will also mean that one's defenses are low. One author speaking about hypnosis, for example, cautions that the increased access to the unconscious (heightened thought variability) and the decreased vigilance (lowered constraints) leave one in a vulnerable state (Fromm, 1980). Individuals encountering troubling material may not be adequately prepared to deal with it in an effective way. An extensive study on the experiences of Buddhist meditation teachers reported that inexperienced individuals, when stripped of their ordinary defenses, may have trouble stabilizing their mind, potentially leading to a variety of adverse reactions (VanderKooi, 1997).

While such conditions may more immediately account for the panic and anxiety-related reactions cited earlier, they could potentially also factor in to the more severe psychotic cases. A number of connections have been noted between psychosis and prior trauma, with some evidence suggesting that sexual abuse and other traumatic events may increase risk for future episodes of psychosis and hallucinatory experiences (Morrison, Frame, & Larkin, 2003). Encountering traumatic memories too suddenly in periods of unusually unconstrained cognition may accelerate decompensation and other undesirable effects—an understanding already heeded in some trauma-processing disciplines (Twombly, 2000), calling for an abundance of preparatory protocols (Paulsen, 1995).

Third, it may also be the case that reduced levels of constraints can allow troublesome patterns of thought to propagate more freely. A recent clinical framework accounts for how spontaneous thought might lead to both adaptive and maladaptive consequences through its possible capacity to amplify affective states (Marchetti et al., 2016). Spontaneous thought, when paired with negative affectivity—as in situations with high stress, or for individuals prone to mood disorders—may result in low self-esteem, hopelessness, cognitive reactivity, and rumination, leading to the deepening of symptoms in depression (Marchetti et al., 2016). Marchetti et al.'s framework also touches on the relationship that spontaneous thought might have to mania, suggesting that a funnelling effect might occur, intensifying already heightened levels of ambitious or unrealistic goal-striving (Marchetti et al., 2016). The idea that dysregulation in goal pursuit is a contributing factor in mania already has substantial evidence in its favor (Johnson, 2005).

Finally, many of the preceding factors might be further magnified by additional constraint reductions associated with perceptual decoupling—a state sometimes associated with spontaneous thought where attention is disengaged from perceptions and sensations (Schooler et al., 2011). Sleep, meditation, and sensory deprivation all seem to involve drastic reductions in the constraining effects that the external environment has on the mind. Prolonged periods of reduced perceptual constraints may facilitate a number of the abnormal experiences mentioned. One experiment, which has since been replicated, found evidence that it is not necessarily just a lack of sensory stimulation, but a lack of meaningful patterns or structures in sensory information that enables hallucinatory experiences to unfold (Gallagher, Dinan, & Baker, 1994; Margo, Hemsley, & Slade, 1981). This understanding is significant because, while complete sensory deprivation is not a common experience in everyday life, situations lacking meaningful stimulation—monotonous, repetitive, or boring conditions—may also be found to facilitate abnormal spontaneous thought experiences. Some anecdotal evidence supporting this hypothesis exists (Heron, 1957; Suedfeld, Rank, & Malůš, Chapter 40 in this volume). If it proves true, prolonged monotonous or boring situations may be found to add some amount of risk for instigating or intensifying the clinical symptoms discussed here (McWelling, 2014).

Conclusion

Spontaneous thought is a mode of mind that appears to have considerable benefit for our day-to-day functioning and general contentment—affording sense-making and the ordering of recent events, anticipations of and projections into the future, and a starting point for some of our creative ideas. Its effects, we have hopefully shown, may go far beyond these into the clinical realm, providing a number of avenues one can take toward psychological well-being. This unconstrained style of thinking appears to be evoked in a variety of therapeutic interventions, enabling suppressed or repressed material to arise and to be addressed, facilitating the formation of insights into dysfunctional patterns of behavior, and promoting a general state of relaxation and ease.

In some circumstances, we have also seen, spontaneous thought may also prove to be destabilizing for some individuals, potentially allowing hallucinatory or psychotic experiences to unfold more easily, or worsening symptoms in a variety of anxiety- or trauma-related conditions. There is enough evidence to suggest that significant reductions in mental constraints should be approached with care, and perhaps more gradually, for individuals in vulnerable states—though more research needs to be done to elucidate the direct factors for risk.

It should be mentioned, however, that a worsening of symptoms may not always be a sign that something is wrong. The habituation and integration of traumatic memories, for example, might require one to experience immense emotional pain in the process, and the confronting of intrusive thoughts surely involves discomfort and anxiety. Navigating these sometimes-fine distinctions between the troubling experiences that heal and the ones that cause further harm might be a process of delicate experimentation. While support and guidance can be critical, the directions may best be chosen by the one walking the path.

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CHAPTER

35

Candidate Mechanisms of Spontaneous Cognition as Revealed by Dementia Syndromes

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Abstract

The capacity to engage in spontaneous self-generated thought is fundamental to the human experience, yet surprisingly little is known regarding the neurocognitive mechanisms that support this complex ability. Dementia syndromes offer a unique opportunity to study how the breakdown of large-scale functional brain networks impacts spontaneous cognition. Indeed, many of the characteristic cognitive changes in dementia reflect the breakdown of foundational processes essential for discrete aspects of self-generated thought. This chapter discusses how disease-specific alterations in memory-based/construction and mentalizing processes likely disrupt specific aspects of spontaneous, self-generated thought. In doing so, it provides a comprehensive overview of the neurocognitive architecture of spontaneous cognition, paying specific attention to how this sophisticated endeavor is compromised in dementia.

Key Words: spontaneous cognition, dementia, neurocognition, cognitive change, memory, self-generated thought

Neurodegenerative disorders are associated with progressive deterioration in cognition, behavior, and personality, linked to the gradual degeneration of large-scale functional brain networks. The cognitive signature of the different dementia subtypes is now well established, leading to a heightened understanding of how complex cognitive processes such as memory and language are represented in the brain. One area that remains poorly understood is the relatively newborn field of self-generated cognition. As such, we have little insight into the frequency or content of spontaneous thoughts generated by individuals living with dementia, and how alterations in self-generated forms of thinking potentially impact psychological well-being and quality of life. In addition, it remains unclear how the characteristic patterns of neuropathology seen across dementia subtypes differentially disrupt aspects of self-generated thought. In this chapter, we propose that unique insights can be gleaned into the internal world of dementia by studying how foundational memory-based/construction and introspection processes are disrupted in these syndromes. In essence, we consider cognitive capacities such as autobiographical memory and future simulation as providing the requisite "building blocks" for memory-based/constructive aspects of self-generated thought, while processes such as mentalization and cognitive control are conceptualized as facilitating the introspective aspects of internal mentation. Using this framework, we will demonstrate that dementia syndromes offer a unique opportunity to study how the progressive deterioration of large-scale brain networks impacts complex expressions of self-generated thought, thus advancing our understanding of the neurocognitive architecture of spontaneous cognition.

Dementia Syndromes as a Window into Large-Scale Brain Networks

Self-generated thought is consistently associated with activity in a distributed network of regions that comprise the brain's default network (Andrews-Hanna, Reidler, Huang, & Buckner, 2010a; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011). This large-scale brain system encompasses key regions in the prefrontal, temporal, and parietal cortices, which converge on core midline hubs in the posterior cingulate and anteromedial prefrontal cortices (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010; Greicius, Supekar, Menon, & Dougherty, 2009; Raichle et al., 2001). Early characterization of this network framed it in terms of the brain's "default mode" of activity when at rest. Beyond this, however, convergent evidence from task-based activation studies supports active engagement of this network during autobiographical memory retrieval, prospection, and theory of mind (Spreng, Mar, & Kim, 2009). A functional-anatomical parcellation of the default network has been advanced whereby an array of complex cognitive functions can be categorized on the basis of two distinct subsystems: (1) a system supporting memory-based construction/simulation anchored in the medial temporal lobe (MTL subsystem); and (2) a system preferentially involved in introspection and theory of mind centered on the dorsal medial prefrontal cortex (dmPFC subsystem) (Andrews-Hanna, Smallwood, & Spreng, 2014; Buckner, Andrews-Hanna, & Schacter, 2008) (see Figure 35.1A).

Of interest in this context is the observation of progressive degeneration of large-scale functional brain networks in neurodegenerative disorders. Notably, the spread of pathology follows a trajectory that recapitulates the underlying functional and structural topography of discrete functional brain networks (Pievani, de Haan, Wu, Seeley, & Frisoni, 2011; Seeley, Crawford, Zhou, Miller, & Greicius, 2009). Here, we focus on three dementia syndromes—Alzheimer's disease, semantic dementia, and the behavioral variant of frontotemporal dementia—each of which is associated with varying degrees of structural and functional change in the default network (Irish, Piguet, & Hodges, 2012) (Figure 35.1B). These conditions have illuminated our understanding of the cognitive and behavioral consequences of selective default network damage across a range of complex cognitive processes (Irish & Piolino, 2016), underscoring the importance of discrete nodes within the default network for subtending aspects of self-generated thought. Regions beyond the default network are also affected to varying degrees across these dementia syndromes, in particular, executive or cognitive control networks implicated in self-generated thought (e.g., Christoff et al., 2009; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015). Given the widespread neural degeneration characteristic of these disorders, it is paramount to establish how aberrations within the default network, but also connectivity between the default network and other large-scale brain networks, impact the capacity for self-generated thought.

Building Blocks Furnishing the Content of Self-Generated Thought

Memory-Based Construction/Simulation

The capacity to recollect specific events from the past via episodic memory represents a largely constructive rather than reproductive endeavor (Bartlett, 1932; Schacter & Addis, 2007) and one that appears particularly well suited to support internally generated forms of thought. Autobiographical memory arguably represents the prototypical expression of the brain's default network, allowing an individual to mentally travel back in subjective time to relive salient past experiences. This form of self-generated thought confers an ongoing sense of identity and continuity across subjective time. Autobiographical memories are typically emotionally charged, imbued with rich sensory-perceptual information, and integrated within a specific spatiotemporal and self-referential framework (Conway, Singer, & Tagini, 2004). This complexity is reflected on the neural level, as a distributed network including the hippocampus and surrounding medial temporal regions, frontopolar cortices, lateral temporal regions, and lateral and medial posterior parietal cortices, including the posterior cingulate cortex, is activated when healthy individuals revisit their personal past (Maguire, 2001; Svoboda, McKinnon, & Levine, 2006). This "core network" displays striking overlap with that of the default network (Spreng & Grady, 2010), a finding that resonates with the observation that autobiographical experiences constitute a very large proportion of self-generated thought during task-free periods in healthy individuals (Andrews-Hanna, Reidler, Huang, & Buckner, 2010b). As such, there is close correspondence between the cognitive and neural mechanisms that must be functional to support autobiographical memory and aspects of self-generated thought.

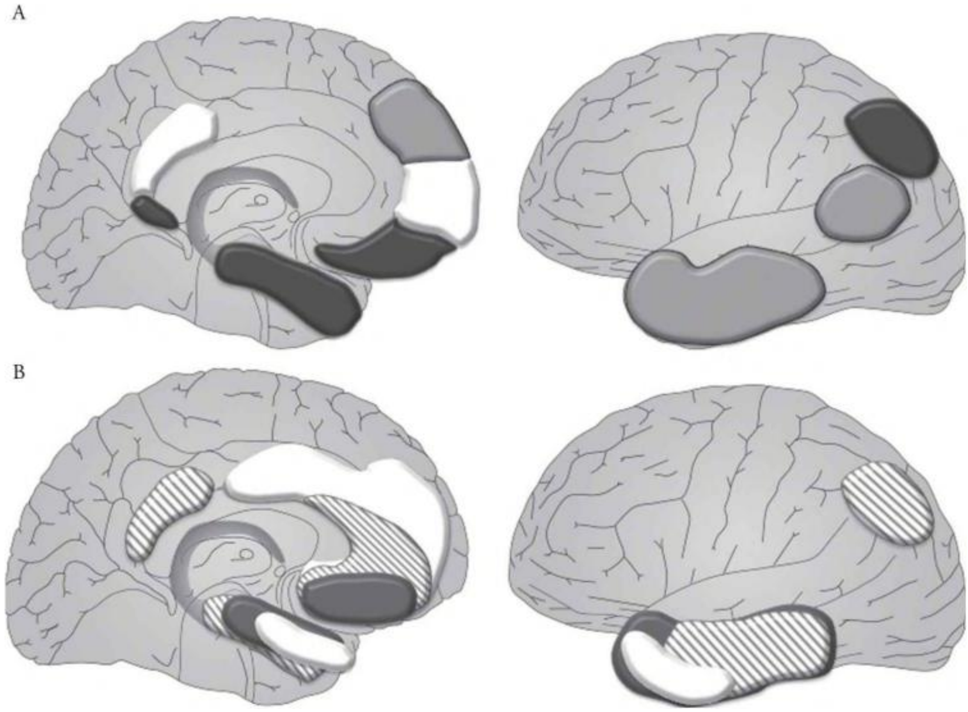

Figure 35.1. (See Color Insert) (A) The default network. The MTL subsystem (dark gray) encompasses the hippocampal formation, parahippocampal cortex, retrosplenial cortex, ventromedial prefrontal cortex, and posterior inferior parietal lobule, whereas the dmPFC subsystem (light gray) comprises the dorsomedial prefrontal cortex, temporoparietal junction, lateral temporal cortex, and temporal pole. The midline core (white) refers to the anterior medial prefrontal cortex, and the posterior cingulate cortex. Regional anatomical boundaries are approximate. Abbreviations: dmPFC = dorsomedial prefrontal cortex; MTL = medial temporal lobe. (B) Characteristic patterns of atrophy in Alzheimer's disease, semantic dementia, and behavioral variant FTD. Patients with Alzheimer's disease (diagonal stripes) show hippocampal, medial temporal and retrosplenial cortex involvement, spreading to lateral parietal and medial prefrontal regions with disease progression. In semantic dementia (dark gray), the typical pattern of atrophy is lateralized (generally left greater than right hemisphere), targeting the anterior temporal lobes and temporal pole, including the hippocampal formation and amygdala, and spreading to ventromedial prefrontal cortical regions as the disease progresses. Patients with behavioural variant FTD (white) show bilateral atrophy in mesial and orbital frontal regions, extending to the temporal pole and hippocampal formation as the disease progresses. Regional anatomical boundaries are approximate. Abbreviation: FTD = frontotemporal dementia. Figure and legend adapted with permission from *Nature Reviews Neurology* (Irish, Piguet, et al., 2012).

Interestingly, anticipatory or prospective forms of thinking also account for a sizable proportion of self-generated thought, suggesting that spontaneous cognition, in the absence of external forms of stimulation, serves an important future planning function (Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011). Again, this proposal is supported on the neural level when we consider the marked convergence between regions in the default network and those that are reliably recruited when healthy individuals envisage the future (Addis, Wong, & Schacter, 2007; Spreng et al., 2009). Moreover, functional neuroimaging studies emphasize distinct commonalities between the brain networks mediating past and future modes of thought, suggesting that a common neurobiological substrate underpins all forms of memory-based construction (Hassabis & Maguire, 2009; Schacter et al., 2012). The MTL subsystem of the default network is consistently implicated across studies that tax these constructive capacities (Andrews-Hanna, 2012), and damage to medial temporal structures compromises not only the ability to recollect the past (Rosenbaum et al., 2005) but also the ability to envisage the future (Race, Keane, & Verfaellie, 2011). We contend that these complex cognitive endeavors, in which an individual mentally revisits the past, extracts relevant sensory-perceptual information, and flexibly assimilates these details into a novel representation, are some of the foundational processes of self-generated thought. In the same manner as the sensory-perceptual contextual details extracted from episodic memory represent the building blocks of episodic future thinking (Schacter & Addis, 2009), we suggest that these contextual elements also support memory-based construction during periods of self-generated thought. We next consider how the progressive degeneration of key areas in the MTL subsystem of the default network adversely impacts memory-based construction/simulation in dementia and how these syndromes, in turn, can potentially inform our understanding of the neurocircuitry subtending self-generated thought.

Importance of the Midline Core in Memory-Based Construction

Memory dysfunction is one of the most pervasive features of dementia, reflecting the fact that the majority of dementia syndromes harbor significant atrophy in key nodes of the core memory network (Irish, Piguet, et al., 2012). Alzheimer's disease, which is characterized by profound memory impairment, is associated with early hippocampal and medial temporal pathological changes, as well as frontal and parietal changes, which are apparent using neuroimaging and reflect the underlying spread of pathology (Braak & Braak, 1991; Jack, 2012). At the network level, both the structural and functional alterations seen in Alzheimer's disease overlap considerably with the default network topography, encompassing the MTL subsystem and the posteromedial hub (Buckner et al., 2005; Seeley et al., 2009; Zhou et al., 2010). The posteromedial hub, in particular, represents a key site of pathological deposition from very early in the Alzheimer's disease course (Buckner et al., 2005). Altered connectivity in the default network tracks with disease stage in Alzheimer's disease, beginning in the early stages with decreases in the posterior default network regions and increases in anterior and ventral regions, before decreased connectivity is seen across all default network regions with disease progression (Damoiseaux, Prater, Miller, & Greicius, 2012). As such, early alterations in the posterior default network are thought to precipitate a "cascade" of connectivity changes throughout the default network, eventually affecting other large-scale networks (Jones et al., 2016).

Prominent deficits in autobiographical memory retrieval are evident from early in the Alzheimer's disease course, often manifesting in temporal gradients whereby retrieval of recently experienced events are disproportionately impaired relative to remote epochs (Greene, Hodges, & Baddeley, 1995; Irish et al., 2006). More recently, however, the use of fine-grained scoring methods reveals a flat gradient of retrieval in Alzheimer's disease, with comparable deficits irrespective of time period (Barnabe. Whitehead, Pilon, Arsenault-Lapierre, & Chertkow, 2012; Irish, Hornberger, et al., 2011). In parallel with this loss of contextual detail for key events from the past, phenomenological changes in the quality and subjective experience of autobiographical memory retrieval are also evident in Alzheimer's disease. Patients lose access to sensory-perceptual details and experience striking deficits in the ability to evoke self-referential visual imagery during autobiographical memory recollection (Irish, Lawlor, O'Mara, & Coen, 2011). This inability to mentally visualize core elements of formerly evocative events dovetails with well-documented impairments in visual imagery in Alzheimer's disease, which may in turn disrupt the capacity to envisage oneself across past and future contexts (Hussey, Smolinsky, Piryatinsky, Budson, & Ally, 2012).

The characteristic impairments in autobiographical memory retrieval in Alzheimer's disease have long been ascribed to the hallmark pathology that begins in the entorhinal cortex and encroaches across the hippocampus and then to the neocortex (Braak & Braak, 1991). While medial temporal lobe volume reduction is unequivocally associated with impaired visual and verbal anterograde memory (de Toledo-Morrell et al., 2000), recent studies have demonstrated that damage to midline posterior cortical regions may hold the key to memory disruption in this syndrome. A study by our group revealed that impaired retrieval of recent events significantly correlated with the structural integrity of the posterior cingulate cortex (Irish, Addis, Hodges, & Piguet, 2012a), and we replicated this finding in a follow-up study (Irish, Hodges, & Piguet, 2013). The posterior cingulate cortex represents a site of immense interest in this regard as it is one of the main hubs of the default network and exhibits dense connections to the MTL subsystem. This structure is posited to underpin a range of self-referential and motivationally-salient functions, including self-reflection and autobiographical memory (Andrews-Hanna, 2012). A recent study has demonstrated that vulnerability of a largely posterior brain network in Alzheimer's disease, which centers on the hippocampus but also includes the posterior cingulate cortex, represents the likely neural substrate of the prominent episodic memory deficits exhibited by these patients (La Joie et al., 2014), and we have corroborated these findings in a subsequent study (Irish et al., 2016). As such, the characteristic pathology in the posterior cingulate cortex, evident from very early in Alzheimer's disease, appears central to understanding compromised autobiographical memory retrieval in this syndrome.

The capacity to simulate personally relevant events at a future time point, or episodic future thinking (Atance & O'Neill, 2001), is also deleteriously altered in Alzheimer's disease, at a level comparable with the deficits observed for past retrieval (Addis, Sacchetti, Ally, Budson, & Schacter, 2009; El Haj, Antoine, & Kapogiannis, 2015; Irish, Addis, et al., 2012a). Interestingly, these symmetries in loss of contextual details across past and future contexts extend to the phenomenological experience in Alzheimer's disease, as patients tend to rate their past and future events comparably in terms of personal significance and emotional intensity (Addis et al., 2009; Irish, Addis, et al., 2012b). Accordingly, the parallel deficits across past and future contexts have been interpreted as reflecting the disruption of a common mechanism integral to all forms of memory-based construction and simulation. Intuitively, this proposal makes sense, but it has been suggested that future simulation deficits in Alzheimer's disease arise due to medial temporal pathology (Addis et al., 2009). Our ongoing work, using automated voxel-based morphometry techniques, however, demonstrates that damage to the posterior cingulate hub of the default mode underpins the future thinking deficit in Alzheimer's disease (reviewed by Irish & Piolino, 2016). Notably, integrity of the posterior cingulate cortex in Alzheimer's disease is the crucial determinant of performance across past and future contexts (Irish, Addis, et al., 2012a; Irish et al., 2013), pointing to this region as the core neuroanatomical substrate mediating memory-based construction deficits in Alzheimer's disease.

More recently, we have revealed that the posterior cingulate cortex is also crucial for the mental construction of spatially coherent scenes (Irish et al., 2015), a process proposed to underlie a host of complex cognitive endeavors such as autobiographical memory, future thinking, spatial navigation, and spontaneous cognition (Hassabis & Maguire, 2009). Patients with Alzheimer's disease display marked difficulties in mentally generating commonplace scenes (e.g., beach, forest, market), providing impoverished descriptions that are spatially fragmented and lacking in overall richness. Voxel-based morphometry revealed that the core region underpinning these construction impairments in Alzheimer's disease is the posterior cingulate cortex (Irish et al., 2015). As such, the evidence from Alzheimer's disease unequivocally points to the role of the posteromedial hub of the default network in supporting complex memory-based constructive endeavors.

From the findings reviewed in the preceding section, it becomes apparent that Alzheimer's disease patients suffer both a loss of contextual detail and the ability to effectively simulate those details when evoking personal memories or envisaging the future. Given that such a high proportion of mind-wandering and self-reflection is spent reminiscing and planning for the future (Andrews-Hanna, Reidler, et al., 2010a; Baird et al., 2011; Stawarczyk, Majerus, Maj, et al., 2011), a loss of contextual detail and the inability to mentally simulate spatially contiguous events suggest that the content of self-generated thought would be profoundly altered in Alzheimer's disease. It has been suggested that Alzheimer's disease patients tend to draw upon overgeneralized, gist-based details when attempting to remember events from the past (Gallo et al., 2006). An intriguing question, therefore, is whether such semanticized abstracted details remain available for Alzheimer's disease patients to harness during periods of internally guided thought in their daily life.

Disruption of the Semantic Framework for Memory-Based Construction

Whereas Alzheimer's disease is typically couched in terms of episodic memory dysfunction, semantic dementia represents the other side of the coin, in that the hallmark feature of this syndrome concerns the progressive loss of semantic knowledge, classically manifesting as a loss of memory for words. This impairment of general conceptual knowledge occurs irrespective of modality and is proposed to reflect the degeneration of a central amodal semantic hub located in the anterior temporal lobes (Patterson, Nestor, & Rogers, 2007). Atrophy in semantic dementia preferentially targets the anterior temporal lobes, most severe initially on the ventral surface and encompassing the anterior fusiform and perirhinal cortices (Mion et al., 2010). Key nodes of the default network are affected, including the temporal pole, parahippocampal cortex, and hippocampus (Galton et al., 2001; Rosen et al., 2002). This pattern of atrophy can be strikingly focal at presentation and is typically lateralized to the left side of the brain. Over time, however, atrophy begins to encroach into the contralateral hemisphere with disease progression, producing bilateral temporal lobe damage (Irish, Hodges, & Piguet, 2014; Mion et al., 2010) and wider network dysfunction in regions that incorporate primary sensory and association cortices, insula, striatal and thalamic regions, as well as medial prefrontal regions of the default network (Agosta et al., 2014; Guo et al., 2013).

Despite profound conceptual deficits, patients with semantic dementia display an array of relatively intact cognitive functions, including that of episodic retrieval (Adlam, Patterson, & Hodges, 2009), particularly on non-verbal tasks (Bozeat et al., 2000). This relative preservation of episodic memory retrieval is somewhat paradoxical given that semantic dementia patients harbor significant atrophy in the hippocampus, at a level comparable or sometimes greater than that typically seen in Alzheimer's disease (Chan et al., 2001; Davies, Graham, Xuereb, Williams, & Hodges, 2004; La Joie et al., 2013). We recently demonstrated that the integrity of posterior parietal regions largely mediates the capacity for intact episodic retrieval in this syndrome (Irish et al., 2016), underscoring the importance of regions beyond the medial temporal lobe in supporting complex memory-based endeavors.

Studies of autobiographical memory in semantic dementia have yielded mixed results, with some revealing interesting dissociations contingent on temporal context. A number of studies have documented a reverse temporal gradient or, more accurately, a step function whereby recent memories are substantially preserved in the context of remote memory dysfunction (Graham & Hodges, 1997; Graham, Patterson, & Hodges, 1999; Hou, Miller, & Kramer, 2005; Irish, Hornberger, et al., 2011; Matuszewski et al., 2009; Nestor, Graham, Bozeat, Simons, & Hodges, 2002). Similarly, using a naturalistic anterograde memory paradigm, Adlam et al. (2009) demonstrated intact retrieval of recently experienced events occurring one day prior in semantic dementia. Importantly, however, a number of studies have failed to demonstrate a reverse temporal gradient in semantic dementia (Maguire, Kumaran, Hassabis, & Kopelman, 2010; McKinnon, Black, Miller, Moscovitch, & Levine, 2006). These conflicting reports potentially reflect differences in experimental paradigms or group differences in disease severity (Ivanoiu, Cooper, Shanks, & Venneri, 2006).

Remote memory deficits in semantic dementia have been interpreted as largely reflecting the loss of semantic information that is integral to the memory trace (Westmacott, Leach, Freedman, & Moscovitch, 2001). Remote memories are hypothesized to undergo a "transformation" from evocative, perceptually rich experiences to abstracted and largely schematic accounts (Winocur & Moscovitch, 2011). By this view, older memories from remote epochs are particularly vulnerable in semantic dementia, underscoring the likely semanticization of these events with repeated rehearsal and the passage of time (Irish & Piguet, 2013). As such, in concert with the progressive degeneration of semantic knowledge in semantic dementia, we see the gradual erosion of conceptual information fundamental to successful autobiographical memory retrieval (Greenberg & Verfaellie, 2010). In contrast, the precise mechanisms supporting successful recent autobiographical memory retrieval in the face of substantial MTL atrophy in semantic dementia remain unclear. It has been suggested that preserved anterograde processes in semantic dementia potentially facilitate the encoding and retrieval of newly experienced events (Matuszewski et al., 2009). Further, recent autobiographical memories disproportionately encompass more sensory-perceptual elements than older semanticized representations from remote memory, and it has been posited that semantic dementia patients rely on these perceptual features to guide recent retrieval (Hodges & Graham, 2001; Irish, Hornberger, et al., 2011). Interestingly, recent autobiographical memories have also been shown to retain their autonoetic flavor in semantic dementia (Piolino et al., 2003), allowing the individual to mentally "relive" the original event in a rich and evocative manner. The accessibility of perceptual details represents a plausible candidate mechanism supporting recent autobiographical memory in semantic dementia, given that these patients perform at control levels on sensory-perceptual processing tasks when feature ambiguity is low (Barense, Rogers, Bussey, Saksida, & Graham, 2010) and appear adept at providing sensory-perceptual details when recounting recent events (Irish, Hornberger, et al., 2011).

Given their well-documented preservation of recent autobiographical memory, patients with semantic dementia arguably possess the requisite sensory-perceptual building blocks to furnish the construction of plausible simulations of the future. Notably, however, converging evidence reveals a profound inability to envisage future scenarios in semantic dementia, despite relatively intact episodic memory (reviewed by Irish & Piolino, 2016). These deficits are asymmetric, in that semantic dementia patients can provide detailed information regarding past experiences and self-representations, yet exhibit marked impairments in constructing future self-images or in generating contextual information to support their conceptions of their future selves (Duval et al., 2012). Compromised episodic future thinking is closely correlated with semantic processing in semantic dementia, suggesting that the inability to simulate the future arises as a direct consequence of semantic memory impairment in this syndrome (Irish, Addis, et al., 2012a). This observation is further qualified by voxel-based morphometry findings demonstrating an exclusive association between atrophy in core semantic-processing regions of the brain and future thinking deficits in semantic dementia (Irish, Addis, et al., 2012a). The finding that semantic memory is essential for constructive simulation of the future represents an expansion of the prevailing view in the field, which to date has focused mainly on the role of episodic memory (Klein, 2013). As such, we have formulated the *semantic scaffolding hypothesis* (Irish, 2016; Irish & Piguet, 2013) in which semantic memory is argued to provide the critical framework to impart meaning and structure to constructive simulation. In many ways, conceptual knowledge is ideally suited to support constructive processes as it provides undifferentiated information that can be extrapolated and generalized across multiple contexts without recourse to any specific experience (Abraham & Bubic, 2015; Hegdé, 2007).

Unsurprisingly, when asked to envisage possible future public domain events, semantic dementia patients display striking deficits, again reflecting their severe anterior temporal lobe dysfunction (Irish, Addis, et al., 2012a). Insights can be gleaned from closer inspection of the subjective reports of semantic dementia patients in this regard.

> *Can you tell me what you think will be the most important medical breakthroughs occurring within the next ten years?*
>
> "There has to be changes [*sic*] in that because it's all come forward [*sic*].
>
> *Can you think of any examples?*
>
> "No. The brain won't work. There has to be some . . . there has to be heaps [*sic*]. It's not something I think about lots." (Irish, unpublished data)

The the individual with semantic dementia displays a profound inability to draw upon general conceptual knowledge to form a cogent representation of possible future developments. In this sense, the degraded conceptual knowledge base dramatically disrupts the capacity for future simulation irrespective of whether the task requires episodic (event-based) or semantic (public domain) construction. This pervasive disruption to constructive simulation, despite access to relatively preserved sensory-perceptual details from episodic memory, is intriguing, particularly when viewed in relation to self-generated thought. If semantic memory represents a foundational repository for all forms of memory-based construction, and given that self-generated thought is associated with an anticipatory or prospective bias in healthy individuals (Stawarczyk, Majerus, Maj, et al., 2011), it follows then that self-generated thought may be uniformly compromised in this syndrome. On the other hand, relatively spared sensory-perceptual details from episodic memory could potentially serve a compensatory function, allowing the semantic dementia patient to populate his or her self-generated thought with content predominantly sourced from recent autobiographical experiences.

Foundational Processes That Sustain Self-Generated Thought: Mentalizing and Cognitive Control

Mentalizing

Contrasting with memory-based construction/simulation activities that are ascribed to the MTL subsystem of the default network, other foundational processes that may enable self-generated thought are associated with integrity of the dmPFC subsystem (Andrews-Hanna et al., 2014). These processes include mentalizing, which supports our ability to infer the mental states of others and use this information to understand and predict behavior (Frith & Frith, 1999). This mentalizing ability enables us to have theory of mind—awareness that others can have different beliefs and intentions from our own, which will govern their behavior—and as such, the terms are often used interchangeably. Mentalizing reliably recruits regions of the dmPFC subsystem in healthy individuals, including the dmPFC and temporoparietal junction (Frith & Frith, 2006; Saxe & Kanwisher, 2003).

It is worth noting that mentalizing remains a much-debated construct. Far from being a unitary process, successful mentalizing draws upon many sub-processes, including fluid executive abilities, face and gaze processing, emotion recognition and moral reasoning (Schaafsma, Pfaff, Spunt, & Adolphs, 2015). Central to mentalizing, however, is the capacity to direct one's attention inward and to introspect, a process that permits the differentiation of one's own "self" from others (Amodio & Frith, 2006). While the self remains a somewhat nebulous construct, the capacity for self-reflection has been linked to default network integrity, predominantly that of the dorsal medial prefrontal subsystem (Brewer, Garrison, & Whitfield-Gabrieli, 2013), although the posteromedial hub of the default network is also strongly implicated (Northoff & Bermpohl, 2004). We propose that self-generated thought is supported by the capacity to mentalize to interpret the mental states of others and to reflect upon our own mental state, which in turn facilitates successful social interactions and promotes psychological well-being (Smallwood & Andrews-Hanna, 2013).

Of the dementia syndromes reviewed here, the behavioral variant of frontotemporal dementia (FTD) represents the prototypical example of compromised capacity for introspection and socioemotional processing. Characterized by pervasive behavioral dysfunction, hallmark features of behavioral variant FTD include disinhibition, loss of motivation (apathy), loss of empathy, blunting of emotional expression, and rigid and stereotypical behaviors—all of which contribute to a general decline in personal and social conduct (Piguet, Hornberger, Mioshi, & Hodges, 2011; Rascovsky et al., 2007). Further, patients have little or no insight into these changes, suggesting a profound inability to introspect. Pathological changes tend to begin in the medial and orbitofrontal cortices, although widespread atrophy is observed in the anterior cingulate/dorsomedial prefrontal cortex, insula, amygdala, thalamus, and striatum from the early stages (Broe et al., 2003; Seeley et al., 2008). These affected regions correspond to key regions of the default network, most notably the dmPFC, anchoring the dmPFC subsystem, and also the ventromedial prefrontal cortex, a key node in the MTL subsystem. In direct contrast to Alzheimer's disease, posterior default network regions show increased connectivity in behavioral variant FTD (Zhou et al., 2010). The most striking alterations in this syndrome, however, occur in the brain's salience network, encompassing dorsal anterior cingulate and orbital fronto-insular cortices (Seeley et al., 2009; Zhou et al., 2010). The salience network has been linked to processing emotionally salient stimuli, and is thought to serve a function of supporting dynamic switches between the internally focused default network and externally focused attention/executive networks (Menon & Uddin, 2010). Accordingly, salience network dysfunction is posited to underpin the hallmark socioemotional disturbances typically seen in this dementia syndrome (Seeley, Allman, et al., 2007).

A consistent finding in the literature is that the capacity for mentalizing is severely compromised in behavioral variant FTD (Bora, Walterfang, & Velakoulis, 2015; Henry, Phillips, & von Hippel, 2014). Notably, these mentalizing deficits are proposed to contribute to the profound disturbances in social behavior seen in behavioral variant FTD, as they are unable to appreciate the impact of their behavior on others, or to engage in self-monitoring (Adenzato, Cavallo, & Enrici, 2010). These impairments occur irrespective of the method of assessment used and include compromised first- and second-order belief interpretation (Gregory et al., 2002), faux pas detection (Bertoux, O'Callaghan, Dubois, & Hornberger, 2015; Torralva et al., 2007), and drawing emotional inferences from facial stimuli and humorous cartoons (Clark et al., 2015; Gregory et al., 2002; Irish et al., 2014; Lough et al., 2006).

The pervasive disruption of mentalizing in behavioral variant FTD is typically viewed in light of hallmark pathology in the frontoinsular salience network, crucial for identifying and processing emotionally relevant information (Dermody, Wong, Ahmed, Piguet, Hodges, & Irish, 2016; Seeley, Allman, et al., 2007). Empirical studies combining targeted experimental tasks of social cognition and neuroimaging analysis techniques, however, reveal the involvement of both the salience network and discrete regions of the dmPFC subsystem in this syndrome. Impaired performance on mentalizing tasks requiring emotion and intention attribution has been associated with gray matter atrophy in the amygdala and insula, but also in the posterior-superior temporal sulcus extending into the temporoparietal junction (Cerami et al., 2014). Applying a different mentalizing task in behavioral variant FTD and semantic dementia, impaired capacity to infer the mental states of others correlated with gray matter loss in areas of the dmPFC subsystem, including the lateral temporal cortices and temporal pole (Irish et al., 2014). Bridging structural and functional modalities, emotional attribution deficits have been linked to both atrophic changes in the salience network and resting state abnormalities in the dorsomedial prefrontal node of the default network (Caminiti et al., 2015). Together, these findings suggest that disrupted salience-default network interactions potentially underlie mentalizing impairments in behavioral variant FTD.

Corroborating these findings of compromised salience and default network interactions in behavioral variant FTD, a recent study has linked disruptions in a related social process, moral reasoning, to diminished functional connectivity between the salience network and the default network (Chiong et al., 2013). This is consistent with a role for the salience network in dynamically modulating the default network. It follows that, along with the direct pathological changes in key regions of the dmPFC subsystem, alterations in the interplay between the salience and default networks might disrupt mentalization in behavioral variant FTD. Compromised salience network function may prevent an active switch away from externally directed attention to engage the default network in introspective processes. Impaired engagement of the default network via this active switching process could further compromise any functions that are already affected by intrinsic damage to the default network, including mentalization or memory-based construction/simulation processes. Further evidence supporting the impact of between-network disturbances is drawn from the observation that some of the deficits displayed by behavioral variant FTD patients on mentalization tasks stem from an inability to inhibit their own perspective, as opposed to an exclusive deficit in inferring the mental state of another (Le Bouc et al., 2012). Inherent in this is the idea that adopting another's perspective necessarily entails inhibition of a prepotent tendency to take one's own perspective (Samson, Apperly, & Humphreys, 2007). The lack of inhibition supporting mentalization suggests a potential break down in co-operation between default and cognitive control networks (Kumfor, Dermody, & Irish, 2015). These findings emphasize that it is not only intrinsic default mode changes that determine alterations in self-generated thought in dementia, but changes in the interrelationship between the default and other large-scale networks. Initial work to elucidate changes in the relationship between default and cognitive control networks is discussed in more detail in the following section.

Cognitive Control Processes

Dynamic interactions have been noted between the default network and the frontoparietal control network, which comprises the lateral prefrontal cortex, precuneus, anterior inferior parietal lobule, medial superior prefrontal cortex, and anterior insula (Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013). Frontoparietal and frontal executive control networks underpin the ability to flexibly alternate between different thought and behavioral states in response to changing environmental demands, as well as supporting aspects of working memory, attention, and task switching (Seeley, Menon, et al., 2007). Frontal control networks have been shown to couple with the default network across many instances of internal thought, including mental simulation, mind-wandering, social processing, and creativity (Beaty, Benedek, Silvia, & Schacter, 2016; Christoff et al., 2009; Gerlach, Spreng, Gilmore, & Schacter, 2011; Meyer, Spunt, Berkman, Taylor, & Lieberman, 2012; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010). As such, sustaining a deliberative, or goal-directed, manner of internal thought likely relies on a combination of both generative and controlled processes, derived from cooperation between default and executive control systems (Smallwood, Brown, Baird, & Schooler, 2012; Smallwood & Schooler, 2006).

As described in the preceding section, alterations in the default network in Alzheimer's disease, behavioral variant FTD, and semantic dementia differentially underpin impairments in memory, simulation, prospection, and theory of mind. In Alzheimer's disease, impairments in attention, executive function, and cognitive control are related to pathological changes in frontoparietal sites and the broader executive control networks (Agosta et al., 2012). Alterations in executive control network involvement during memory performance is evident in Alzheimer's disease (Dhanjal & Wise, 2014). When additional executive regions are recruited during memory tasks, patients' performance is better maintained, suggesting a compensatory function (Grady et al., 2003). Such findings highlight the fact that changes in the interaction between default network-mediated functions and executive control processes have important behavioral ramifications in dementia. Alterations within executive control networks, and in the interactions between the executive and default networks, suggest that aspects of internal thought in dementia may also be compromised via decreased ability to establish and maintain purposeful streams of thought. While this proposal is intuitively plausible, the cognitive and behavioral consequences of altered cooperation between the executive control and default systems have not, to date, been thoroughly characterized in the dementias.

Elucidating the dynamic interactions between functional networks that support the content of self-generated thought, and enable our ability to sustain it, represents a critical area for future research in cognitive neuroscience. In the case of dementia, differential damage to the default mode and cognitive control networks will likely manifest in unique ways. For example, dissociations may arise where spontaneous thought might readily occur, but in the absence of intact executive control processes, it might be difficult for the individual to organize internal thoughts into coherent streams that can be maintained over a period of time. Given that some of the most adaptive features of self-generated thought are to allow us to plan for the future or to mentally simulate the consequences of events (Smallwood & Andrews-Hanna, 2013; Stawarczyk, Majerus, Maj, et al., 2011), an inability to properly control internal thought could have significant consequences for everyday functioning in dementia. The functional implications of disordered forms of self-generated thought represent another key area for future research.

Behavioral Consequences of Impaired Spontaneous Thought in Dementia

To date, there is a paucity of literature on the topic of self-generated thought in neurodegenerative disorders. Despite this clear gap in the literature, it is important to consider how disruptions in the internal world of dementia potentially manifest on the broader behavioral level. Given the many ways in which internally guided cognition may support adaptive functioning, alterations in the capacity to generate and sustain this form of thinking in dementia will likely have grave consequences for the everyday functional independence of the individual (reviewed by Irish & Piolino, 2016). For example, memory-based construction/simulation deficits in dementia could underscore many problems in daily life, including difficulties with future planning and in simulating possible outcomes for different courses of action to guide decision-making processes (Dermody, Hornberger, Piguet, Hodges, & Irish 2016b; Kamminga, O'Callaghan, Hodges, & Irish, 2014). Mentalization difficulties, which affect patients' ability to both appreciate others' reactions to their behavior and to self-reflect on their own, would severely impair their ability to meaningfully engage in social settings (Adenzato et al., 2010). Alterations in interpersonal relationships as a result of these social difficulties can have profound effects, including isolation and added strain on friends or family members.

In addition, we speculate that a reduced capacity for self-generated thought in dementia could potentially underpin something akin to a "mental apathy," whereby an individual has a reduced ability to engage in, and sustain, internal cognitive activity. Apathy is typically associated with a reduction in daily activities, reduced emotional responsiveness, or self-reported loss of interest or drive (Marin, 1991). These forms of apathy are highly prevalent across neurodegenerative disorders, and are present to a degree in all of the dementia syndromes we discuss here (Chase, 2010). Although the notion of "mental emptiness" has been described in neurodegenerative conditions (Levy & Dubois, 2006), it remains unclear whether the diminished outward drive and activity we typically associate with apathy might be paralleled with a mental apathy reflecting reduced self-generative thought. The gross disruption to the building blocks of self-generated cognition outlined here, including a loss of content (i.e., memory, prospection) and a loss of the sustaining processes (i.e., mentalization, cognitive control), arise in the context of experimental tasks in which the individual is required to respond to external task demands. It follows, then, that impairments in the foundational processes of self-generated thought may be more pronounced when the individual is left to her own devices without external direction or input. Rather than being "lost in one's own thoughts," we suggest that the internal world of the individual living with dementia may in fact lack many of the sophisticated forms of internally guided cognition that we so take for granted in our daily lives, especially with disease advancement. In turn, this impaired capacity to generate and sustain complex forms of internally guided cognition may render the individual more reliant upon external forms of stimulation. This hypothesis would have significant implications for the care of individuals living with dementia and requires careful empirical investigation.

A Path for the Future: Developing Novel Procedures to Study Spontaneous Thought in Cognitively Impaired Populations

The evidence reviewed here suggests that alterations in the capacity for spontaneous self-generated thought are highly likely in dementia. These alterations, however, may have suffered the same fate as other "silent" symptoms in neurodegenerative disease in comparison to more obvious features such as movement disturbances, memory loss, disorientation, or personality change. In particular, memory loss and behavioral transgressions can overshadow subtler cognitive changes, which, in the context of lack of insight in dementia, may go unnoticed by the caregiver or unreported by the patient.

One confounding issue with regard to obtaining an accurate appraisal of spontaneous cognition in dementia is that many of the currently available tasks devised to study spontaneous thought in healthy populations are ill-suited for use in individuals with widespread cognitive impairment. Common approaches to assessing spontaneous cognition require participants to perform a relatively monotonous, but attention-demanding, task to promote off-task mind wandering, with the underlying assumption that participants can accomplish the task without using all of their cognitive resources. In the various versions of this methodology, experimenters might probe at random intervals to capture the instances of off-task thoughts, or the participant might be trained to self-identify when an off-task thought occurs (Christoff et al., 2009; Stawarczyk, Majerus, Maquet, et al., 2011). Self-report following engagement in a separate task or after a scanning session might also be used to retrospectively establish what the thought content had been during the task or scan (Maillet & Rajah, 2013). The various demands placed on multitasking, self-awareness, and memory processes render such tasks incompatible for use in dementia populations.

The availability of cognitive resources is also posited to play a significant role in the frequency of mind-wandering occurrences during laboratory tasks. Consistent with the notion that cognitive resources deplete with healthy aging, decreased mind-wandering has been found in older relative to younger adults (Jackson & Balota, 2012). The demand on cognitive resources in mind-wandering assessment therefore can impact the degree to which spontaneous off-task thought is elicited. Yet other determinants also have a significant effect, including level of interest in the task, motivation, and the extent to which an individual may have many other ongoing current concerns in his life that might distract from the task at hand (Maillet & Schacter, 2016). Measures developed to assess spontaneous thought in clinical cohorts need to carefully consider these potentially confounding factors, as all can undergo significant changes in neurodegenerative disorders.

A key challenge for the future, therefore, is to develop appropriate ways of studying spontaneous thought processes in dementia populations in a manner that circumvents marked cognitive decline. Methodological advances in this area will not only benefit the study of self-generated thought in dementia, but also other neuropsychiatric disorders that present with both cognitive impairment and default network dysfunction (e.g., Schizophrenia; Whitfield-Gabrieli and Ford, 2012). We have developed a task that addresses many of the methodological issues inherent in the assessment of mind wandering in dementia. In the "Shape Expectations" task (O'Callaghan, Shine, Lewis, Andrews-Hanna, & Irish, 2015), participants are required to view a series of colored shapes appearing one by one on a computer screen, while letting their minds wander freely. Following presentation of each shape, they are asked to report on their thought content during the time the shape was displayed. Mind-wandering frequency is measured by instances where reported thoughts are independent from the shape-stimulus, the task, or the current environment, and clearly demonstrate unique self-generated thought. Phenomenology of mind-wandering episodes is also established by classifying thought content into (1) memory-based construction/simulation, or (2) introspection/metacognitive-based thoughts, based on the functional-anatomical taxonomy of the default network advanced by Andrews-Hanna and colleagues (Andrews-Hanna, Reidler, Sepulcre, et al., 2010). This paradigm therefore permits online investigation of both the frequency and content of mind-wandering in the context of low cognitive demands, making it suitable for dementia populations. Continued development of novel paradigms that can probe spontaneous cognition in clinical cohorts will offer unique insights into the neural mechanisms and component processes that sustain adaptive forms of thinking.

Conclusion

We conclude this chapter at an exciting juncture in cognitive neuroscience research. It is clear that many of the foundational building blocks and facilitative processes of self-generated thought are compromised in dementia, attributable to alterations in the structural and functional connectivity of large-scale networks in the brain. How such aberrations manifest in terms of the everyday adaptive functioning of the individual living with dementia remain unclear, but there is evidence to support the view that internally generated spontaneous forms of thought will be significantly dampened. The potential disruption of uniquely human aspects of cognition speaks to a critical issue in terms of patient management and care. Understanding how alterations in self-generated thought impact psychological well-being in terms of mood, motivation, and socio-emotional engagement represents a crucial area for future research and one that ultimately will inform the delivery of targeted interventions to improve quality of life for individuals living with dementia.

Acknowledgments

C. O. is supported by a National Health and Medical Research Council Neil Hamilton Fairley Fellowship (GNT1091310). M. I. is supported by an Australian Research Council Future Fellowship (FT160100096).

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CHAPTER

36 Rumination Is a Sticky Form of Spontaneous Thought

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Abstract

This chapter examines rumination as a unique mode of thought capable of arising in both normative and pathological contexts. Although there has been extensive interest in rumination as a trait-level contributor to psychopathology, research on the neural correlates of ongoing rumination is relatively recent. Viewed through the lens of spontaneous thought, the chapter considers rumination as a spontaneously occurring form of thought that becomes "stuck" in a repetitive, highly constrained context. In considering the implications of this viewpoint, the chapter explores the contexts in which rumination has been identified, as well as its relationship to other forms of spontaneous thought such as mind-wandering.

Key Words: rumination, mind-wandering, pathology, spontaneous thought, psychopathology

Spontaneous thoughts form currents in our stream of consciousness. These thoughts can be defined as effortlessly arising, non-instrumental cognition, moving the stream of consciousness in ways unbidden by the thinker (Klinger, 2009). Although these currents generally flow forward, they can also loop and circle back as an eddy. Thoughts that form such mental eddies are marked by their perseverative and repetitive nature and are commonly referred to as ruminations (Watkins, 2008). Rumination is a form of repetitive thinking that is often self-referential in nature (Segerstrom, Stanton, Alden, & Shortridge, 2003), and it has been recognized both as a trait-level contributor to psychopathology (Nolen-Hoeksema, 2000) and as a more state-like mode of thought (LeMoult, Arditte, D'Avanzato, & Joormann, 2013).

In this chapter, we review the research literature on rumination through the lens of spontaneous thought. Although rumination is a stereotyped thought process, its spontaneous emergence can provide important insight into its neural correlates and behavioral outcome. In this chapter, we therefore consider rumination as a spontaneously occurring form of thought whose progression is highly constrained and repetitive (see Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016, for a review of spontaneous thought). We begin by defining trait and state rumination and examine how they are operationalized and measured in research and clinical settings. We examine the factors that precipitate ruminative thoughts, the contexts in which they persist, and the impact of ruminative thinking on other domains of cognitive and affective function. We then review the cognitive neuroscience of rumination, characterizing the brain regions involved. Finally, we contrast rumination with another commonly studied form of spontaneous thought—mind-wandering. This comparison will serve to challenge commonly held conceptions of rumination and suggests the possibility of ruminative thought as a protracted, or "sticky," form of spontaneous mind-wandering. We conclude the chapter by describing potential research and clinical implications and how rumination may provide a unique vantage point from which to investigate the role of affect in spontaneous thought.

Rumination: Definition and Measurement

Rumination is defined primarily by its perseverative nature, with a specific focus on the self and self-relevant concerns. The theoretical conceptualization of rumination remains an area of debate (see Smith & Alloy, 2009). For example, the *goal-progress* model (Martin, Tesser, & McIntosh, 1993) considers rumination to be a general self-regulation strategy; in contrast, the *response styles theory* (Nolen-Hoeksema, 1991) regards rumination as a specific form of cognitive dysfunction, associated with a heightened vulnerability to depression. These differing perspectives have shaped much of the research into rumination. In particular, the response styles theory has been the most influential model in cognitive neuroscience investigations of rumination, which have emphasized rumination's role as a precipitating factor in psychopathology. Response styles theory defines rumination as a passive, repetitive, and self-relevant thought process occurring in reaction to or in concert with negative affect (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This definition considers rumination to be a stable, trait-like response that is triggered in reaction to negative events, such as the death of a loved one (Nolen-Hoeksema & Davis, 1999).

Response styles theory studies of rumination typically measure rumination using the Ruminative Responses Scale (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003), a 22-item questionnaire that assesses the tendency to experience thoughts such as "Why do I always react this way?" As the RRS measures the degree to which individuals generally engage in ruminative thoughts, it provides a marker of trait rumination. Trait rumination can be conceived of as an individual difference in cognitive bias toward ruminative thoughts. As we discuss in greater depth later in the chapter, trait rumination has been associated with functional brain organization, consistent with the idea that the tendency to ruminate may arise from stable individual differences (Ray et al., 2005).

A cognitive bias toward rumination, however, is distinct from engaging in a ruminative episode. Active, or state, rumination is a mode of thought that has been associated with specific affective states and cognitive abilities. State rumination following a stressor negatively predicts emotional recovery, even after controlling for trait rumination levels (LeMoult et al., 2013). State rumination has also been associated with cognitive functions such as increased abstract-verbal processing, reduced concrete imagery (Goldwin & Behar, 2011), and poor task switching ability (Whitmer & Gotlib, 2012b).

Obtaining reliable measures of rumination has proven challenging. This is particularly the case for assessments of trait rumination, where measures can have markedly different stability estimates. Trait rumination, as measured by RRS scores, exhibits low reliability over time. In individuals who recover from depression over a six-month period, a significant relationship between change in RRS scores and change in depressive symptoms was found ($r = 0.41$, $p < 0.01$; Kasch, Klein, & Lara, 2001). This suggests that rumination as measured by the RSS is closely related to clinical status, rather than measuring a non-pathological individual difference. Others have argued that this low stability across diagnostic categories derives from the inclusion of symptom-focused items of the RRS, which can be expected to change with improved clinical status (Bagby, Rector, Bacchiochi, & McBride, 2004). They thus propose that RRS items with a symptom focus may reflect a current depressive episode, while items that assess individual differences in ruminative tendency may be more self-focused and therefore better predict future occurrence of depressive episodes.

This parcellation of the RRS into symptom- and self-focused items has been further refined into three RRS subscales: reflection, brooding, and depression-related (Treynor et al., 2003). The depression-related RRS subscale has been criticized for its overlap with the Beck Depression Inventory (Beck, Rush, Shaw, & Emery, 1979) and is not widely used in assessing the unique determinants of non-depressive rumination. RRS-Reflection (RRS-R) items are considered to reflect an intentional, internal evaluation of negative affect as a means of cognitive problem-solving; RRS-Brooding (RRS-B) items reflect a passive, persistent comparison of one's response style with an unachieved ideal (Treynor et al., 2003). Both RRS-R and RRS-B subscales share negative outcomes, including current major depressive episode severity and memory biases toward negative information (Nolen-Hoeksema et al., 2008). Nonetheless, these subscales have been differentially implicated in depressive episode duration, leading to the suggestion that RRS-R reflects an adaptive form of rumination, in contrast with the more maladaptive RRS-B (Treynor et al., 2003). This is in agreement with individual subjective experience, where participants with high RRS-R scores are more likely to self-report that their ruminations enable productive problem-solving (Watkins & Moulds, 2005).

The close association between rumination and psychopathology in the response styles theory model has led to suggestions that a normative range of rumination cannot exist within a response styles theory framework. Instead, the RRS-R, rather than reflecting a subtype of rumination, would represent a distinct form of repetitive thought known as reflection (Watkins, 2008). This is an important, if unresolved, distinction, and it has been largely unexplored in investigations of state rumination. Repetitive thought has been linked to positive behaviors, including improved problem-solving (Watkins & Baracaia, 2002), suggesting that state rumination can yield constructive outcomes (Baars, 2010). In considering rumination as a form of spontaneous thought, exploration of such normative, reflective forms of rumination will be an important avenue for future research.

Rumination: Causes and Contexts

Rumination has been identified in both healthy (Piguet et al., 2014) and clinical populations, such as those with depression, anxiety, obsessive-compulsive disorder (OCD), and post-traumatic stress-disorder (PTSD; Nolen-Hoeksema et al., 2008). Exploring rumination in these populations provides insight into the factors that affect the emergence and maintenance of ruminative thought.

Rumination in Healthy Populations

In healthy individuals, several factors affect the emergence and persistence of rumination. Perhaps the most robust of these is gender. A meta-analysis by Johnson and Whisman (2013) found that women are significantly more likely to report higher levels of trait rumination, regardless of diagnostic status (Cohen's d = 0.24). This is consistent with the increased prevalence of depression in women (Kessler et al., 2015). Indeed, response styles theory was developed in part to explain the higher incidence of depression in women (Nolen-Hoeksema et al., 2008). The cognitive and neural mechanisms associated with sex differences in rumination have yet to be investigated (but see Belleau, Taubitz, & Larson, 2015).

Age is also an important moderator of rumination, with decreasing prevalence across the lifespan. Although rumination has been relatively underexplored in children, the significant gender difference noted in adults has been reported in adolescents as young as 12 years of age (Jose & Brown, 2007). At the other end of the lifespan, rumination is seen to markedly decrease from its adolescent peak, reaching its lowest levels in individuals over 60 years of age (Sütterlin, Paap, Babic, Kübler, & Vögele, 2012). As with sex disparities, the mechanisms underlying these age-related differences in rumination have yet to be fully investigated. Recent interest in the impact of aging on spontaneous cognition (Maillet & Schacter, 2016; see also O'Callaghan & Irish, Chapter 35 in this volume), however, promises future developments.

Rumination in Psychopathology

Unlike studies of healthy adults, substantially more work has characterized the prevalence, presentation, and determinants of rumination in psychopathology. In major depressive disorder, rumination is characterized as an uncontrollable, intrusive focus on the causes and consequences of depressed mood (Morrow & Nolen-Hoeksema, 1990). Initial work with response styles theory focused largely on rumination as a risk factor in the development and maintenance of depression (Nolen-Hoeksema, 1991). In a longitudinal study of bereaved adults, rumination was found to be associated with higher depression levels at six months post-loss, independent of other factors such as social supports, negative cognitive outlook, baseline depression, and co-occurring environmental stressors (Nolen-Hoeksema, Parker, & Larson, 1994).

The association between rumination and depression has been argued to be an artifact of its definition within the response styles theory model. For example, work investigating the stability of trait rumination in longitudinal samples has observed low test-retest reliability, with RRS total scores strongly influenced by depression status (Kasch et al., 2001). Nonetheless, the association between rumination and depression has been reliably observed in studies that have adopted alternative theoretical frameworks. The *self-regulatory executive function* model advanced by Matthew and Wells (2004) also suggests that rumination may play a role in the onset of depression as well as other mood disorders.

In recent years the response styles theory conceptualization of rumination has been investigated as a thought-pattern associated with other psychiatric disorders, including non-suicidal self-injury, anxiety, substance abuse, and eating disorders (Nolen-Hoeksema et al., 2008). Initial work focused largely on the expression of rumination in these disorders when comorbid with depression, such as mixed anxiety/depressive disorders (Nolen-Hoeksema, 2000). Although depression has a high comorbidity with other psychopathology, particularly anxiety (Kessler et al., 1996), rumination has been demonstrated to occur in these illnesses independent of depression. Rumination is a dominant feature of generalized anxiety disorder (GAD), OCD, and PTSD.

GENERALIZED ANXIETY DISORDER

Rumination scores on the RRS correlate strongly with anxiety symptoms (Brozovich et al., 2015), although this is not the most common form of repetitive thought in GAD. The core cognitive feature of GAD is a predominance of worry—an intrusive apprehension of future events (American Psychiatric Association [APA], 2013). There are several similarities between worry and rumination, such as their shared description as unproductive, repetitive thought patterns; their abstract-verbal nature; and their close associations with psychopathology (Fresco, Frankel, Mennin, Turk, & Heimberg, 2002). Both worry and rumination correlate significantly with anxiety and depressive symptoms (Segerstrom, Tsao, Alden, & Craske, 2000) and are associated with neuroticism (Perkins, Arnone, Smallwood, & Mobbs, 2015).

Nonetheless, worry and rumination have distinguishing characteristics. For instance, a factor analysis of worry and rumination items reveals that they load upon separate factors (Fresco et al., 2002). Rumination and worry differentially mediate the relationship between neuroticism and psychopathology, with worry contributing more to anxiety disorders and rumination contributing more to depression (Muris, Roelofs, Rassin, Franken, & Mayer, 2005). Importantly, worry and rumination also have different time orientations, with worry focused on future events or outcomes and rumination concentrating on past experience (Nolen-Hoeksema et al., 2008). Accordingly, worry has been hypothesized as a form of emotional coping via cognitive distancing from threatening internal experiences (Behar, DiMarco, Hekler, Mohlman, & Staples, 2009), while rumination involves fixation on the source and symptoms of distress (Curci, Lanciano, Soleti, & Rimé, 2013).

OBSESSIVE-COMPULSIVE DISORDER

There is a substantial comorbidity between OCD and depression, with approximately 17% of individuals meeting criteria for both disorders in an epidemiological sample (Andrews, Slade, & Issakidis, 2002). Individuals suffering from non-comorbid OCD, however, also report high scores on the RRS (Dar & Iqbal, 2015). This may be due in part to the similarities between rumination and compulsive thoughts. The characterization of rumination as a failure to disengage from repetitive, internal thought is remarkably similar to obsessive-compulsive disorder, a condition characterized by the occurrence of persistent, repetitive thoughts (obsessions) and the completion of rituals (compulsions) in response to those thoughts (Bokor & Anderson, 2014).

Similar behavioral deficits have been documented in both OCD and rumination, including reduced task-switching ability (Meiran, Diamond, Toder, & Nemets, 2010). Unlike rumination, however, obsessions can be both visual and verbal and are not necessarily self-focused, instead involving general concerns such as fear of harm or contamination (Franklin & Foa, 2011). These concerns arouse feelings of anxiety and distress, thereby driving subsequent compulsions. Rumination, on the other hand, reduces the likelihood that individuals will enact solutions to perceived problems (Ward, Lyubomirsky, Sousa, & Nolen-Hoeksema, 2003).

POST-TRAUMATIC STRESS DISORDER

Rumination is a common symptom of PTSD, with 94% of assault survivors in one study reporting ruminating on their experience of the assault (Michael, Halligan, Clark, & Ehlers, 2007). Interestingly, high levels of rumination have been suggested to play a causal role in the course of PTSD, particularly in the development and maintenance of intrusive memories (Ball & Brewin, 2012). Such memories, a central feature of PTSD, are a spontaneous re-experiencing of previous negative events and cause substantial subjective distress (APA, 2013).

Although both intrusive memories and rumination focus on past experiences, there are important differences. Chief among them is the ability of rumination to extend beyond a specific event (e.g., thinking "Why do I always react this way?"). There is also a strong difference in their subjective experience, with intrusive memories experienced as primarily visual (Ehlers et al., 2002) whereas ruminations are largely abstract in nature and verbally mediated.

Rumination is also reported as a feature in pathological aging. Although rumination has been shown to decrease with advancing age (Sütterlin et al., 2012), high trait rumination has been suggested to play a role in Alzheimer's disease (Marchant & Howard, 2015). Further explorations of the prevalence of rumination in aging and neurodegenerative disease will be helpful in characterizing the neural basis of ruminative thought.

Impact of Rumination on Cognitive and Emotional Functioning

In the previous section we considered the prevalence of ruminative thought in health and psychopathology. Here we examine associations between rumination and specific areas of cognitive and affective functioning.

Rumination and Memory

Memory plays a critical role in rumination. Rumination involves a fixation on past experiences and their subsequent effects (Nolen-Hoeksema et al., 2008), a process that depends in large part on memory for these previous experiences. Memory in rumination, however, has been suggested to exhibit specific cognitive biases. These include negative memory bias, such that individuals recall negatively valenced events more easily than those of neutral or positive valence (Lyubomirsky, Caldwell, & Nolen-Hoeksema, 1998). Rumination has also been associated with over-general memory, or reduced specificity of recalled events (Raes, Hermans, Williams, Geypen, & Eelen, 2006; Watkins & Teasdale, 2001).

There has been debate as to whether negative memory bias and over-general memories are specific to rumination or are simply associated with rumination due to their more general occurrence in depression (Elliott, Rubinsztein, Sahakian, & Dolan, 2002; Park, Goodyer, & Teasdale, 2004). Perhaps the strongest evidence for their dissociation comes from neuroimaging work. In treatment-naïve depressed patients, high levels of trait rumination were associated with increased resting-state functional connectivity (RSFC) of the medial prefrontal cortex and anterior cingulate cortex to the broader default network (DN) (Zhu et al., 2012), including the posterior cingulate cortex, medial prefrontal cortex, medial temporal lobe, and inferior parietal lobule (Bucker, Andrews-Hanna & Schacter, 2008; Raichle et al., 2001). In the same patients, increased RSFC of the posterior cingulate cortex to the DN correlated with more over-general memory (Zhu et al., 2012). This anterior-posterior dissociation suggests that, at least in depressed individuals, distinct neural mechanisms may support cognitive biases toward trait rumination as compared to over-general memory. However, a recent investigation suggests that the brooding subtype of rumination is specifically associated with an over-general memory bias (Romero, Vazquez, & Sanchez, 2014), opening future lines of inquiry into the mechanism for this association.

The role of rumination in memory biases continues to be explored (e.g., Hach, Tippett, & Addis, 2014), but this work is complicated by the co-occurrence of depression. It is likely that part of the difficulty in disentangling the effects of rumination and depression on memory is due to the assessment of trait rather than state measures of rumination. Trait rumination has been seen to fluctuate with depression (Kasch et al., 2001), making it difficult to parse their relative impact on memory biases.

Rumination and Executive Control

Executive control appears to be closely associated with ruminative thought. Both state (Watkins & Brown, 2002) and trait (Joormann, Levens, & Gotlib, 2011) rumination have been associated with a failure of executive control. Behavioral studies demonstrating associations between executive control and rumination have operationalized executive control in myriad ways, including stereotyped responding (Watkins & Brown, 2002) and working memory manipulation (Joormann et al., 2011). Studies investigating the impact of trait rumination on executive control using a working memory paradigm, have reported increased activation of DN regions (Bartova et al., 2015) and decreased activation of visual areas (Piguet et al., 2014).

Task-switching paradigms have also been used to examine the effect of rumination on executive function. Indeed, rumination has been likened to a difficulty in switching between internal and external attention (Northoff & Sibille, 2014), suggesting that rumination should yield significant impairments in task switching. In line with this hypothesis, trait rumination has been associated with impaired filtering of currently irrelevant tasks (Owens & Derakshan, 2013). State rumination, in contrast, has been demonstrated to yield the opposite pattern of results, with slower task switching but no impairment in filtering of irrelevant tasks (Whitmer & Gotlib, 2012b). However, this association was only observed in depressed participants (Whitmer & Gotlib, 2012).

The *attentional scope model of rumination* proposed by Whitmer and Gotlib (2013) addresses this discrepancy by arguing that individual differences in executive control are associated with susceptibility to rumination. The authors suggest that trait rumination as a cognitive bias may be more likely to impact automatic inhibition processes such as inhibiting irrelevant tasks; state rumination as an ongoing mode of thought would instead impact inhibition that relies on executive control (Whitmer

& Gotlib, 2013). This is in contrast to the suggestion that rumination depletes cognitive resources, yielding impaired executive control (Curci et al., 2013).

Rumination and Negative Affect

Rumination has been closely associated with negative affect. Indeed, within the framework of response styles theory, rumination is defined to occur in reaction to or in concert with negative affect (Nolen-Hoeksema et al., 2008). Experimental results have confirmed this relationship, and negative affect has been reliably associated with experimentally induced state rumination as well as with high levels of trait rumination (Thomsen, 2006).

Negative affect is also a defining feature of major depression (APA, 2013). The association between depression and rumination, particularly trait rumination (Kasch et al., 2001), therefore provides a potential complication in assessing the unique effects of rumination on affect. By examining state rather than trait rumination, however, these processes have been reliably dissociated. Studies that have induced rumination in depressed individuals have seen an increase in negative affect beyond baseline (Nolen-Hoeksema & Morrow, 1993). Similarly, inducing rumination in healthy individuals increases negative affect (Huffziger et al., 2012), which is distinct from depressive symptoms (Pasyugina, Koval, De Leersnyder, Mesquita, & Kuppens, 2015). These studies suggest that there is a clear positive relationship between state rumination and negative affect. However, the direction of this relationship is complicated by evidence that individuals who engage in rumination have a bias toward negative stimuli (Ray et al., 2005). That is, ongoing rumination may directly feed forward into negative affect, or preferentially interpreting negative stimuli may create a feedback loop that then yields increased rumination. Future work using a state assessment of rumination will continue to provide a clearer picture of the relationship between rumination and affect.

Neural Basis of Ruminative Thought

Spontaneous thought has been consistently linked with a core set of brain regions including the medial prefrontal cortex, medial temporal lobe, posterior cingulate cortex, and inferior parietal lobule (Andrews-Hanna, 2012; Andrews-Hanna, Smallwood & Spreng, 2014; Bucker et al., 2008). These regions constitute the DN, a large-scale neural network implicated in self-relevant thoughts such as memory, prospection, and theory-of-mind (Buckner & Carroll, 2007; Spreng, Mar, & Kim, 2009). Recent meta-analytic work has suggested that non-DN regions are equally important in spontaneous thought, including the lingual gyrus, dorsal anterior cingulate cortex, temporopolar cortex, insula, and rostrolateral prefrontal cortex (Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015). In examining rumination as a form of spontaneously occurring thought, it is valuable to see how its associated functional neuroanatomy—both in trait and state assessments—aligns with other forms of spontaneous thought.

Trait Rumination

Resting-state functional connectivity (RSFC) magnetic resonance imaging (MRI) is a widely used tool to investigate the intrinsic functional architecture of the human brain. Patterns of RSFC reveal important relationships with individual differences in cognition and behavior (Stevens & Spreng, 2014). Among groups assumed to exhibit different levels of trait rumination—such as healthy individuals versus those with psychopathology—early investigations attributed differences in RSFC profiles to differing ruminative tendencies (Grecius et al., 2007). In depressed individuals, increased RSFC between the subgenual prefrontal cortex and DN structures was associated with higher RRS scores, particularly on the brooding subscale (Berman et al., 2011; Hamilton, Farmer, Fogelman, & Gotlib, 2015). High RRS scores in remitted depression have also been associated with reduced middle frontal gyrus connectivity with the DN and the subgenual anterior cingulate cortex of the salience network (SN) (Jacobs et al., 2014). The SN, including the dorsal anterior cingulate and fronto-insular cortex, has been suggested to play a crucial role in attending to biologically relevant stimuli (Seeley et al., 2007). That both the SN and DN exhibit altered connectivity at high levels of trait rumination aligns with the triple-network model of psychopathology (Menon, 2011). According to this view, psychopathology emerges from impairment in the DN, SN, a central executive network, or their interactions. The central executive network, including the posterior parietal cortex and dorsolateral prefrontal cortex, is thought to be responsible for the control of attention and planning (Menon, 2011). Indeed, all three networks have been implicated in depression (Hamilton, Chen, & Gotlib, 2013; Nejad, Fossati, & Lemonge, 2013; Sheline et al., 2009).

Both functional and structural neural correlates of trait rumination have been explored in healthy populations. Gray matter volume in the inferior frontal gyrus, anterior cingulate cortex, and mid-cingulate cortex is associated with higher RRS scores (Kuhn et al., 2012). In the same study, reduced amplitude of intrinsic, low-frequency fluctuations in functional connectivity among these regions is also associated with greater trait levels of rumination. Increased entorhinal cortex and reduced middle occipital gyrus activation during resting intervals has also been associated with higher RRS scores (Piguet et al., 2014). During a negative cognitive reappraisal task investigated with functional MRI, higher RRS scores have been associated with greater amygdala activity (Ray et al., 2005).

The identification of regions outside of the DN in studies of trait rumination is perhaps surprising, given the clinical focus on the DN as the neural substrate of ruminative thought (Hamilton et al., 2013; Marchetti, Koster, Sonuga-Barke, & De Raedt, 2012). However, this association of the DN and rumination may be an artifact of a priori selection of the DN as regions of interest in previous research. Hamilton and colleagues (2011) specifically isolated activation from the DN to compare with activations outside the DN. The authors reported that depressed individuals with more consistent DN activations, or "DN-dominance," reported higher RRS–Depression Related scores. They hypothesized that this over-activation might reflect a failure of the right fronto-insular cortex to attenuate DN activity. Another study used posterior cingulate seed-based connectivity to define the DN in depressed and healthy individuals (Berman et al., 2011). Berman and colleagues found that greater RSFC between the DN and subgenual anterior cingulate cortex correlated with higher RRS scores (2011). A more recent study assessed the dynamic RSFC—or fluctuation of RSFC across a scanning session—of a medial prefrontal cortex seed region to investigate differential DN trajectories in depression (Kaiser et al., 2015). Here, increased medial prefrontal cortex and insula dynamic connectivity was linked to higher levels of self-reported rumination within the past two weeks (Kaiser et al., 2015). Despite their explicit focus on the DN, each of these studies implicates non-DN regions in trait rumination, particularly in the presence of depressive symptomatology.

State Rumination

State rumination, in contrast to the cognitive bias of trait rumination, reflects ongoing ruminative thought and is commonly examined via rumination induction. When compared to rest, rumination induction is associated with heightened functional connectivity between the right frontal pole and left lateral occipital cortex, as well as between the right basolateral amygdala and left inferior frontal gyrus (Milazzo et al., 2016). Berman and colleagues (2014) found that the brain activation in depressed individuals during ongoing rumination significantly differed from that observed in a separate unconstrained resting-state run, with increased connectivity between the posterior cingulate cortex and regions including the inferior frontal gyrus and subgenual cingulate cortex. Such studies of rumination induction are rare, however, and significant work remains to be done examining task-evoked ruminative states.

Distraction has been suggested as an adaptive reaction to rumination (Nolen-Hoeksema, 1991). For this reason, task-based functional MRI has examined state rumination relative to distraction. In a study by Cooney and colleagues (2010), induced rumination ("Think about why things turn out the way they do") was contrasted with concrete ("Think about a fan slowly rotating back and forth") and abstract ("Think about what contributes to team spirit") forms of other-focused distraction. The authors found that in healthy individuals, rumination relative to concrete distractions was associated with increased activation in inferior parietal lobule, precuneus, pre- and post-central gyrus, and superior parietal lobule. Rumination relative to more abstract distractions was associated with increased activation in the cuneus, precuneus, medial prefrontal cortex, and dorsolateral prefrontal cortex. The engagement of DN regions, such as the precuneus, inferior parietal lobule, and medial prefrontal cortex, is consistent with the self-referential nature of rumination. The increased activation of non-DN regions such as the dorsolateral prefrontal cortex, however, suggests that other networks play a significant role in ongoing rumination. The involvement of multiple large-scale cortical networks in rumination suggests comparisons to another form of spontaneous thought, mind-wandering.

Rumination and Mind-Wandering as Forms of Spontaneous Thought

Spontaneous thought occupies a large part of daily experience (Killingsworth & Gilbert, 2010; Singer & McCraven, 1961). However, as the work in this volume clearly demonstrates, defining the nature and the content of spontaneous cognition is an active area of research. Much of the research literature investigating spontaneous thought has focused on *mind-wandering*—also known as *day-dreaming* or *stimulus-independent thought.* It is a form of internal cognition related to individual goals, concerns, and experiences (Smallwood & Schooler, 2015). While rumination is also internally directed and self-referential in nature, there has been little consideration of rumination as a form of spontaneously occurring cognition, and no studies to date have directly contrasted mind-wandering and rumination as different forms of spontaneous thought. In this final section, we briefly compare mind-wandering and rumination with respect to their life-span prevalence, functional impacts, and cognitive and neural correlates. We conclude the section by proposing a novel perspective on rumination as a form of protracted—or "sticky"—mind-wandering and spontaneous thought.

Rumination and mind-wandering both show decreasing prevalence in older adulthood (Jackson & Balota, 2012; Sütterlin et al., 2012), as older adults report less spontaneous cognition than young adults (Maillet & Schacter, 2016). Rumination and mind-wandering have also both been associated with negatively valenced thought and negative affect (Wilson et al., 2014; but see Fox, Thompson, Andrews-Hanna, & Christoff, 2014; Poerio, Totterdell, & Miles, 2013). Mind-wandering, however, has also been associated with positive psychological outcomes, including future planning and an enhanced sense of meaning (Smallwood & Schooler, 2015), whereas rumination has been associated with negative outcomes and the emergence of psychopathology (but see Andrews & Thomson, 2009). Nonetheless, as discussed earlier, there is evidence that the reflective subtype may be an adaptive form of rumination (Treynor et al., 2003).

Cognitively, mind-wandering is associated with flexible thinking and creative problem-solving (Baird et al., 2012). In contrast, rumination is associated with cognitive rigidity and reduced problem-solving capacity, especially in dynamically changing contexts. However, this consideration of context may be the critical link between mind-wandering and rumination as forms of spontaneous thought. Both can occur automatically, disrupting ongoing thought processes and leading to off-task behaviors. While mind-wandering may facilitate mental flexibility and adaptive responding to a dynamically shifting problem-space, rumination, particularly the reflective subtype, may open the way to a more considered appreciation of long-standing, entrenched problems. Consistent with this view, rumination has recently been associated with an adaptive and intentional reprocessing of events (Fawcett et al., 2015).

This association between mind-wandering and rumination as forms of spontaneous thought may also be observed at a neural level. The mental flexibility linked to mind-wandering is associated with efficient coupling and decoupling of the default and frontoparietal control networks (Andrews-Hanna, Smallwood, & Spreng, 2014). In contrast, rumination, which has been linked with cognitive rigidity, has been associated with greater coupling of the default and salience networks (Carew, Miline, Tatham, MacQueen, & Hall, 2013). Critically, both the frontoparietal and salience networks are associated with shifting between internal and external foci of attention (Goulden et al., 2014; Spreng et al., 2013). This suggests that inefficient network coupling may lead to increased DN activity and the intrusion of off-task thoughts, whether brief wanderings or more protracted ruminations, into ongoing, goal-directed cognition.

These network interactions have recently been synthesized in a proposed model for spontaneous thought, put forward by Christoff and colleagues (2016). In it, the authors argue that mind-wandering arises as a result of differential variability and constraint between sensorimotor areas as well as dorsal attention, frontoparietal, salience, and default networks. In particular, variability within the medial temporal lobe (MTL)–centered subsystem of the DN may generate spontaneous thought, which is then automatically constrained by the core component of DN and the SN to personally relevant concerns. When mind-wandering occurs, the frontoparietal control network can shift internal attention to impose deliberate constraints on the flow of spontaneous thought, thus ending the mind-wandering episode. We propose that rumination may emerge from the mechanisms outlined in this model but with an inefficient engagement of the frontoparietal control network to shift internal attention. Instead, the tight coupling of the salience and default networks yields a "sticky" pattern of highly self-relevant thought from which an individual is unable to shift internal attention.

Considering these similarities between rumination and mind-wandering as manifestations of spontaneously occurring thought—at the level of the brain and behavior—we therefore propose that rumination should be considered as a more protracted or "sticky" form of mind-wandering and spontaneous thought. Seen through this lens, the mental eddy currents of rumination emerge as spontaneous thoughts that become mired in affectively salient and entrenched problems. In this way, it is the content and context of spontaneous thought that delineate mind-wandering and rumination. If correct, this reconceptualization of rumination as a protracted form of mind-wandering and spontaneous cognition may open new paths for identifying novel diagnostic markers and intervention strategies to mitigate the negative functional impacts of ruminative thought.

Future Directions

Future investigations of rumination, utilizing this framework of spontaneous thought, will be important in guiding the development of new interventions to attenuate ongoing depressive rumination. The role of mindfulness meditation in reducing depressive rumination has shown some promise (van Vugt, Hitchcock, Shahar, & Britton, 2012). There is also evidence that distraction-based interventions may be helpful (Hilt & Pollak, 2012), though the extent to which this is true may vary with the novelty of the distractor (Bar, 2009). Transcranial direct current stimulation has also been examined in decreasing both mind-wandering (Kajimura & Nomura, 2015) and rumination (Vanderhasselt et al., 2015), providing further support that these processes may share a common neural substrate.

In sum, rumination, long recognized as a cognitive bias in psychopathology, may also be a more protracted mode of spontaneous thought, perhaps reflecting altered interactivity between large-scale neural networks. Clear challenges lie ahead in the development of paradigms to more reliably probe aspects of rumination and its associated neural substrates. Doing so, however, will open the way for more effective treatments and provide a novel lens through which to study the cognitive, affective, and neural basis of spontaneous thought.

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CHAPTER

37 Pain and Spontaneous Thought

Aaron Kucyi

Abstract

Pain is among the most salient of experiences, while also, curiously, being among the most malleable. A large body of research has revealed that a multitude of explicit strategies can be used to effectively alter the attention-demanding quality of acute and chronic pains and their associated neural correlates. However, thoughts that are spontaneous, rather than actively generated, are common in daily life, and so attention to pain can often temporally fluctuate because of ongoing self-generated experiences. Classic pain theories have largely neglected to account for unconstrained fluctuations in cognition, but new studies have demonstrated the behavioral relevance, putative neural basis, and individual variability of interactions between pain and spontaneous thoughts. This chapter reviews behavioral studies of ongoing fluctuations in attention to pain, studies of the neural basis of spontaneous mind-wandering away from pain, and the clinical implications of this research.

Key Words: pain, acute pain, chronic pain, cognition, behavioral, spontaneous thought, mind-wandering

Pain is among the most salient of experiences, while also, curiously, being among the most malleable. Although pain signals danger and thus demands attention, a simple difference in context or framing can drastically change the experience. Someone who is undergoing a tongue piercing can experience increased pain if focusing on the fear of further injury, or can have decreased pain if being distracted by the calming remarks of a friend or if musing about the desired aesthetic effect. The past few decades of research have revealed that a multitude of explicit strategies can be used to effectively alter the attention-demanding quality of pain (reviewed by Eccleston & Crombez, 1999; Seminowicz & Davis, 2007; Torta, Legrain, Mouraux & Valentini, 2017; Wiech, 2016). Modern electrophysiology and functional neuroimaging studies have revealed how placebo analgesia, active distraction, reappraisal, anticipation, and mood manipulation modify the activity of brain networks that respond during pain (reviewed by Wiech, Ploner, & Tracey, 2008).

An overwhelming proportion of studies on pain-attention interactions involve either an intervention to explicitly manipulate the cognitive state or an instruction requiring an individual to actively control or distract from pain. In naturalistic settings, however, attention to acute and chronic pain can often fluctuate because of ongoing spontaneous thoughts. Whether a person's thought contents during a tongue piercing procedure are focused on negative or positive aspects of the procedure, or are completely unrelated, may not be under her active control and may not even be directly influenced by the present sensory environment. While classic pain theories have largely neglected to account for such unconstrained fluctuations in cognition, spontaneous thoughts are a defining part of daily life—as illustrated throughout this *Handbook*—that must be included in any comprehensive, ecologically valid description of the pain experience (reviewed by Kucyi & Davis, 2015, 2016). The contents of spontaneous thoughts are also critical to consider clinically in acute and chronic pain. In this chapter, I review behavioral studies of ongoing fluctuations in attention to pain, studies of the neural basis of spontaneous mind-wandering away from pain, and the clinical implications of this research.

Spontaneous Attentional Fluctuations and Pain

Pain is an unpleasant sensory and emotional experience that can be measured only by self-report. Advances in functional neuroimaging allow prediction of self-reported acute pain states with greater than 90% accuracy under certain contexts (Wager et al., 2013; Woo et al., 2017). Importantly, these applications rely on comparison with self-report as the gold-standard measure, and there is currently no validated technology that can objectively confirm or rule out the presence of pain (reviewed by Davis, Kucyi, & Moayedi, 2015). Reliance on self-report, however, has several shortcomings and may be inadequate for fully capturing all aspects of the pain experience (reviewed by Wager & Atlas, 2013).

When assessing pain-attention interactions, one major issue is that being asked to rate pain inherently biases attention toward that pain. In daily life, attention may naturally wax and wane. Pain qualities cannot be reported on in a valid manner during moments when attention is on something other than pain. Indeed, people experiencing prolonged pain may not commonly be in states in which attention is fully engaged with features such as the exact current intensity or unpleasantness of pain.

One way to study how attention to pain naturally varies over time is to use the experience-sampling approach. This method, in which people are probed at random intervals about their attention, is similar to that often used in the study of spontaneous thought (reviewed by Smallwood & Schooler, 2006). In a handful of studies, experience sampling has been used in patients with chronic pain, who were probed about their level of attention to pain (e.g., rating the statement "Right now, I am focusing on my pain") at random intervals during daily life (Crombez, Viane, Eccleston, Devulder, & Goubert, 2013; Peters & Crombez, 2007; Roelofs, Peters, Patijn, Schouten, & Vlaeyen, 2004; Viane, Crombez, Eccleston, Devulder, De Corte, 2004). These studies confirm that attention to pain varies naturally over time, and that some patients tend to attend away from pain more than others. However, it has not been fully determined whether attention away from pain is typically due to spontaneous thought or to other distractors (e.g., externally driven events). Given that mind-wandering occurs frequently in everyday waking life (Kane et al., 2007), it is likely that spontaneous thoughts commonly drive attention away from pain in daily life, and that the content and frequency of these thoughts vary both within and across individuals.

While interactions of spontaneous thought with chronic pain remain to be characterized, significant advances have been made in the study of acute pain. In research that combined painful stimulation, experience sampling, and neuroimaging, 51 healthy adults were asked after several 20-second trials of painful (transcutaneous electrical) stimulation whether their attention had just been on pain or on something else (Kucyi, Salomons, & Davis, 2013). Although stimulus intensity was kept constant to evoke a predetermined pain intensity level, the degree of self-reported attention varied across trials. At the group level, subjects reported on average that thoughts away from pain were mostly due to mind-wandering (i.e., thoughts completely unrelated to the stimulus or other features of the present sensory environment), but sometimes attention away from pain was due to distinct factors such as external distractions (e.g., hearing sounds). Importantly, subjects were tested with this experience-sampling paradigm on two separate days, and the degree of self-reported attention away from pain was highly consistent between sessions, suggesting that people may have trait-like tendencies that predispose them either to attend to pain or instead to become immersed in spontaneous thoughts.

Supporting this idea of trait-like tendencies, in a separate, demanding cognitive task (without experience sampling), individual differences in self-reported mind-wandering away from pain (as previously recorded with experience sampling) were predictive of the effect of pain on behavior. Specifically, reaction time showed greater slowing in the presence of pain in subjects who had reported more attention to pain (Kucyi et al., 2013). This behavioral link, together with brain activity measurements (described in the following), was critical to validating the self-reports obtained with experience sampling.

Neural Basis of Mind-Wandering Away from Pain

The relationship between brain activity and spontaneous thought during painful stimulation must be interpreted in light of what is currently known about pain- and attention-related brain networks. Critically, nociceptive signals in the peripheral nervous system (the sensory response to harmful or potentially harmful stimuli) do not always result in pain (Melzack & Wall, 1965). Pain arises from a specific pattern of dynamic brain activity that may sometimes get engaged, and may at other times not get engaged, by the same input stimulus (reviewed by Kucyi & Davis, 2015). When engaged, ascending spinal cord and brainstem pathways send signals to several regions within the cerebral cortex (including insula, somatosensory cortex, and cingulate cortex) (Apkarian, Bushnell, Treede, & Zubieta, 2005) that are thought to reflect the characteristic sensory, cognitive-affective, and motivational aspects of pain perception (Melzack & Casey, 1968). When not engaged, a separate system known as the descending pain modulatory system (or antinociceptive system) is likely to be at play. This descending system, first characterized in animal models (reviewed by Basbaum & Fields, 1984) and now with supporting evidence from human functional neuroimaging studies (reviewed by Tracey & Mantyh, 2007), is thought to include specific areas within the cerebral cortex (including prefrontal subregions) that project to key brainstem nodes (periaqueductal gray [PAG] and rostroventral medulla) that inhibit incoming nociceptive input from the spinal cord.

Importantly, modern neuroimaging has revealed pain-related networks that may be preferentially involved in attentional aspects of pain. The salience network (Seeley et al., 2007), a bilateral system including the anterior insula and an anterior part of the temporoparietal junction, is activated with general, salient changes in the environment arising from any input modality, including pain (Downar, Crawley, Mikulis, Davis, 2000; Downar, Mikulis, & Davis, 2003), and some subregions of this network show greater within-network connectivity for right- compared to left-hemisphere homologous regions (Kucyi, Hodaie, & Davis, 2012a; Kucyi, Moayedi, Weissman-Fogel, Hodaie, & Davis, 2012b). Attentional modulation of pain through active distraction has been shown to decrease activity in areas within the salience network and to engage the descending pain modulatory system (reviewed by Seminowicz & Davis, 2007; Kucyi & Davis, 2015). Another system known as the default mode network (DMN), which generally deactivates when attention is directed to the external environment (Raichle et al., 2001), is typically deactivated during pain (Coghill et al., 1994; Loggia et al., 2012). A highly consistent effect in functional magnetic resonance imaging (fMRI) studies is that the DMN shows increased activation during self-reported mind-wandering (Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015), although recent studies have revealed a non-exclusive role in self-reported mind-wandering and potential importance to other aspects of attention (Crittenden, Mitchell, & Duncan, 2015; Kucyi, Esterman, Riley, & Valera, 2016a).

When healthy adults performed experience sampling during fMRI with noxious stimulation, several patterns of state-related activity were found in pain- and attention-related networks (Kucyi et al., 2013) (summarized in Figure 37.1). First, self-reported attention to pain was associated with greater activation within right hemisphere areas of the salience network (particularly the anterior insula, dorsolateral prefrontal subregions, and temporoparietal junction), as well as regions implicated in a distinct "frontoparietal control network" (anterior intraparietal sulcus, dorsolateral prefrontal subregions). The engagement of salience network regions, particularly those in the right hemisphere, during sustained attention to pain is consistent with previous work (Downar et al., 2003) and with the notion that the automatic, attention-demanding quality of pain is reflected in this network. While more speculative, the activity of regions in the frontoparietal control network could reflect a "high-jacking" via interactions with active regions of the salience network to impair the ability to shift away from pain.

A second finding was that self-reported attention away from pain was associated with lesser deactivation of the DMN, including the medial prefrontal cortex (mPFC) and posterior cingulate cortex (PCC)/retrosplenial cortex, as well as areas within the medial temporal lobe and dorsomedial prefrontal DMN subsystems. The subjects who reported that their attention away from pain was due to a high degree of mind-wandering (as opposed to external distraction) showed the greatest decrease of DMN deactivation. Finally, during self-reported attention away from pain, there was also increased functional connectivity (greater correlation of signals) between the PAG, a key node of the descending pain modulatory system, and core areas of the DMN (including mPFC, PCC, and retrosplenial cortex). The change in PAG-DMN coupling occurred over-and-above regional (de)activation effects, thus highlighting the important role of inter-regional interactions in mind-wandering (see also Kucyi, 2017).

Further insights came from study of individually varying tendencies in relation to brain structural and functional connectivity (Kucyi et al., 2013).

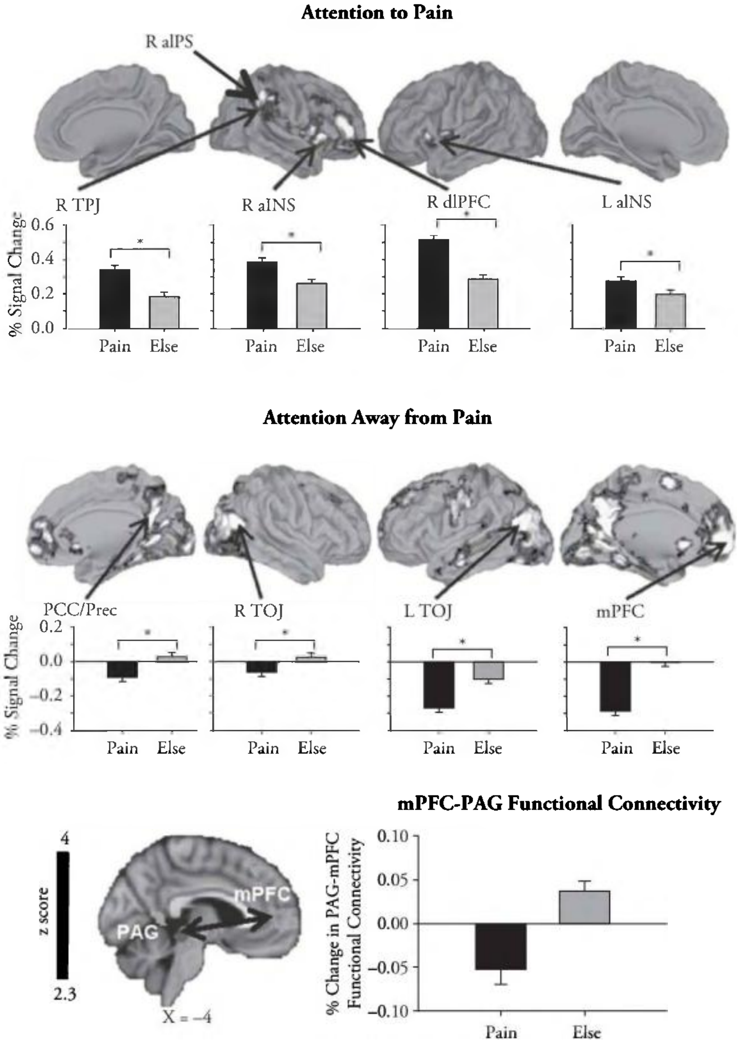

Figure 37.1. (See Color Insert) Brain dynamics of self-reported attention to and spontaneous mind-wandering from pain. Brain regions within salience and frontoparietal networks show increased activation during attention to pain, compared to attention away from pain (top). During attention away from compared to toward pain, brain regions in the default mode network show decreased deactivation (middle) and the periaqueductal gray shows increased functional connectivity with the medial prefrontal node of the default mode network. aINS = anterior insula; aIPS = anterior intraparietal sulcus; mPFC = medial prefrontal cortex; dmPFC = dorsomedial prefrontal cortex; dlPFC = dorsolateral prefrontal cortex; MTL = medial temporal lobe; mPFC = medial prefrontal cortex; PAG = periaqueductal gray; PCC = posterior cingulate cortex; Prec = precuneus; TOJ = temporo-occipital junction; TPJ = temporoparietal junction. Adapted with permission from Kucyi et al. (2013).

An analysis of diffusion MRI data revealed that individuals who reported more frequent attention away from pain were found to have higher fractional anisotropy (a measure potentially indicating stronger, or more intact, structural connectivity; Johansen-Berg & Rushworth, 2009) in the pathway between the mPFC (within DMN) and PAG. Additionally, the spontaneous activity between these same two regions during approximately nine minutes of wakeful rest was similarly related to individual differences. Subjects who reported more frequent attention away from pain had greater functional connectivity variability (possibly indicating more dynamic communication) between the mPFC and PAG (Kucyi et al., 2013). Spontaneous resting-state functional connectivity on the timescale of minutes is well known to be largely reflective of intrinsic, individual-specific functional anatomy (reviewed by Buckner, Krienen, & Yeo, 2013), and so these findings further support the idea of a trait-like nature of the tendency to mind-wander from pain (Kucyi et al., 2013). Taken together, the work suggests that brain activity underlying mind-wandering away from pain may share some similarities with active distraction from pain (e.g., decreased salience network activity), but that idiosyncrasies are also likely (e.g., decreased DMN deactivation and interaction with the descending pain modulatory system).

The study of the neural basis of mind-wandering and pain is in its infancy, and several caveats of the described neuroimaging findings should be considered. Perhaps most critically, to classify a neural process as truly antinociceptive, it is necessary to establish that the process underlies decreased pain. When measuring self-reported attention with experience sampling, pain ratings cannot be taken together with attention ratings. Possible interference with spontaneous attentional fluctuations may occur, and the validity of such ratings when attention is away from pain would be questionable. Thus, independent experiments, or a different paradigm, would be needed to confirm that mind-wandering away from pain involves antinociception (cf. Krakauer, Ghazanfar, Gomez-Marin, MacIver, & Poeppel, 2017). Further experiments are also needed to determine the neural correlates of different types of spontaneous thoughts (e.g., past- versus future-related, positive versus negative emotional content, etc.). Another critical question for future research is whether altered communication occurs between the DMN and antinociceptive system during all mind-wandering (i.e., away from any sensory modality), or specifically during mind-wandering away from pain.

Although studies in non-human animals can help to provide insights when generating hypotheses, the nuanced self-reports needed to measure interactions between spontaneous thought and pain limit direct studies of the underlying physiological processes to humans—and thus, mainly to non-invasive neuroimaging modalities with limited spatial and temporal resolution. Invasive studies of structural connectivity in non-human primates provide support for plausible direct neuroanatomical pathways underlying the human findings that emphasize a role of connectivity between DMN areas and the PAG. Evidence indicates that areas within mPFC and within retrosplenial cortex have efferent connections to the PAG (An, Bandler, Ongur, & Price, 1998; Parvizi, Van Hoesen, Buckwalter, & Damasiom, 2006).

Further evidence is needed to demonstrate that the full antinociceptive system (beyond PAG; see model in Figure 37.1) is spontaneously engaged during mind-wandering away from pain. Key brainstem and spinal cord nuclei within the antinociceptive system are relatively small in size (sometimes below the scale of millimeters) and are difficult to study with fMRI due to technical limitations. Complicating matters, the PAG is composed of several subregions with distinct connectivity and function (Coulombe, Erpelding, Kucyi, & Davis, 2016; Linnman, Moulton, Barmettler, Becerra, & Borsook, 2012). Recently, advances with relatively high-resolution human spinal cord fMRI have allowed detection of the modulation of nociceptive signals in placebo analgesia (Eippert, Finsterbusch, Bingel, & Buchel, 2009), nocebo hyperalgesia, and active distraction from pain (Sprenger et al., 2012). The applications of spinal cord functional imaging and high-resolution brainstem imaging could be fruitful in the study of the antinociceptive system during paradigms involving measures of both pain and spontaneous thought.

Finally, the neurochemical basis, electrophysiological dynamics, and causal neural circuitry of mind-wandering away from pain remain unknown. The PAG is rich in opiate-containing neurons that mediate endogenous functions of the antinociceptive system (reviewed by Millan, 2002), and further studies could provide insight into whether fluctuations within the opioidergic system co-occur with spontaneous thought in the context of pain. Feedforward and feedback communication cannot be determined from fMRI changes, whereas frequency-specific signals from electrophysiological measurements could give mechanistic clues pointing toward the nature of dynamics within the salience network and DMN during mind-wandering away from pain (reviewed by Ploner, Sorg, & Gross, 2017). Interventions that involve perturbation of activity within these networks, for example with electrical brain stimulation, could be critical to establishing the causal roles of various structures in spontaneous levels of attention to pain. In summary, findings to date provide a platform for testable hypotheses regarding detailed neural mechanisms of interactions between pain and spontaneous thought.

Clinical Implications

Although not often explicitly considered within clinical contexts, a close look at the pain field reveals that clinicians and researchers widely recognize the potentially important role of spontaneous thought in coping with chronic pain. Commonly used clinical scales include inquiries about the temporal fluctuations of pain (e.g., the McGill Pain Questionnaire

[Melzack, 1975] and painDETECT [Freynhagen, Baron, Gockel, & Tolle, 2006]), including some scales that directly inquire about how pain tends to intrinsically capture attention. The Pain Catastrophizing Scale (Sullivan, Bishop, & Pivik, 1995) includes a subscale on rumination about pain, defined as perseverative negative thinking about pain and its possible causes or consequences (i.e., a lack of spontaneity in thought [Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016]; see also DuPre and Spreng, Chapter 36 in this volume). The Pain Vigilance and Awareness Questionnaire (McCracken, 1997) and Experience of Cognitive Intrusion of Pain scale (Attridge, Crombez, Van Ryckeghem, Keogh, & Eccleston, 2015) include probes about the tendency to attend to or mind-wander away from pain. Spontaneous thoughts are predominantly accompanied by positive or neutral affect (at least in healthy populations; see Fox, Thompson, Andrews-Hanna, & Christoff, 2014) and thus could be protective against negative emotions commonly associated with rumination about and excessive attention to pain.

Individual variability in rumination about chronic pain has been studied both behaviorally and at the neural level. Studies of chronic pain populations have revealed that patients with a greater tendency to ruminate about pain tend to experience a greater level of pain and have poorer clinical outcomes (Buenaver et al., 2012; Sullivan, Bishop, & Pivik, 2002; Van Damme, Crombez, Bijttebier, Goubert, & Van Houdenhove, 2002). In chronic pain patients with temporomandibular disorder, enhanced resting-state functional connectivity within the DMN was associated with greater rumination about pain (Kucyi et al., 2014). The same study also found a positive correlation between rumination and functional connectivity between the mPFC and PAG areas (among others) (Kucyi et al., 2014). This could suggest a compensatory mechanism, given that mPFC-PAG functional connectivity increases during mind-wandering away from pain (Kucyi et al., 2013). While intriguing, such findings should be replicated and further extended in independent cohorts and in other chronic pain populations.

A theme in this chapter has been that the tendency to attend to spontaneous thoughts in the presence of nociceptive input may be a trait-like quality. However, an important, unanswered question concerns whether trainable cognitive states could allow patients to overcome excessive attention to pain in tandem with reorganization of brain structure and function. There has been considerable recent progress in development of and research on mindfulness meditation-based training for chronic pain, in which patients are encouraged to attend to and accept sensory (but not affective) aspects of their pain from a non-evaluative standpoint (reviewed by Zeidan & Vago, 2016). While mindfulness is thus proposed to work therapeutically via a specific form of *enhanced* attention to pain, there is currently no comparable, established behavioral treatment that specifically focuses on *reducing* attention to pain (e.g., increasing spontaneous thoughts away from pain and/or reducing rumination about pain). If an intervention could reliably increase levels of mind-wandering away from pain, a testable hypothesis would be that such a therapy is effective in patients who may not benefit from mindfulness.

The practice of cognitive-behavioral therapy (CBT) for pain, a structured psychotherapeutic approach, involves training patients to actively control their pain and the associated negative affect (Thorn, 2004; Turk, Meichenbaum, & Genest, 1983). A goal of this approach is to get learned coping strategies to trickle into everyday spontaneous coping. Potential effects on the tendency to mind-wander from pain could be considered in future studies as a clinical outcome measure. Interestingly, cognitive-behavioral training has been shown to alter DMN resting connectivity, as well as DMN deactivation during acute pain (Kucyi, Salomons, & Davis, 2016b). Also, in chronic pain, CBT led to increased resting connectivity between DMN areas and the PAG (among additional effects in other networks) (Shpaner et al., 2014). These neural changes in brain systems relevant to spontaneous pain-attention interactions suggest that CBT could influence the tendency to mind-wander, but independent studies directly testing this hypothesis are needed.

Uncovering the brain mechanisms of spontaneous thought in the context of chronic pain could inform the development of neurorehabilitation strategies. Based on available data in acute pain and preliminary findings in chronic pain, pathways between the DMN and descending pain modulatory system (e.g., between mPFC and PAG) could represent potential neuromodulatory targets for alleviating excessive attention to and rumination about pain. However, the causal roles of these pathways in spontaneous pain-attention interactions and the potential importance of broader networks associated with these pathways have not yet been clarified. It also remains to be seen whether the brain dynamics of mind-wandering away from acute pain are representative of what occurs in chronic pain. Thus, any development of a relevant, potentially effective therapy must be informed by detailed future studies with a specific focus on the qualities of spontaneous thought, and associated brain mechanisms, in patients with chronic pain.

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CHAPTER

38 Spontaneous Thought in Contemplative Traditions

Halvor Eifring

Abstract

For more than two millennia, contemplative traditions across the Eurasian continent have seen spontaneous thought as a distraction that binds the devout to the phenomenal world, clogs the gateway to fundamental aspects of reality, and is used by demons to tempt the pious away from their prayer or meditation. At the same time, many traditions have believed the fruits of contemplative practice to come about spontaneously, rather than as a result of deliberate effort, and they have treated certain aspects of spontaneous thought as helping the process forward. Various traditions have recommended different approaches to spontaneous thought, including active suppression, mindful observation, harmonious regulation, reluctant or wholehearted acceptance, and either gently or forcefully turning one's attention to the object of meditation or prayer. Specific antidotes have included the recital of sacred texts or mantras, as well as the performance of good deeds, ascetic exercises, or rituals of repentance and confession.

Key Words: contemplation, Eurasia, spontaneous thought, meditation, prayer, mantra

Long before the rise of modern psychology and literary modernism, the many contemplative traditions of the Eurasian continent vehemently debated the nature of spontaneous thought and the various ways to deal with it. This chapter focuses on mind-wandering and other forms of spontaneous thought occurring during wakefulness; dreams, though of great interest, are often treated differently and will not be discussed here.

This chapter covers several contemplative traditions, in particular Christian mysticism, Yoga, Mahāyāna Buddhism, and early Chinese thought. All of these traditions focus on practice, not just philosophical understanding. They tend to be concerned with meditation and prayer, ritual, and worship, as well as various forms of asceticism, withdrawal, and moral behaviour. The typical purpose is to approach and integrate into one's life the most fundamental aspects of existence, whether these are conceived of as belonging to God, the Self, Buddhahood, or the Way.

As we shall see, contemplatives often view mind-wandering and other forms of spontaneous thought as distractions, disturbances, and obstacles, sometimes believed to come from demons or the Devil. On the other hand, they often see the results of contemplative practice as depending on spontaneous impulses beyond human control, sometimes in the form of fortuitous and inspirational constellations within mind and body, at other times externalized as the grace of God or aid offered by angels, deities, or buddhas. The attitude toward spontaneous processes, therefore, is often ambivalent and full of contradictions.

Most contemplative traditions exist to this day in only slightly modernized form. Even more popular, however, are meditation practices that have been pulled out of their original religious contexts and are taught within secular and science-oriented settings, most notably non-directive meditation and mindfulness meditation. The former includes Transcendental Meditation, Acem Meditation, Relaxation Response, and Clinically Standardized Meditation, all of which involve the gentle repetition of a meditation sound while both peripheral and digressive thought are given full freedom. The latter includes a number of breath- and body-based practices conveniently divided into Focused Attention, which typically aims to minimize both peripheral and digressive thought, and Open Monitoring, which deliberately directs the attention toward aspects of spontaneous thought. While modern meditation practices and their neural correlates are discussed in more detail in Hasenkamp's Chapter 39 in this volume, this chapter will focus on the extended historical context of contemplative traditions.

The cultural history of spontaneous thought is not yet well studied (see Pang, Chapter 12 in this volume). The following exposition builds on my own admittedly modest comparative work, partly presented in Eifring (2015), and the work by other scholars on individual contemplative traditions.

Concepts

The various contemplative traditions conceptualize spontaneous thought in different ways. None of the relevant concepts corresponds exactly to any modern notion of "spontaneous thought" or "mind-wandering." There is, however, sufficient overlap to justify comparison between the various traditions, as well as between the traditional and the modern material.

The early Christian understanding of spontaneous thought centers on three Greek terms: *logismoi*, *pathos*, and *fantasia*. The first of these is the plural form of *logismos* ("thinking; reasoning; calculation"), and may denote both spontaneous and deliberate thinking. The famous desert ascetic Evagrius Ponticus (ca. 345–399) is the one who begins to use the term consistently to refer to the thoughts (including feelings and images) that spontaneously enter into the mind during prayer or other ascetic practices.[1] He and other early Christian mystics relate it to *pathos* ("passion"), which denotes "an experience undergone passively; hence an appetite or impulse such as anger, desire or jealousy, that violently dominates the soul"[2] and thus explicitly refers to spontaneous impulses. The Christians and the slightly earlier Neo-Platonists of Late Antiquity inherited the ideal of *apatheia* ("dispassion") from the Stoics, not necessarily implying a lack of passion (and not "apathy" in its modern sense), but a detached or "pure" way of relating to passion.[3] The term *fantasia* ("fantasy; imagination") resembles some terms in modern cognitive science in specifically referring to mental images that are "spontaneous," "task-unrelated," and "stimulus-independent," but is primarily concerned with experiences during contemplative prayer, not everyday life. It typically refers to images produced by the mind, or emerging from the subconscious, as the contemplative process deepens and the impact of external sensations and ordinary thoughts is reduced.[4]

In the Yoga tradition, based on the second-century *Yoga Sūtra*, one of the most famous concepts is the technical term *citta-vṛtti* ("fluctuations of the mind"). While clearly relevant, this term provides less of a concrete reference to specific spontaneous thoughts and more of an abstract philosophical concept covering *all* mental states and processes, which the contemplative process is expected to bring to rest. Only slightly more specific and concrete is *citta-vikṣepa* ("distractions of the mind"), which again is a technical term referring widely to all things that are thought of as afflictions (*kleśa*) or disturbances (*antarāya*) for the contemplative process—in other words, mental factors that activate the fluctuations of the mind rather than bringing them to rest. In contrast, the three successive stages of focused concentration and meditative absorption called *dhāraṇā*, *dhyāna*, and *samādhi* all refer to states in which these fluctuations have been brought to rest. As in the early Christian tradition, this presupposes dispassion, called *vairāgya*, derived from the term *rāga* ("passion"; literally, "color"), which is perhaps the closest we get to a concrete and specific term for spontaneous thought or mind-wandering in the Yogic material.[5]

In the Chinese version of Mahāyāna Buddhism, spontaneous thought is often referred to by the term *niàn* 念, which is inherited from a Classical Chinese verb meaning "to bear in mind; to remember" and is used in Buddhist contexts to translate the Sanskrit nouns *smṛti* ("mindfulness; remembrance") and *kṣaṇa* ("moment of time; thought-moment").[6] The frequent reference to spontaneous thought is based on the latter meaning. It often occurs in compounds, such as *wàng-niàn* 妄念 ("deluded thoughts"), *zá-niàn* 雜念 ("diverse thoughts"), and *wàn-niàn* 萬念 ("myriad thoughts"); these are sometimes contrasted with *zhèng-niàn* 正念 ("right mindfulness"; from the former meaning). Another compound frequently used to refer to spontaneous thought is *wàng-xiǎng* 妄想 ("deluded thoughts"), the Classical Chinese verb *xiǎng* 想 ("to think") being used in Buddhist terminology to translate the Sanskrit noun *saṃjñā* ("conceptualization;

ideation"), referring to how ideas regarding shape, color, length, pleasure and pain, and so on, are brought together and associated with an object.[7] Technically, neither *niàn* nor *xiǎng* refers specifically to spontaneous thought; *wàng-xiǎng* includes any kind of "deluded conceptualization," and *wàng-niàn* any kind of "deluded thought," whether spontaneous or actively produced. In many texts, however, both terms are almost exclusively used to refer to spontaneous thought and mind-wandering.

In the writings of pre-imperial (and pre-Buddhist) China (before 221 BCE), the closest we come to notions of spontaneous thought is a number of fixed or semi-fixed lists of natural emotions, such as

> *xǐ nù āi lè* 喜怒哀樂
>
> "joy and anger, sadness and pleasure"
>
> *xǐ nù yōu huàn* 喜怒憂患
>
> "joy and anger, worry and vexation"
>
> *yōu lè xǐ nù yù lì*憂樂喜怒欲利
>
> "worry and pleasure, joy and anger, desire and profit-seeking"

The first of these survives as a current phrase even in Modern Chinese. Toward the end of the pre-imperial period, such lists begin to be associated with the notion of *qíng* 情 ("inborn response"), which gradually acquires the meaning "emotion," and which is closely connected to the notion of *xìng* 性 ("human nature"). Both *qíng* and especially *xìng* had been part of the philosophical debate for a couple of centuries before this, and they remained so throughout the more than two millennia-long imperial period. The treatment of emotions plays a central role in both the Confucian and Daoist forms of self-cultivation.

Thoughts as Digressions

Contemplative traditions differ from each other in their practices, concepts, and underlying worldviews, and these differences are reflected in their attitudes toward spontaneous thought. Despite all the differences, however, the various traditions have surprisingly much in common.

First of all, almost all contemplative traditions display a skeptical attitude toward spontaneous thought. Contemplative texts from different historical periods and various cultural backgrounds often describe in detail the struggle to achieve a mind without thoughts.

This skepticism is partly related to the frustrations felt by anyone who has tried and failed to concentrate on a task. The contemplative process is typically linked to a high degree of absorption and single-mindedness, and digressions or distractions are easily perceived as running counter to this process. When the mind begins to wander, it is brought away from its intended contemplative focus.

For instance, the notion of "undistracted prayer" repeatedly used by Evagrius Ponticus and other early Christians partly builds on this view of spontaneous thought. So does the notion of *yī xīn niàn fó* 一心念佛 ("wholeheartedly recite the name of the buddha") in Chinese Pure Land Buddhism.

Thoughts as Phenomena

The skeptical attitude toward spontaneous thought is also linked to a dichotomy that is widespread within contemplative traditions, though hardly present in the modern scientific discourse on mind-wandering. In contrast to the Cartesian distinction between mind and body (or spirit and matter), contemplative traditions typically see mind and body as belonging on the same side of a more fundamental distinction between what we might call, for lack of a better term, the phenomenal and the non-phenomenal aspects of reality.

Along with the body and the senses, thoughts, feelings, and fantasies belong to the phenomenal realm and are often seen as keeping the mind from entering the non-phenomenal domain to which contemplatives aspire. In widely different contemplative traditions, this more fundamental aspect of existence is frequently declared to be ineffable and is described as being beyond the senses and beyond conception, emotion, and imagination. Cultural historians debate to what extent the descriptions of different traditions actually refer to the same underlying reality, as the perennialists would argue, or to different cultural creations, as the cultural constructivists insist.[8]

Variants of this dichotomy are found in all the contemplative traditions under discussion, whether they are classified as dualist (Christianity and Yoga), non-dualist (Mahāyāna Buddhism), or squarely monist (Daoism). The skepticism toward mind-wandering and spontaneous thought in these traditions is often implicitly or explicitly linked to this dichotomy. In Christian mysticism, the dichotomy is conceptualized as an opposition between the uncreated (= God) and the created (= God's creation), as when Evagrius Ponticus says that "though . . . contemplation [of inner essences] is dispassionate, yet since it is of created things, it impresses their forms upon the intellect and keeps it away from God,"[9] or when the fourteenth-century English work *The Cloud of Unknowing* urges the contemplative to hide all creation under a cloud of forgetting "whether you think of [the creatures] as physical or spiritual beings, or of their states or actions, or of their goodness or badness."[10] In Yoga, a similar distinction holds between *puruṣa* (the ultimate Self) and *prakṛti* (the material world), since Yoga "regard[s] not just the physical body but also the mind, ego, and all cognitive functions as belonging to the realm of inert matter."[11] Mahāyāna Buddhism rejects, in theory, all forms of duality, but in practice often displays a keen concern with the contrast between "emptiness" (Chinese *kōng* 空; Sanskrit *śūnyatā*) and the five "aggregates" (Chinese *yùn* 蘊; Sanskrit *skandha*), and although "emptiness" is a metaphysical term denoting the absence of a perdurable self or an intrinsic nature of all things, the term is often used quite concretely to refer to a mind that is empty of thoughts.[12] In Daoist thinking, the Way (Chinese *dào* 道) is an overarching metaphysical principle that permeates everything as part of a monist worldview. Even so, Daoist texts often display a clear dichotomy between this principle and all other forms of existence, including spontaneous thoughts and impulses. In the attempt to realize the Way, the natural emotions included in the semi-fixed lists mentioned in the preceding are often seen as keeping the mind away from it.[13]

Thoughts as Obstructions

The role of mind-wandering and spontaneous thought within the distinction between phenomenal and non-phenomenal aspects of reality is, however, quite complex. The fact is that *everything* we see, hear, or feel belongs to the phenomenal realm. And while some contemplative traditions advocate a certain degree of withdrawal from the outer world, there is no expectation that the material world, or even the individual body, will disappear. Thoughts are a different matter, as shown by the widespread thirst for thoughtlessness.

So why are mind-wandering and spontaneous thought regarded as particularly problematic? The most plausible answer is that the mind is seen as a gateway to the dimension beyond our worldly reality, in some sense closer to it than other parts of our mundane existence. For this gateway to function, it must be built of subtle material. The continuous stream of spontaneous thought is far from subtle in this sense. It is coarse and therefore threatens to block or clog the gateway.

In fact, most contemplative traditions make distinctions between different kinds of spontaneous thought, of which some are subtler and thus less problematic than others. In Christian mysticism, Evagrius Ponticus distinguishes between angelic, demonic and simply human thoughts. In Yoga, fluctuations of the mind may be either associated with "afflictions" or not (*kliṣṭākliṣṭāḥ*), and karmic imprints (*saṁskāra*) may be either "outgoing" (*vyutthāna*; detrimental) or "restraining" (*nirodha*; conducive). In Daoism, plain emotions are often seen as detrimental,[14] while other mental states, such as tranquillity (*jìng* 靜), calmness (*ān* 安) and stability (*dìng* 定) help the mind in its quest for the Way. The various lists of conducive and detrimental factors, to which we shall return later, point in the same direction. Thus, some forms of spontaneous thought, or states of mind, are conceived of as being subtler and closer to the non-phenomenal realm and therefore more helpful to the contemplative process than plain, coarse mind-wandering. In the end, however, even these belong to the phenomenal realm and need somehow to be transcended.

In a modern reading of Teresa of Ávila (1515–1582), Vilma Seelaus gives a more process-oriented understanding of the impact of spontaneous thought, in her terminology referred to as "distractions in prayer." They are negative in the sense that they temporarily pull the contemplative out of his or her prayers, but positive in the sense of containing important information about areas of the mind in need of further cultivation. "God speaks to us through them, . . . inviting us to greater self-knowledge and to deeper surrender of the mind and heart to God."[15] For instance, the "*anxiety* we experience around fear of losing either possessions or status" tells us that "addictions/attachments still have a strong hold on the psyche."[16] In the end, "to attempt to completely rid oneself of distractions in prayer could prove to be another form of distraction."

Thoughts as Demons

In some traditions, spontaneous thought is linked to demons. This is most obviously the case in the early Christian discourse on prayer and the Buddhist discourse on meditation. Both in Christian prayer and Buddhist meditation, demons are seen as envious beings that cannot stand the sight of a true contemplative, and in order to lure the contemplative over to their side, they typically try to disguise their true identity.

In the Christian case, spontaneous thought is sometimes seen as a means by which demons enter the mind to tempt the contemplative away from his or her pious practice, the way Satan tried to tempt Jesus away from the right path after 40 days of fasting in the wilderness. Evagrius Ponticus makes frequent reference to demons, and all the eight kinds of thought with which he is concerned reflect different kinds of demons. Not all thoughts are demonic, since "the mind itself naturally brings up appearances of created things."[17] As already mentioned, Evagrius distinguishes between "angelic, human and demonic thoughts."[18] However, his writings are clearly much more concerned with demonic thoughts than with either angelic or human ones. The demons make use of thoughts, memories, images, and physical sensations to lure the contemplative away from his enterprise. Although they usually cannot be seen, their presence is often surprisingly physical:

> Some say that the demons set in motion the passion of fornication by fastening on to the bodily members by dreams; and this movement relates defiled fantasies to the mind. But some say that they set in motion the desire by appearing to the mind in shameful forms and lightly touching the members.[19]

Based on the brain theory of Galen, Evagrius held that a demon can "[attach] himself to the area around the brain" and thereby "[manipulate] the light around the mind at will,"[20] making the contemplative falsely believe that the light is divine and that it signals spiritual achievement.

In the Buddhist case, spontaneous thought is taken to be a sign of the presence of demons that need to be dealt with, whether they are seen as products of the mind or as having external and independent existence, or both. The Buddhist demons also have a scriptural basis, as many poetic passages in the early Buddhist Canon relate how the demon Māra tries to tempt the Buddha away from his contemplative goals. Māra is also supposed to have turned himself into a frightening vulture in an unsuccessful attempt to distract Buddha's disciple Ānanda from his meditation.[21]

The highly influential Chinese Buddhist meditation master Zhìyǐ 智顗 (538–597) was deeply concerned with the challenges posed by demons. His early *Small Treatise of Concentration and Insight* (Xiǎo zhǐguān 小止觀) and the later and more comprehensive *Great Treatise of Concentration and Insight* (Móhē zhǐguān 摩訶止觀) both contain a chapter entirely devoted to the problem. We are told how demons appear in a number of different disguises to confuse the contemplative and make him lose his meditative absorption. Their external shapes include those of wild animals, insects, or even parents or siblings, but also various sounds or odors. In the end, however, we are told that the basic problem resides in the mind of the practitioner, not in the demons themselves. The "armies" of the demons include the following aspects of spontaneous thought:[22]

> 1. desire (*yù* 欲), 2. worries (*yōuchóu* 憂愁), 3. hunger and thirst (*jīkě* 飢渴), 4. craving (*kě'ài* 渴愛), 5. sleep (*shuìmián* 睡眠), 6. fear (*bùwèi* 怖畏), 7. doubts and regrets (*yíhuǐ* 疑悔), 8. anger (*chēnhuì* 瞋恚), 9. profit-seeking (*lìyǎng* 利養), 10. arrogance (*zìgāo* 自高).

Significantly, both Jesus and the Buddha met with temptation when they were on the verge of a spiritual breakthrough and, after they had defeated their tempters, went on to gather disciples to whom they preached their message. They had defeated the demonic forces.

Lists of Detrimental Factors

Since contemplative traditions are more concerned with practice than theory, they need to produce knowledge that is easy to remember. One way of ensuring the practical value of their viewpoints is to create mnemonic lists of factors that influence the contemplative process. Many types of spontaneous thought end up on lists of detrimental factors, much like Zhìyǐ's list of demonic thoughts cited in the preceding.

One such list is Evagrius Ponticus's enumeration of "eight kinds of thought":[23]

> 1. *gastrimargia* "gluttony," 2. *porneia* "fornication," 3. *philargyria* "greed," 4. *lypē* "sadness," 5. *orgē* "anger," 6. *akēdia* "listlessness," 7. *kenodoxia* "vainglory," 8. *hyperēphania* "pride."

This list was translated into Latin by Evagrius's disciple John Cassian, after which, a couple of centuries later, Pope Gregory I (ca. 540–604) combined sadness with anger and vainglory with pride, and added envy, resulting in the famous list of "seven deadly sins."

In a similar vein, the Yoga Sūtra provides a list of nine primary and five secondary "disturbances" (*antarāyāḥ*):[24]

> 1. *vyādhi* "disease," 2. *styāna* "idleness," 3. *saṁsaya* "doubt," 4. *pramāda* "carelessness," 5. *ālasya* "sloth," 6. *avirati* "lack of detachment," 7. *bhrānti-darśana* "misapprehension," 8. *alabdha-bhūmikatva* "failure

to attain a base for concentration," 9. *anavasthitatva* "instability."

1. *duḥkha* "suffering," 2. *daurmanasya* "dejection," 3. *aṅgam-ejayatva* "trembling," 4. *śvāsa* "inhalation," 5. *praśvāsa* "exhalation."

It also contains a list of five "afflictions" (*kleśa*):[25]

1. *avidyā* "ignorance," 2. *asmitā* "egotism," 3. *rāga* "desire," 4. *dveṣa* "aversion," 5. *abhiniveśāḥ* "clinging to life."

Most notably, it provides a list of five "fluctuations" (*vṛtti*):[26]

1. *pramāṇa* "right knowledge," 2. *viparyaya* "error," 3. *vikalpa* "imagination," 4. *nidrā* "sleep," 5. *smṛti* "memory."

However, although the fluctuations bind the mind to the wheel of rebirth, they are not always considered detrimental to the contemplative process. The commentaries to the Yoga Sūtra distinguish between subtle fluctuations, associated with the lucid primordial element of *sattva*, and coarse fluctuations, associated with the impassionate *rajas* and the dark *tamas*.[27]

The various lists of emotions from early Chinese texts have already been mentioned. In some texts, these are codified as an inventory of "seven emotions" (*qī qíng*), which becomes a standard term, referring to the following enumeration:

xǐ nù āi jù ài wù yù 喜怒哀懼愛惡欲

"joy and anger, sadness and fear, love, aversion and desire"

The equally old notion of "six desires" (*liù yù*) sounds like a reference to a similar list, but the list itself is nowhere to be found in the early material. While the texts most closely associated with Daoism are often skeptical toward emotions and desires, many of the texts considered Confucian see them as starting points for self-cultivation.

Buddhism contains several different lists of "afflictions" (Sanskrit *kleśa*, Pali *kilesa*). The Theravāda canon, written in Pali, lists ten such afflictions:

1. *lobha* "desire," 2. *dosa* "aversion," 3. *moha* "ignorance," 4. *māna* "pride," 5. *diṭṭhi* "wrong view," 6. *vicikicchā* "doubt," 7. *thīnaṁ* "torpor," 8. *uddhaccaṁ* "restlessness," 9. *ahirikaṁ* "shamelessness," 10. *anottappaṁ* "recklessness."[28]

Of these, the first three are given special prominence as the roots of suffering.

Mahāyāna texts, written in Sanskrit, sometimes list five afflictions:

1. *moha avidya* "ignorance," 2. *rāga* "desire," 3. *dveṣa* "aversion," 4. *māna* "pride," 5. *īrṣyā* "envy."

Other Mahāyāna texts list six afflictions:

1. *rāga* "desire," 2. *pratigha* "anger," 3. *avidya* "ignorance," 4. *māna* "pride," 5. *vicikitsā* "doubt," 6. *dṛṣṭi* "wrong view."

Again, the first three afflictions are seen as the most basic ones. Yet other Buddhist lists include up to 50 afflictions.

There are also several different lists of "five obstacles" (*pañca āvaraṇāni; pañca nivaraṇāni*), of which the following is perhaps the most famous one:[29]

1. *rāga* "desire," 2. *pratigha* "anger," 3. *styāna* "torpor," 4. *auddhatya-kaukṛtya* "restlessness," 5. *vicikitsā* "doubt."

It is not surprising that several lists in Yoga and Buddhism contain many of the same items, since both traditions derive from the same ancient Indian culture. More remarkable is the fact that similar items also occur in Evagrius Ponticus's list. A historical link is possible even here, since Evagrius's writings have been linked to Buddhism,[30] though more plausibly these similarities have to do with the common challenges that contemplatives need to face wherever they are located.

Lists of Conducive Factors

The relationship between spontaneous thought and the contemplative process is sometimes closer and more positive than one would think. We have already seen that Chinese Buddhism uses the same basic term, *niàn* 念, for thoughts considered to be disturbing and for the mindfulness that is considered to be essential for progress on the spiritual path. This term is also used in a third sense—"to recite"—and the recital of the Buddha Amitābha's name (Chinese *Āmítuó Fó*) is a widespread practice not only in the Pure Land school, but throughout East Asian Buddhism. Sometimes the double ambiguity of the term *niàn* is utilized for rhetorical purposes:

> So the Tathāgata teaches people to recite [*niàn*] the phrase Amitābha Buddha, so that they may assimilate all their hundreds or thousands or 850 million scattered thoughts [*niàn*] into mindful absorption [*niàn*], and recite [*niàn*] until not a single thought [*niàn*] arises, and spontaneously get a fully realised view of Amitābha Buddha.[31]

所以如來教人念一句阿彌陀佛，正攝
其百念千念八億五千萬雜念於一念，
念至一念不起，自然證見阿彌陀佛。
然後知一念百念千念八億五千萬雜念皆阿
彌陀佛之念。

In the same vein, we note that Evagrius Ponticus's Greek term *logismoí* is derived from *logos*, which both he and other Christians closely associate with God's inner nature; hence the connotations of the term *logismoí* are far from entirely negative.

As mentioned earlier, contemplative traditions are sometimes explicit in seeing certain aspects of spontaneous thought as conducive to contemplation. The demonic thoughts of early Christian mysticism have their counterpart in angelic thoughts that help the practitioner come closer to God, and both the "fluctuations of the mind" and the "karmic imprints" of the Yoga tradition are sometimes seen as helping, rather than disturbing, the contemplative process. Any attempt at ridding the mind of spontaneous thought, therefore, must not get in the way of such conducive factors.

Some states of mind often seen as conducive or even essential to contemplative practice are typically characterized by the absence of thoughts, images, and disruptive emotions. This includes the widespread focus on "emptiness" or "void," "absorption" or "concentration," "silence" or "stillness," and "tranquillity" or "calm," perhaps even "joy" or "bliss." The texts are often ambiguous as to whether these states are deliberately produced by the person or come about as spontaneous results of contemplative practice.

In the latter case, even these states should be included in a wide definition of "spontaneous thought." This would fit well with the idea that the results of contemplative practice come "without effort," as the grace of God or as a spontaneous response to fortuitous constellations of circumstances inside or outside the person. Contemplative practice may increase the chances of this happening, but does not come with a guarantee, and the end result is not believed to depend on human effort as much as it depends on factors beyond human control, including particular kinds of spontaneous thought. In early Daoism, for instance, the realization of the Way is repeatedly said to "come by itself" (自來), "arrive by itself" (自至), "return by itself" (自歸), or "become stable by itself" (自定).[32]

Antidotes to Spontaneous Thought

According to contemplative traditions, the most obvious antidote to the disturbing influence of spontaneous thought is perseverance in the contemplative undertaking (i.e., continued meditation, prayer, ritual, worship, etc.). In many cases, however, the challenges involved are seen as so substantive that they call for special treatment.

Some traditions are explicit in recommending the active suppression of thoughts. This is most common within Christianity, as in the following suggestions from *The Cloud of Unknowing*:[33]

- quickly put [the thoughts] down
- trample them down under foot
- suppress all thought under the cloud of forgetting
- as often as they come up, push them down.

Yoga, Buddhism, and Daoism are less prone to endorse active suppression, and sometimes explicitly warn against it, as in the following statement by the Chinese Buddhist meditation master Hānshān Déqīng 憨山德清 (1546–1623):[34]

> You must not oppose [the thoughts] or seek to cut them off on purpose, nor should you seek to stop them on purpose or prolong them.
>
> 切不可與之作對，將心要斷他， 亦不得將心
> 止他，亦不可相續他。

Even when explicitly rejecting suppression, however, many traditions advocate an increased concentration on the object of meditation or prayer, the intensity of which would probably be hard to achieve without an element of suppression. Hānshān Déqīng, for instance, tells meditators to "act brutally" (下毒手) and "clench [their] teeth and refuse to let go" (咬定牙關，決不放捨), "as if exerting all the strength of the body pushing a heavy cart up the hill" (如推重車上坡相似渾身氣力使盡). Since at the same time he (like many other meditation teachers) also advocates "gentleness" (緩緩), we are perhaps witnessing the kind of ambivalence and inner contradiction spontaneous thought often seems to elicit. Reminiscent of modern mindfulness practitioners, he advocates "again and again letting go" (放下又放下) of the thoughts, without clarifying how this differs from suppression.

An alternative approach involves an increased awareness of the thoughts passing through the mind, whether in terms of the "mindfulness" (Sanskrit *smṛti*; Chinese *niàn* 念 or *guān* 觀[35]) of the Buddhist (and sometimes Yogic) practices or the "watchfulness" (Greek *nipsis*), "attentiveness" (*prosochi*), or "guarding of the heart" (*phylaki/tirisis kardias*) of early Christianity.[36] Even this, however, is often believed to eventually make the thoughts go away, or at least stay away from the inner core of the mind.

In much of Daoism, spontaneous thought, usually in the form of emotions, is seen as harmful only when it is excessive. The best antidote, therefore, is to regulate them and keep them in harmony, rather than to attempt to get rid of them, though both approaches are mentioned.[37]

The open acceptance of spontaneous thought is also sometimes recommended. The twelfth-century Jain scholar Hemachandra compares the lustful mind to a sexually aroused elephant, which becomes wilder and more dangerous the more one tries to stop it, but soft and supple if one lets it satisfy its desires.[38]

Both Christianity and Asian traditions often see thoughts as such as natural and unproblematic, as long as one does not hold on to their sometimes unhealthy and unholy content. If, on the other hand, one "deliberately conjure[s] up the memory of somebody or something or other" and "allow[s] houseroom to this thing that you naturally like or grouse about," then it is "deadly sin," according to *The Cloud of Unknowing*.

While *The Cloud of Unknowing* recommends that all thoughts be "quickly put down," it also recognizes that this will not always be possible, in which case it suggests the use of a "spiritual dodge." Either "do everything you can to act as if you did not know that [the thoughts] were so strongly pushing in between you and God," or "cower down before [the thoughts] like some cringing captive overcome in battle, and reckon that it is ridiculous to fight against them any longer."[39] Both "dodges" amount to a kind of acceptance, albeit unwilling, of the presence of spontaneous thought.

Beyond the direct treatment of spontaneous thought itself, many contemplative activities are specifically designed to deal with the problems that such thought poses and the obstacles it represents. According to Evagrius Ponticus, man "destroys desire through fasting, vigils and sleeping on the ground, and he tames his incensive [i.e., impassionate and wild] power through long-suffering, forbearance, forgiveness and acts of compassion" (Palmer et al., 1979–1999, p. 39). In Buddhist contexts, repentance rituals are often considered effective antidotes, as are simpler forms of meditative practice, such as *sūtra* reading and the recitation of buddha names. As a treatment for excessive desire, visiting a charnel ground and contemplating the gradual rotting process of corpses in different stages are considered particularly helpful![40]

When the thoughts are associated with demons, one way of countering them is to identify who or what the demons are and speak out their names. Zhìyǐ suggests that the best way to determine the identity of the demon is to see at what time of day or night it appears:[41]

> By noticing the time when the demon typically appears, the contemplative will know its animal spirit, and saying its name and rebuking it will make it disappear.
>
> 行者若見常用此時來。即知其獸精。說其名字訶責即當謝滅。

Zhìyǐ gives detailed instructions of how to drive away a demon by closing the eyes in full concentration and rebuking it, saying "I know who you are" and "I keep the precepts and do not fear you." Then, we are told, the demon will turn around and leave.

The Buddha is himself supposed to have defeated Māra by showing that he had identified him in spite of the latter's disguise. In terms of structure (not content), this kind of identification is similar to the modern practice of "labeling" thoughts before "letting go" of them, as is sometimes taught by mindfulness instructors.

Another way to counter such demons is to recite sacred texts, the way Jesus is thought to have defeated Satan by quoting Holy Scripture. The title of Evagrius Ponticus's book *Antirrhetikos* is translated as *Talking Back*, and the entire book is a collection of Bible quotations suitable for rebuking the eight demons associated with the eight kinds of thought.[42] In Buddhism, reciting entire *sūtras* rather than shorter excerpts is supposed to be most efficacious.

Similar examples include the saying of specific prayers or the chanting of specific mantras. In both Christianity and Buddhism, repentance rituals and, in Christianity, confession, are also considered effective means to deal with demons. The borderline between the external demon and the internal mind is sometimes blurred.

According to Evagrius Ponticus, the practitioner stands a good chance of winning the fight:

> Against the demonic thought there are three opposing thoughts that cut it off if it endures in our thinking. They are the angelic thought, the thought that is influenced by our resolve for the better, and the thought given by human nature in keeping with which even pagans are moved to love their own children and honour their parents. But against the

good thought there are only two opposing thoughts. They are the demonic thought and the thought that devolves from our resolve for the worse.[43]

It also helps that "no thought is evil from nature."

Traces of the Past

Most contemplative traditions focus on spontaneous thought as a negative influence originating in the past. This sometimes relates to the concrete past-oriented content that often fills the mind, as in the following statements by Evagrius Ponticus:[44]

> . . . when the intellect is activated by man it is its nature to bring forth the images of past events.
>
> When you pray, keep close watch on your memory, so that it does not distract you with recollections of your past.
>
> While you are praying, the memory brings before you fantasies either of past things, or of recent concerns, or of the face of someone who has irritated you.

At other times, the relation to the past is more philosophical. The fourteenth-century Christian work *The Cloud of Unknowing* is loath to link spontaneous thought to the past sins of the individual, but instead links it to original sin:

> For a spontaneous thought, springing to mind unsought and unwittingly, cannot be reckoned to be sin. It may be sin, if you like, in the sense that it is the result of original sin, depriving you of power over all your thoughts—you were cleansed from the guilt of that when you were baptized.[45]

In the various Indic traditions, spontaneous thought is typically seen as a product of karmic imprints (*saṁskāra*) from this or earlier lives. The connection is a complex one and goes both ways, since "*kleśas* [which include such spontaneous states as ignorance, egotism, desire, aversion, and the clinging to life, H. E.] provoke *karma*, and *karma* fuels the *kleśas*."[46]

This orientation toward the past is in some ways reminiscent of (though by no means identical to) the Freudian view of free association as a key to the understanding of inner conflicts that ultimately originate in childhood traumas. The strong link between spontaneous thought and the past is also often emphasized within recent cognitive studies.

Conclusion

Spontaneous thought, whether conceptualized as mind-wandering, thoughts, passions, fantasies, emotions, thought-moments, or fluctuations of the mind, plays a central role in contemplative traditions across the Eurasian continent.

It is often seen as a problem, a mental factor distracting the person from his or her prayer or meditation, binding him or her to the phenomenal world, in its coarseness clogging the gateway to non-phenomenal and fundamental aspects of reality, and being used by demons to tempt the person away from the contemplative process. On the other hand, some aspects of spontaneous thought are typically seen as elements conducive to prayer and meditation, and the fruits of contemplative practice are often thought to come spontaneously, rather than as a direct result of deliberate effort. Moreover, even distractive thought is sometimes seen as providing some help to the contemplative process, since it contains information about areas of the mind in need of further progress and cultivation.

The various contemplative traditions recommend different approaches to spontaneous thought, including harsh suppression, mindful observation, and harmonious regulation, as well as reluctant or wholehearted acceptance. Alternatively, attention can be either gently or forcefully turned to the object of meditation and prayer, away from spontaneous thought. There are also specific contemplative practices, such as the reading, recitation, or chanting of religious texts, the repetition of mantras, the performance of repentance rituals or confession, various ascetic exercises, or the practice of good deeds.

While modern secularized meditation practices tend to be more accepting of spontaneous thought than the traditional religious approaches, many of the same issues remain. This includes, most notably, the contrast between non-directive meditation, which accepts thoughts without reservations, and mindfulness meditation, which tends to mix the acceptance of thoughts with ideals of their disappearance.

Notes

1. Casiday, 2006; Brakke, 2009; Stewart, 2005.
2. Palmer et al., 1979–1999, vol. 1, p. 363.
3. Louth, 2009.
4. Palmer et al., 1979–1999, vol. 4, pp. 430f.
5. On *vairāgya*, cf. *Yoga Sūtra* I.12, I.13, I.15, I.16, III.50; on *rāga*, cf. I.37, II.3, II.7; see Bryant, 2009; Feuerstein, 1989.
6. *Digital dictionary of Buddhism*: 念.
7. *Digital dictionary of Buddhism*: 想.
8. Forman (1996) represents the perennial view, while Katz (1978) represents the cultural-constructivist view.
9. Palmer et al., 1979–1999, vol. 1, p. 62.
10. Wolters, 1978, p. 67.
11. Bryant, 2009, p. xlv.

12. Buswell & Lopez, 2014: *śūnyatā*. For instance, *Yúnqī jìngtǔ huìyǔ* says, "If you are unable to empty your mind, then just practice buddha recollection. Keep doing so incessantly, and the mind will by itself become empty." 未能空心，且勤念佛。念念不已，心當自空。
13. Eifring, 2015, p. 208.
14. See Roth 1999: "It is lost inevitably because of sorrow, happiness, joy, anger, desire, and profit-seeking." 其所以失之,必以憂樂喜怒欲利 (p. 51); "When you are anxious or sad, pleased or angry, the Way has no place within you to settle." 憂悲喜怒,道乃無處 (p. 95).
15. Seelaus, 2005, p. 2.
16. Seelaus, 2005, p. 23.
17. Casiday, 2006, p. 92.
18. Casiday, 2006, p. 95.
19. Casiday, 2006, p. 174
20. Casiday, 2006, p. 194.
21. Buswell & Lopez, 2014: *gṛdhrakūṭaparvata*.
22. Lǐ Ān, 1996, p. 48f.
23. Casiday, 2013, p. 120.
24. Bryant, 2009, p. 118ff.
25. Bryant, 2009, p. 175.
26. Bryant, 2009, p. 32.
27. Bryant, 2009, p. 31.
28. *The Pali Text Society's Pali-English dictionary: kilesa*.
29. Cíyǔ, 1985, p. 1194.
30. Tiso, 2005.
31. *Liánbāng shīxuǎn*.
32. Roth, 1999.
33. Wolters, 1978.
34. *Hānshān lǎorén mèngyóu jí*.
35. *Guān* 觀 is originally the Chinese translation of Sanskrit *vipaśyanā* rather than *smṛti*.
36. Palmer et al., 1979–1999, p. 437f.
37. Roth, 1999.
38. See Bronkhorst, 2016.
39. Wolters, 1978, p. 98.
40. Dessein, 2014; Shaw, 2006.
41. Lǐ Ān, 1996, p. 47.
42. Brakke, 2009.
43. Casiday, 2006, p. 110.
44. Palmer et al., 1979–1999, vol. 1, pp. 39 and 61.
45. Wolters, 1978, pp. 74–75.
46. Bryant, 2009, p. 196.

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CHAPTER

39 Catching the Wandering Mind: Meditation as a Window into Spontaneous Thought

Wendy Hasenkamp

Abstract

This chapter considers a form of attention-based meditation as a novel means to gain insight into the mechanisms and phenomenology of spontaneous thought. Focused attention (FA) meditation involves keeping one's attention on a chosen object, and repeatedly catching the mind when it strays from the object into spontaneous thought. This practice can thus be viewed as a kind of self-caught mind-wandering paradigm, which suggests it may have great utility for research on spontaneous thought. Current findings about the effects of meditation on mind-wandering and meta-awareness are reviewed, and implications for new research paradigms that leverage first-person reporting during FA meditation are discussed. Specifically, research recommendations are made that may enable customized analysis of individual episodes of mind-wandering and their neural correlates. It is hoped that combining detailed subjective reports from experienced meditators with rigorous objective physiological measures will advance the understanding of human consciousness.

Key Words: meditation, mind-wandering, meta-awareness, spontaneous thought, focused attention

One of the central challenges in studying spontaneous thought is the fact that mind-wandering often occurs without intention or awareness (Smallwood & Schooler, 2015). This leads to inevitable difficulty in assessment, as participants cannot accurately report on mental experiences about which they are unaware. In light of this, strategies that may increase awareness of mental states would seem to have particular utility for the study of spontaneous thought. In this chapter, I consider a form of attention-based meditation as a novel means to gain insight into the processes underlying spontaneous thought and the ability to detect it.

In Western culture, scientific as well as popular interest in various forms of meditation has burgeoned over the last decade. In 2012, the National Health Interview Survey estimated that 18 million Americans used meditation as a complementary health approach (Black, Clarke, Barnes, Stussman, & Nahin, 2015). In addition, scientific research on contemplative practices like meditation continues to accumulate at a rapid pace, with over 2,000 publications since just 2010. While the field is still in its infancy, early results point to some promising clinical applications, as well as neural changes associated with repeated meditation practice (e.g., Fox et al., 2014; Goyal et al., 2014; Tang, Hölzel, & Posner, 2015).

Most forms of meditation currently used in the West have Buddhist origins, but many have been adapted in a secular way to emphasize the mental training aspects and avoid the more religious or ritualistic elements of traditional practices (McMahan, 2008). Meditations vary widely in the cognitive and emotional states they endeavor to foster, as well as the instructions they use to achieve these goals. For example, open monitoring styles of meditation seek to strengthen and expand awareness to include anything entering the mind, while compassion practices are used to cultivate specific emotional states toward oneself and others (Dahl, Lutz, & Davidson, 2015; Lutz, Slagter, Dunne, & Davidson, 2008).

Despite this plurality, many contemplative practices are based on a foundation of attention training that serves to familiarize a person with his or her thoughts and emotions and to gain control over cognitive faculties (Dahl et al., 2015; Lutz et al., 2008; Wallace, 2006). It is this basic attention training that I would like to consider in this chapter, as it may hold potential to advance our understanding of the cognitive and neural mechanisms underlying the arising and detection of spontaneous thought.

Cognitive and Neural Dynamics During Focused Attention (FA) Meditation

One common meditation practice—known as focused attention (FA), concentration meditation, or *shamatha*—can be viewed from a cognitive perspective as a kind of sustained attention task. During FA meditation, attention is placed and maintained on a chosen object (e.g., sensations of breathing, ambient sounds, a visual image, etc.). Because spontaneous thought, or mind-wandering, will almost invariably occur, the practitioner is instructed to simply notice when the mind has strayed from the object of focus, and return her or his attention to the object without engaging in elaborative thinking or judgment (Wallace, 2006). At some point after attention is returned to the chosen object, mind-wandering will usually occur again, and the cycle repeats. Thus, a session of FA meditation practice is an iterative cycle through the dynamic cognitive states of focused attention (FOCUS), mind-wandering (MW), awareness of mind-wandering (AWARE), and shifting attention back to the object (SHIFT; Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012). A basic cognitive model of this process is shown in Figure 39.1.

An interesting aspect of FA meditation is that the instructions are to keep one's attention on a given object, which sets up an apparent "goal state" of single-pointed focus. In this situation, any cognitive state that diverges from that goal (e.g., MW) becomes a "target" to detect using the faculty of meta-awareness. In effect, the selection of an attentional object in this practice sets up a subjective counterpoint to the normal fluctuating contents of the mind, bringing the scattered nature of thought into relief against the contrast of a steady object. Over time and with repeated practice, the meditator is actually building skills not only of sustaining or maintaining attention (FOCUS), but also—and perhaps more important—of monitoring and recognizing naturally arising mental states or spontaneous thoughts (AWARE), as well as disengaging and

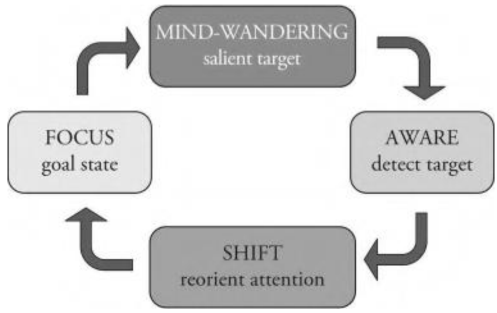

Figure 39.1. Cognitive dynamics of FA meditation. A session of FA meditation is an iterative cycle of mental states including object-focused attention (FOCUS), mind-wandering (MW), awareness of mind-wandering (AWARE), and shifting attention back to the object (SHIFT). The FOCUS state is the intended "goal," while MW represents a deviation from that goal, and becomes a salient mental target in the context of FA meditation. Image modified with permission from Hasenkamp (2014).

redirecting attention (SHIFT). Even though these additional skills may not be the instructed goal of the practice, a major aim of this kind of training, in both its traditional and current applications, is to develop meta-awareness alongside attentional control (Dahl et al., 2015; Lutz et al., 2008).

Given that FA meditation is characterized by an oscillation between states of focus and spontaneous thought, it may be of particular benefit in the context of cognitive research. My colleagues and I developed a functional magnetic resonance imaging (fMRI) paradigm that leverages the unique framework of FA meditation, coupled with subjective report, to study the neural correlates of mind-wandering and attention (Hasenkamp et al., 2012). We studied meditation practitioners who had experience with FA meditation, assessing brain activity with fMRI as they engaged in this practice for 20 minutes. Participants were instructed to keep their attention on the sensations of breathing (specifically, the air coming in and out of the nostrils), and whenever they noticed their mind had wandered completely away from this object, to press a button and then return their focus to the breath. Thus, the task was similar to a typical FA meditation session, simply adding a button press at the moment of awareness of mind-wandering (AWARE; see Figure 39.2). As participants are asked to identify and report episodes of spontaneous thought, this design can also be considered a self-caught mind-wandering task.[1]

In our study, the button press provided a temporal marker for the moment of awareness of mind-wandering, and presumably also the end of the mind-wandering episode. Based on this marker, we divided the data into four distinct phases (3

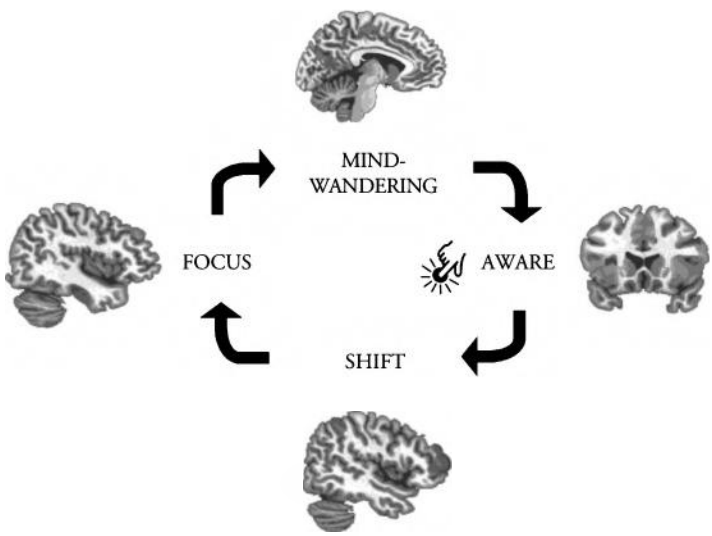

Figure 39.2. (See Color Insert) Brain networks involved in FA meditation. Using a button-press from the participant to mark the moment of awareness, four brief cognitive phases were defined around this time point, and neural activity was analyzed accordingly. These results show activity during the FOCUS, AWARE, and SHIFT phases compared to the MW phase; MW activity is compared to SHIFT activity. Mind-wandering was associated with default mode regions (gray), awareness of mind-wandering was associated with the salience network (gray; dark gray shows activations due to a motor control for the button press), and shifting and maintaining attention was associated with the executive network (gray, light gray). Image modified with permission from Hasenkamp (2014).

seconds each) corresponding to the cognitive model in Figure 39.1. By analyzing fMRI data within only these brief phases, we could restrict our window of analysis to a specific time, during which we could be relatively confident of the participant's mental experience. Notably, even though this approach meant including only a fraction of our data in the analysis, our findings were quite robust, and consistent with the functions of well-studied brain networks (see discussion later in this chapter). Of course, significant variability undoubtedly still exists both between and within individuals, making this model highly oversimplified and subject to noise (see Hasenkamp et al., 2012; Hasenkamp, 2014, for a discussion of limitations and possibilities for extending the model). Nevertheless, it appears that using subjective report to define a narrow window of analysis served to increase the signal-to-noise ratio rather than reduce power.

Comprehensive results from this study have been discussed elsewhere (Hasenkamp & Barsalou, 2012; Hasenkamp et al., 2012; Hasenkamp, 2014), but a short summary is provided here for reference (Figure 39.2). During the MW phase, analyses revealed activity in brain regions associated with the default mode network (medial prefrontal cortex and posterior cingulate cortex), which have been strongly implicated in spontaneous thought (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Andrews-Hanna, Smallwood, & Spreng, 2014; Buckner, Andrews-Hanna, & Schacter, 2008; Davey, Pujol, & Harrison, 2016; Ellamil et al., 2016; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Mason et al., 2007; Raichle, 2015). In the AWARE phase, the salience network (bilateral anterior insula and dorsal anterior cingulate cortex) was strongly activated. This network has been implicated in the identification of salient or relevant stimuli across domains, and helps to engage and control attention (Mooneyham, Mrazek, Mrazek, & Schooler, 2016; Seeley et al., 2007). During the SHIFT phase, elements of the executive network were active that have been implicated in disengagement and reorienting of attention (dorsolateral prefrontal cortex and inferior parietal lobule; Corbetta, Patel, & Shulman, 2008; Mooneyham et al., 2016; Posner & Petersen, 1990; Seeley et al., 2007). Finally, a region of the dorsolateral prefrontal cortex associated with working memory and sustained attention (Curtis & D'Esposito, 2003; D'Esposito, 2007; Miller & Cohen, 2001) was active during the FOCUS period, indicating continued executive network activity.

In general, the functions of brain networks that were activated during these four brief cognitive phases aligned with the mental functions we believed to be occurring at those times. Specifically, mind-wandering was associated with default mode regions, awareness of mind-wandering was associated with the salience network, and shifting and maintaining attention were associated with the executive network. Additional analyses showed that neural activity during these cognitive phases, as well as resting state functional connectivity, were modulated by lifetime meditation experience, suggesting experience-dependent plasticity in relevant networks (Hasenkamp & Barsalou, 2012; Hasenkamp et al., 2012). This work highlights the utility and importance of subjective report in the study of dynamic mental states, and has helped to refine our understanding of the complex neural and cognitive correlates of FA meditation.

Meditation Practice and Cognitive Processes Around Spontaneous Thought

Given the overarching goals of FA meditation and its emphasis on catching the wandering mind, it is often assumed that with repeated practice, meditators will experience decreased mind-wandering and increased attentional control. Such cognitive effects have long been noted within contemplative traditions (Dahl et al., 2015; Wallace, 2006), and recent research also supports these claims to varying degrees.

Contemplative research has found evidence of reduced mind-wandering following brief mindful breathing (Mrazek, Smallwood, & Schooler, 2012), following several weeks of meditation practice (Jazaieri et al., 2015; Jha, Morrison, Parker, & Stanley, 2016; Morrison, Goolsarran, Rogers, & Jha, 2014; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; but see Banks, Welhaf, & Srour, 2015), and following one and three months of intensive retreat practice (Zanesco et al., 2016). In addition, experienced meditators reported less mind-wandering than non-meditators in several studies (Brewer et al., 2011; Garrison, Zeffiro, Scheinost, Constable, & Brewer, 2015; Levinson, Stoll, Kindy, Merry, & Davidson, 2014), and showed reduced default mode network activation compared to controls during various types of meditation (Brewer et al., 2011). This agrees with other studies suggesting that meditation experience is associated with differential default mode activity and connectivity (Farb, Segal, & Anderson, 2013; Garrison et al., 2015; Hasenkamp & Barsalou, 2012; Jang et al., 2011; Mooneyham et al., 2016; Taylor et al., 2013). Several lines of research also suggest that repeated meditation improves various aspects of attention (Jha et al., 2015; Jha, Krompinger, & Baime, 2007; Lutz et al., 2009; MacLean et al., 2010; Malinowski, 2013; Sahdra et al., 2011; Slagter et al., 2007; Zanesco, King, Maclean, & Saron, 2013). Moreover, many studies have found evidence for neural changes in relevant networks following meditation, supporting the idea that a process of experience-dependent neuroplasticity may underlie the development of these cognitive effects (see Fox et al., 2014; Tang, Hölzel, & Posner, 2015 for review).

Thus, a growing body of evidence supports the notion that repeated meditation leads to changes in attentional capacity and reductions in mind-wandering. A related question is whether meditation practice can enhance meta-awareness. This is a reasonable hypothesis, as monitoring for distraction is an essential part of maintaining focused attention. By setting up the specific cognitive framework of FA meditation in the mind of the practitioner, spontaneous thought becomes highlighted because it diverges from the goal state of directed focus. In this context, the processes around, and contents of, mind-wandering acquire increased salience because they have become a target for meta-awareness to detect. In our study, the moment of detection (AWARE) was associated with robust activation of the brain's salience network, similar to results from simple target-detection tasks in other modalities (Seeley et al., 2007; Uddin, 2014).[2] This neural convergence across tasks suggests that during FA meditation, the cognitive state of mind-wandering (e.g., an internal, mental target) may function in the same way as standard visual or auditory targets used in other tasks (e.g., external, sensory targets)—something that is arbitrarily defined as salient, which the mind then monitors for and detects when it is identified. This finding extends our understanding of the function of the salience network, which has often been described as detecting mainly external stimuli, toward a more general salience detector that can be equally tuned to internal events such as mind-wandering (Andrews-Hanna et al., 2014; Uddin, 2014). In FA meditation, then, repeatedly ascribing salience to internal thoughts and training oneself to detect them may well enhance metacognitive abilities.

Anecdotal reports commonly affirm that the arising of spontaneous thought becomes more readily detectable in experienced practitioners (Wallace, 2006), presumably reflecting such an increase in meta-awareness or monitoring capacity. While meta-awareness is a challenging construct to operationalize due to difficulties in confirming accuracy, recent work has begun to approach this question as it relates to meditation. One study found that experienced meditators performed more accurately than novices on a breath-counting measure (confirmed with physiological tracking of breathing), suggesting improved meta-awareness in practitioners (Levinson et al., 2014). Another study found that following 8 weeks of mindfulness training, participants who practiced more exhibited greater self-reported meta-awareness of mind-wandering during the sustained attention to reponse task (SART) (Jha et al., 2016). Introspective accuracy also appears to be improved by meditation training, as shown in metacognitive ability for memory (Baird, Mrazek, Phillips, & Schooler, 2014) and emotional self-awareness (Sze, Gyurak, Yuan, & Levenson, 2010). Finally, two longitudinal studies found that after intensive meditation training, practitioners reported a greater proportion of self-caught mind-wandering episodes following training, after adjusting for a reduced overall number of episodes (Zanesco et al., 2016).

While these studies are suggestive of increases in meta-awareness following meditation, they do not speak directly to whether meditators can more accurately or validly detect mind-wandering. For example, probes about meta-awareness during the SART, as well as reports of self-caught mind-wandering during a task, rely only on self-report with no behavioral validation; breath counting, while validated with a physiological measure, does not address awareness of spontaneous thoughts. Along these lines, Zedelius and colleagues (2015) used a novel paradigm to determine whether incentivizing people to catch task-unrelated thoughts during reading would increase their accuracy. By correlating self-caught mind-wandering with a covert behavioral measure of mind-wandering, the researchers found that motivating participants to monitor their thoughts did indeed increase the number of self-catches, as well as increasing the validity of these reports.[3] Future studies could use this kind of approach to investigate whether meditation training affects one's capacity to monitor thoughts and detect them accurately.

Thus, while research is still in the early stages, initial results, coupled with considerable anecdotal evidence, suggest that repeated meditation may improve meta-awareness, leading to an enhanced ability to detect spontaneous thought. If this is the case, experienced meditators may be particularly beneficial as participants in studies of self-caught mind-wandering.

Defining an Episode of Spontaneous Thought

A challenge in all studies of spontaneous thought is that the temporal window of mind-wandering is extremely variable, and our ability to define it highly imprecise. To make progress in understanding the phenomenology and physiology of mind-wandering, we will need to more clearly outline the criteria for—and temporal boundaries of—the onset and termination of a single episode (Ellamil et al., 2016; Metzinger, 2013; Smallwood & Schooler, 2015). Existing paradigms are subject to several limitations in this regard. Using self-caught designs, experimenters can only measure the moment of detection of mind-wandering, not its onset. Probe-caught paradigms similarly do not shed light on the temporality of a mind-wandering episode, again only collecting subjective input at the moment of the probe. In a recent review, Smallwood and Schooler (2015, p. 511) suggest that the field should work to identify "reliable behavioral and physiological measures that can indicate the onset and offset of mind wandering without having to rely on individuals' self-reports." While these third-person measures will certainly be important, researchers may also be able to leverage self-report in a more careful way to address current limitations.

Particularly when attempting to determine neural correlates of mind-wandering, defining the temporal boundaries of a single episode is essential, but methods for doing so have been elusive. In our study, we chose a relatively short window (3 seconds prior to detection) in an attempt to limit variability in cognitive states during the MW phase. Previous studies have used longer temporal windows to examine neural activity prior to self-reported mind-wandering in response to thought probes (e.g., 10 seconds or more, see Allen et al., 2013; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011). While this approach increases statistical power by using more data, it may complicate the interpretation of related brain activity by including time points that correspond to cognitive states occurring prior to the onset of mind-wandering (i.e., attentional/on-task states; Figure 39.3). Within a given temporal window defined by the experimenter, the signal-to-noise ratio of actual mind-wandering depends on the participant's subjective state during each TR,[4] which will vary trial by trial. In some cases, mind-wandering will have begun before the window of analysis, making the data fully representative of the neural correlates of spontaneous thought (Figure 39.3A). In other

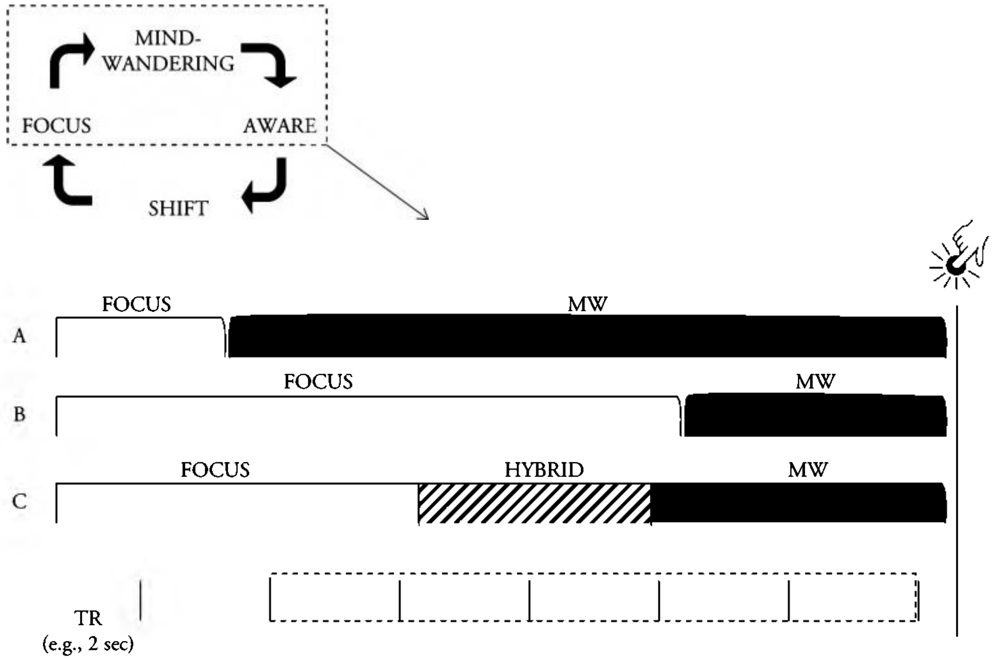

Figure 39.3. (See Color Insert) Defining the temporal window of analysis. This schematic depicts three hypothetical cognitive scenarios and related window of analysis for a neuroimaging study of self-caught mind-wandering. Tick marks denote TRs (the fMRI scanner's sampling rate, here 2 seconds each), and the light gray bar represents an analytical window of 10 seconds prior to the button press. (A) A scenario where the window of analysis is accurate and only includes mind-wandering states. (B) A scenario where the window is too long, and includes contaminating focused states. (C) A graded transition between focused attention and mind-wandering, showing a hybrid state where some portion of the attention remains on the object for a time, but spontaneous thought still occurs. In this case, the window contains all three mental states, again confounding the analysis.

cases, mind-wandering may be brief, and focused attention will also have occurred within the window of analysis—if this happens, the signal-to-noise ratio is reduced, and attempts to interpret neural activity become confounded (Figure 39.3B).[5]

A related and largely unexplored issue is whether conscious attention can be directed toward multiple objects at the same time. Many experiments using probe-caught mind-wandering ask not just whether the participant's mind was on- or off-task, but provide a continuous scale for reporting (e.g., one endpoint representing completely on-task and the other representing completely off-task). Participants often answer somewhere in the middle (e.g., Allen et al., 2013; Christoff et al., 2009; Jha et al., 2016; M. Mrazek, personal communication), suggesting that the transition from focused attention into mind-wandering is not a dichotomous experience, but rather occurs in a graded way—at least phenomenologically.[6] This results in a kind of "hybrid" subjective experience of being partially focused and partially distracted (Figure 39.3C).[7] Splitting of attention has been examined in studies of visual attention (Awh & Pashler, 2000; Kramer & Hahn, 1995; Müller, Malinowski, Gruber, & Hillyard, 2003), but has rarely been considered in studies of spontaneous thought (see Dixon, Fox, & Christoff, 2014). As it seems likely that this kind of parallel attention is a common phenomenological experience that would have important implications for the accurate identification of neural correlates, it warrants further study in cognitive science and represents another area for more detailed subjective reporting.

Regardless of the duration of the temporal window of analysis, it is notable that all studies to date have calculated the start time of a mind-wandering or off-task episode *relative to the endpoint* (either self-caught or probe-caught), and not based on any other subjective input. This introduces an obvious lack of precision in analysis, which may hinder our ability to accurately understand the neurophysiological underpinnings of spontaneous thought.

Potential Utility of Subjective Report During FA Meditation

The FA meditation paradigm outlined here is well suited to highlight the unfolding of spontaneous thought in the mind of the participant, and could be leveraged in numerous ways to obtain more detailed and accurate subjective information about the onset, contents, and termination of mind-wandering episodes. It is also likely that experienced FA meditation practitioners would be able to provide very fine-grained reports on both the temporal and phenomenal unfolding of spontaneous thought, thereby enabling a heretofore unavailable level of analysis in cognitive research (Lutz & Thompson, 2003). Previous studies have leveraged experienced meditators' heightened cognitive and emotional control as well as nuanced reporting ability to examine experiences such as non-referential compassion (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004), non-dual awareness (Josipovic, 2014), specific degrees of intensity of compassion generated during meditation (Klimecki, Leiberg, Lamm, & Singer, 2013), and mind-wandering (Ellamil et al., 2016; Hasenkamp et al., 2012). The motivation for such an approach is informed by the project of neurophenomenology put forth by Francisco Varela (Varela, 1996). As explained by Lutz and Thompson (2003), within this framework, "phenomenologically precise first-person data produced by employing first-person methods provide strong constraints on the analysis and interpretation of the physiological processes relevant to consciousness." In the following sections, I examine the potential utility of incorporating such subjectively derived constraints in the study of spontaneous thought.

From a temporal perspective, it is notable that meditation practitioners may be able to detect mind-wandering relatively quickly after its onset. Evidence to support this claim comes from a recent study (Zanesco et al., 2016) in which experienced meditators performing a reading task identified gibberish text more quickly than non-meditators in other studies using the same paradigm (Smallwood, Fishman, & Schooler, 2007; Zedelius, Broadway, & Schooler, 2015), suggesting faster detection of cognitive targets. Indeed, a recent study was based on this assumption, using an FA meditation paradigm with experienced *Vipassana* practitioners, asking them to indicate the arising of a thought with a button press as soon as they were aware of it (Ellamil et al., 2016). Presuming that the button press in fact occurred very shortly after thought onset based on the heightened introspective ability of these participants, they set the window of analysis at 4 seconds (2 TRs) prior to the button press. Contrasting brain activity associated with detection of thoughts versus words (which were presented at the same frequency as detected thoughts via online stimulus matching), and subsequently modeling hemodynamic response functions, they identified distinct brain areas related to the generation of thoughts. This study offers an excellent example of careful neurophenomenology, coupling the introspective ability of meditators, an FA paradigm, and third-person brain imaging measures to advance our knowledge of the neural correlates of spontaneous thought.

There are many possible next steps to continue leveraging this kind of unique methodological marriage. One promising avenue involves further customization of thought regressors, with the aim of estimating individual parameters on a trial-by-trial basis. It is readily apparent that each experience of spontaneous thought is distinct in both duration and content, but our methodological approaches to date have "flattened" them by averaging across episodes, assuming similarities where none may in fact exist. This kind of experimental design, while understandable from a research perspective, is far from ideal, and may be significantly limiting our ability to understand the subtlety and complexity of the mind's natural activity.

Figure 39.4 depicts several examples of reporting options that could be used alone or in various combinations to characterize individual episodes of spontaneous thought that occur within an FA meditation paradigm. Of course, it is important to remember that requiring multiple subjective reports will interfere with the naturalistic flow of meditation; however, if the aim is to enable more detailed characterization of each spontaneous thought episode, some interruption of the normal meditation process seems acceptable. Indeed, as noted by Ellamil and colleagues, this type of "noting" strategy, in which the practitioner quickly categorizes thoughts as they arise, is a common variant of FA meditation (Ellamil et al., 2016; Sayadaw, 2002). Even so, care should be taken to avoid employing too many measures simultaneously, as such "over-characterization" may begin to reduce accuracy and would also limit statistical power.

Onset and Termination of Mind-Wandering

Assuming thoughts could be detected within several seconds of onset, advanced meditators could likely provide fairly accurate estimates of the duration of each mind-wandering episode upon detection, thus enabling a rough estimation of start time (Figure 39.4A). Using a trial-by-trial approach with the help of such skilled participants, researchers may thus be able to construct not only very fine-grained

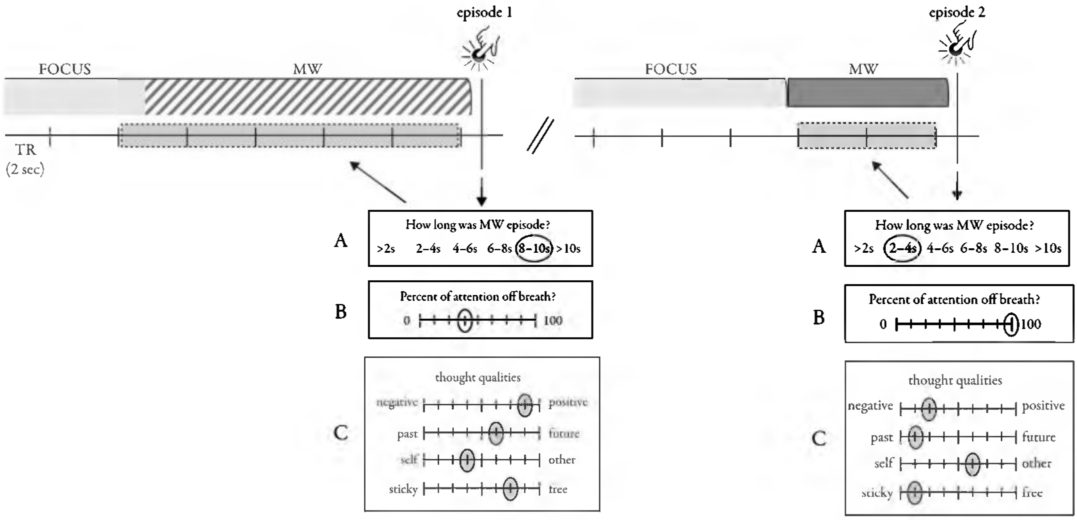

Figure 39.4. (See Color Insert) Possible characterization of individual thought episodes through first-person reports during FA meditation. This schematic shows two temporally and phenomenally different episodes of mind-wandering that could occur during the course of FA meditation. In this kind of design, each time the practitioner becomes aware of mind-wandering, she would press a button, and then provide subjective report on any number of variables, including (A) the estimated duration of the episode (based on units of analysis, such as TRs); (B) percentage of off-task attention; and (C) various dimensions of thought content. These and other measures could be gathered alone or in combination, depending on the research question. Subjective data could then be used to drive analyses of physiological correlates by providing both temporal and phenomenological constraints. For example, the window of analysis for mind-wandering could be customized for each episode, as shown by the gray bars. Other approaches could combine episodes with similar characterizations (e.g., percent attention, thought content, etc.) to determine specific neural correlates.

but also *customized* maps of the temporal unfolding of spontaneous thought in an individual. Such maps could then be correlated with physiological measures to allow for a more detailed understanding of both the arising and cessation of spontaneous thought. In other words, each episode could be ascribed its own unique duration, and statistical averaging would be applied only across episodes with similar durations, thereby constraining analysis and increasing precision.

A similar approach could be taken to estimate the proportion of attention remaining on the object for each mind-wandering episode, thus beginning to address the neural underpinnings of a hybrid or split attention discussed earlier (Figure 39.4B). From a qualitative perspective, participants could also provide phenomenological data on the experience of perceptual decoupling (Schooler et al., 2011)—the process of disengaging attention from current perceptions that initiates spontaneous thought—as well as the arising of meta-awareness that enables self-catching. Further refinements of the phenomenology of mind-wandering could also be explored. For example, Metzinger (2013) has proposed that a "self-representational blink" occurs at the moment of perceptual decoupling, which he defines as the subjective loss of attentional control and the sudden appearance of unintentional mental behavior. He further suggests that at the same moment, there may be a shift in the "unit of identification"—the phenomenal content with which one identifies as an autonomous self. All of these subtle subjective states could be illuminated with precise first-person reports at the moment of their occurrence in the context of FA meditation.

Phenomenal Qualities of Thought Content

Another challenge in studying spontaneous thought is the sheer variety of content that can be experienced. Significant advances have recently been made in distinguishing phenomenal qualities of mind-wandering episodes. Common dimensions include past–future, positive–negative, and self–other (e.g., Andrews-Hanna et al., 2013; Hoffmann, Banzhaf, Kanske, Bermpohl, & Singer, 2016; Jazaieri et al., 2015; Killingsworth & Gilbert, 2010; Ruby, Smallwood, Engen, & Singer, 2013). One intriguing aspect of spontaneous thought that is beginning to be studied is the difficulty with which one disengages from it, also referred to as the "stickiness" of thoughts (van Vugt & Broers, 2016). These qualities have been found to influence mood, task performance, caring behavior, and constructs such as depression, rumination, and mindfulness (Andrews-Hanna et al., 2013; Hoffmann et al., 2016; Jazaieri et al., 2015; Killingsworth & Gilbert, 2010; Ruby et al., 2013; van Vugt & Broers, 2016). Using the approach described here, trial-by-trial reporting could also be employed to learn more about the neural correlates of specific thought content. For example, upon detection of mind-wandering within an FA paradigm, participants could categorize thought content along these or other dimensions. Customized regressors could then be created for each episode, and those with similar characterizations could be combined to identify brain activity underlying distinct types or qualities of spontaneous thoughts (Figure 39.4).

Participant Selection

While this suggested approach assumes that participants are experienced meditators, it should be noted that careful phenomenological interviews have also been used successfully with non-meditators to gather richly detailed accounts of very narrow windows of experience (Le Van Quyen & Petitmengin, 2002; Petitmengin, 2006). In addition, non-meditating groups of participants have often been used to gather data on the content of spontaneous thoughts (Andrews-Hanna et al., 2013; Jazaieri et al., 2015; Killingsworth & Gilbert, 2010; Ruby et al., 2013; van Vugt & Broers, 2016). Moreover, in piloting our study, we found that novices were easily able to perform FA meditation and report awareness of mind-wandering episodes. Thus, it may be that the approaches outlined earlier need not be restricted to experienced meditators. However, it is likely that beginners will have lower levels of meta-awareness, and therefore experience more frequent mind-wandering and/or longer periods of mind-wandering before detection occurs. If this is true, novices may not be ideal for providing highly fine-grained subjective reporting, particularly with respect to precise temporal estimations of mind-wandering.

While experienced meditators are preferable as participants for this careful work, studying novices as they engage in meditation *over time* may offer another unique opportunity to gain new insights into the landscape of spontaneous thought. For example, longitudinal studies could examine the time course and trajectory of changes in meta-awareness and self-caught mind-wandering in a group of novices as they train in FA meditation. Frequency and periodicity of spontaneous thought could be tracked even during home practice, yielding behavioral information at a level that has not been explored previously. Participants could also be studied in lab-based paradigms designed to probe meta-awareness, thus increasing our understanding of how this capacity can be trained and fostered. Neuroimaging studies could investigate whether and how repeated meditation influences activity within brain networks related to cognitive control. Finally, changes in the content of specific mind-wandering episodes may be detectable over time; it is tempting to speculate that shifts toward more positive or other-focused thoughts may occur as practice proceeds (e.g., Jazaieri et al., 2015), although this remains an open question for future research.

Conclusion

The study of spontaneous thought has advanced rapidly in recent years. As we seek to further refine our understanding of both the phenomenology and neural underpinnings of this ubiquitous mental experience, we will need novel methods of gathering and integrating first-person subjective information into experimental design and analysis. In this chapter, I've examined the practice of FA meditation as a kind of self-caught mind-wandering paradigm, involving repeated fluctuations between focused attention and mind-wandering. By considering this common contemplative practice through the lens of cognitive research, numerous opportunities arise that may further the study of spontaneous thought.

Specifically, by leveraging the enhanced ability of experienced meditators to detect episodes of mind-wandering during FA meditation, researchers could obtain richly detailed information about the duration and content of individual episodes. This may substantially increase analytical precision in the search for neural correlates of spontaneous thought, allowing for averaging across only those episodes with similar characteristics. Such a trial-by-trial approach, dovetailed with the reporting abilities of experienced meditators, may hold great promise for advancing our understanding of the mind's natural fluctuations.

On a broader scale, relying more heavily on subjective input to drive analysis may help us shift toward a more nuanced approach to the scientific study of consciousness. As it becomes increasingly clear that the mind is ever-changing and strongly influenced by multiple contexts, we must find alternatives to traditional, reductive methods that assume similarities across individuals and even across a single individual's varied mental experiences. The integration of first-person information into our research paradigms will be essential if we are to deeply understand and honor the true complexity of human thought.

Notes

1. Two major approaches to studying spontaneous thought include probe-caught and self-caught designs (Smallwood & Schooler, 2006, 2015). In probe-caught paradigms, the experimenter introduces thought probes during an ongoing task to assess whether the participant was on-task or off-task. In self-caught designs, the participant is instructed to report mind-wandering whenever she becomes aware of it. The self-caught approach is not as accurate as probe-caught for determining frequency of spontaneous thought because it depends on the participant's awareness of mind wandering, which is only intermittent. However, self-caught designs are more useful for understanding the mechanisms underlying the emergence and detection of spontaneous thought, and have strong potential for elucidating general processes through which people become aware of mental states (Smallwood & Schooler, 2006).
2. The insula, a major hub of the salience network, is also proposed to be a "switch" between the default mode network, associated with mind-wandering, and the executive network, associated with attentional control (Menon & Uddin, 2010; Sridharan, Levitin, & Menon, 2008). This is supported by the findings shown in Figure 39.2, with insula activity bridging default mode and executive network activity.
3. If one considers the explicit intention behind FA meditation as a type of motivation to detect mind-wandering, this finding may provide further support for the idea that repeated FA practice will increase meta-awareness.
4. An fMRI scanner acquires an image of brain activity data once every few seconds depending on the parameters of the scan; the time it takes to collect a full pass of data is called a TR.
5. It should be noted that even a 3-second window of analysis is relatively long when compared to the subjective experience of transient states (e.g., a moment of meta-awareness, or shifting attention between two objects), and our analysis may well have included data from non-mind-wandering states, as discussed in Hasenkamp et al. (2012).
6. Interestingly, Buddhist psychology theorizes that even though from a phenomenological perspective it may seem like attention can be placed on two objects simultaneously, in reality attention is rapidly shifting from one object to another and back again. This happens more quickly than our conscious awareness can process, so the mind blurs moments together, creating an illusion that we are attending to multiple things at once (Wallace, 2006).
7. In piloting our experiment described earlier, many participants reported this kind of parallel or hybrid attention, with some percentage of attention retained on the breath, and some portion engaged in thought. In light of this, our task instructions were to press the button only when they noticed their attention was *completely* off the object and they were immersed in thought—in this way, we hoped to identify the most robust periods of mind-wandering for analysis.

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CHAPTER

40

Spontaneous Mental Experiences in Extreme and Unusual Environments

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Abstract

This chapter reviews the effects of a special category of environments on cognitive and cognitive/emotional processes. These extreme and unusual environments (EUEs) are characterized by drastic differences from the individual's accustomed milieu, and by posing serious challenges to well-being, health, and survival. There is a massive and wide-ranging body of writing on this topic, from history, anthropology, sociology, literature, and biography, as well as from psychology. The chapter covers information from studies of religion and ritual, mysticism, exploration, spaceflight, artistic endeavor, psychotherapy, and laboratory experiments. Sojourners in EUEs have experienced changes in memory and cognitive performance, perceptual anomalies, states of dissociative fugue, and unusual flights of imagination, among other consequences. Both positive and negative effects have been found and are discussed.

Key Words: extreme, exploration, environment, cognition, spaceflight

This chapter summarizes much of what we know concerning the free-floating thoughts, memories, emotions, and imagery of people in environments that are out of the ordinary for most of the world. The environments range from the most highly technical life-support capsules that modern science and technology have devised, to the deserts, icefields, and other natural environments of mystics and explorers, and to experimental and therapeutic apparatus. Accounts of life (and death) in such situations, recounted in history, biography, literature, and film, show seldom-observed aspects of human nature, and have therefore attracted the interest of millions of readers and viewers. Behavioral scientists have been somewhat slower to pay much attention to the phenomena encountered in these environments, although interest has been increasing in the past several decades, and a growing body of knowledge is developing.

Extreme and Unusual Environments (EUEs)

Extreme and/or unusual environments (hereafter referred to as EUEs) have an aura of being rare and exotic, and possibly fearsome and awe-inspiring. This is at least in part due to the fact that the term "extreme" in the label is related to the discomforts and in many cases dangers that characterize such environments—and anything "unusual" is mysterious, daunting, and perhaps unsafe. EUEs include experimental or therapeutic facilities such as flotation tanks and other restricted stimulation environments, life-support shelters located in areas of dangerous or lethal natural areas, such as polar and space stations (and their analogues), and the situations of individuals or small groups who find themselves in such dangerous or lethal areas but without safe shelter. The last, unlike the earlier two examples, sometimes—but by no means always—involves people who have no desire to be there, no preparation for being there, and a high probability of injury or death.

In this chapter, we review both scientific findings and historical accounts from many sources related to the thoughts, memories, emotions, and perceptions that have been reported from a wide range of EUEs. The distinctions among these and other kinds of mental experiences can be blurry. The "continuity hypothesis" (Savage, 1975) posits that there is a continuum spanning sensations, perceptions, thoughts, fantasies, dreams, memories, illusions and hallucinations; and the transitions among these may be especially subtle under the conditions discussed here. The chapter is organized by the type of environment in which different kinds of spontaneous mental experiences occur, and concentrates on EUE environments that are relatively low in the level and/or variety of physical and social stimulation.

Isolated, Confined Environments (ICEs)

EUEs can be almost anywhere on the Earth, or off it, as in the case of spacecraft. Many of the places described by the abbreviation EUE also fit the acronym ICE, which stands for isolated, confined environments. In general, ICEs are also EUEs, at least for the majority of the human population: that is, most people are seldom isolated or confined, which makes either situation unusual for them. Further, many ICEs are located in places that are either permanently or temporarily extreme along such dimensions as temperature, altitude, danger, or the availability of food, water, shelter, and other resources required for safety and comfort. On the other hand, not all EUEs are also ICEs: soldiers on the battlefield, citizens surviving an earthquake or a tsunami, and teams trekking through a desert or jungle are neither isolated nor confined.

Of course, these labels really mean extreme *and/or* unusual, isolated *and/or* confined; in both contractions, environments that fit the definition of one often, but not necessarily, fit the other (see Table 40.1). The criteria for judging whether a given environment is an EUE or ICE are relative rather than absolute. They must be applied against a background of diverse life experiences, cultural norms, and individual personalities. In general, "isolated" includes not only lone individuals, but also small groups in locations far removed from populated areas; "confined" includes having restricted mobility, such as polar winter crews that can move freely inside their base but are restricted by the weather to go beyond its immediate vicinity.

Some environments are unquestioningly accepted as meeting the criteria, such as submarines, Antarctic stations, spacecraft, and the top of Mount Everest. But obviously, what is low in stimulation (or extreme, unusual, isolated, or confined) for a New York apartment dweller may not be so for a nomadic High North caribou herder, and vice versa. Most studies of EUE/ICE take as the baseline from which these environments differ to be a populated community located between about 60° North and South latitude and not too far above or below sea level—that is, the environments in which most of the human population lives. Underwater habitats and space beyond the atmosphere are EUE/ICEs, by definition.

Another way to categorize EUE/ICEs is on the basis of why they are entered, and by what kind of people (Suedfeld, 2012). For example, the most extreme EUEs require special, and often high-tech, life-support systems, the failure of which can mean instant or prolonged death (e.g., spacecraft, submarines, polar trekking). Yet highly trained, physically and psychologically able, properly equipped volunteers enter such environments almost every day. Most of them not only survive, but flourish, accounting themselves better for the experience. Figure 40.1 shows Bruce McCandless II, during the first-ever untethered extravehicular activity in space.

Table 40.1 EUE/ICEs Disaggregated: A Few Examples

	Isolated, Not Confined	Confined, Not Isolated	Isolated and Confined
Extreme, not unusual	Lone sailing vessels, highest mountains	Air raid shelters	Commercial fishing vessels
Unusual, not extreme	Mining or logging camps	Prisons, nursing homes	Missile silos
Extreme and unusual	Desert caravans, deep-sea construction	Concentration camps, nuclear submarines	Spacecraft, polar outposts

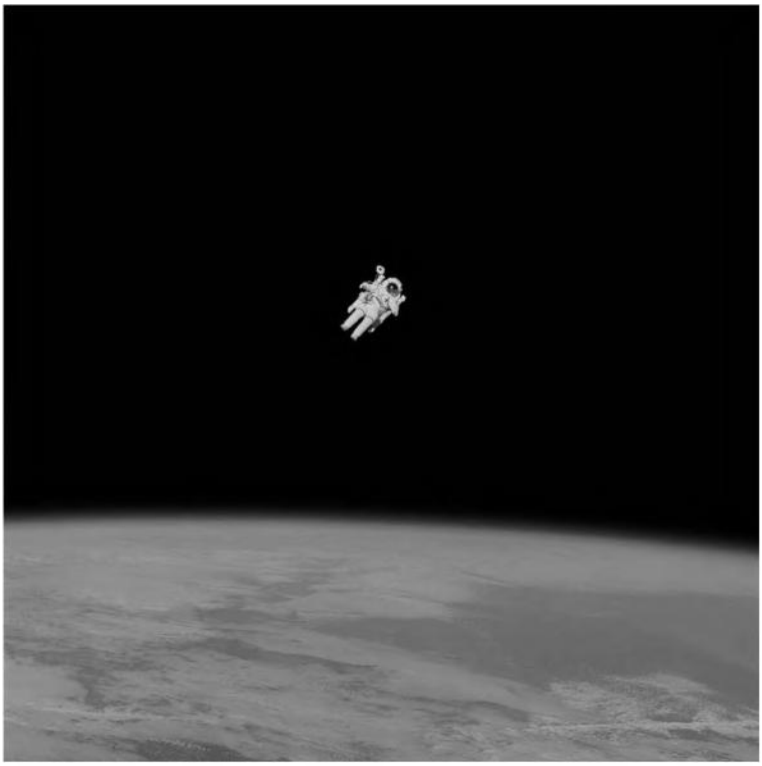

Figure 40.1. (See Color Insert) Bruce McCandless II, floating alone in the darkness of space. Source: NASA.

On the other hand, survivors of natural disasters or concentration camps, civilians trapped in combat zones, and the like, are not volunteers for those environments. As a rule, they are highly diverse in age, physical and mental fitness, and life experience. They have little or no training, specialized equipment, or escape routes. But, again, many or most survive; and testimonies as to post-experience growth and resilience are more the rule than the exception (Cherry & Galea, 2015; Suedfeld, 2012).

In this chapter, we concentrate on the many EUE/ICE environments that are low in the level and/or variety of physical and social stimulation. There has been abundant research on how such environments affect human psychology and physiology. But for the most part, the focus of researchers and their sponsors has been on such issues as job performance, group dynamics, leadership, communications, and physical safety. The studies use a wide variety of instruments and methods: self-report questionnaires (including standard psychometric measures), interviews, content analyses of memoirs and diaries, participant observation, and the sampling and recording of blood, saliva, urine, hormonal secretions, brain waves, skin conductance, heart rate, and so on. Perhaps because it is much more difficult to quantify, and its connection to survival is less obvious, spontaneous thought is seldom considered, much less investigated.

The paucity of systematic investigation does not translate into a lack of information; but that information is mostly anecdotal, derived from reminiscences. It roughly divides (with a fuzzy border and many exceptions) into dramatic tales of how the individual or group faced and survived adversity and peril, characteristic of many accounts of explorers and adventurers facing (and some historians writing about) exotic natural environments, and more matter-of-fact descriptions of life in a space vehicle, polar weather station, or political prison. The former group is represented by titles such as *The Worst Journey in the World* (Cherry-Garrard, 1922) and *Arctic Hell-Ship* (Barr, 2007); the latter, by *Riding Rockets* (Mullane, 2006) and *A Silent World* (Cousteau & Dumas, 1953).

Free Time, Busy Time, Dream Time

One step toward turning interviews and reminiscences into quantitative data was the analysis of materials from the diaries of participants in six Arctic and seven Antarctic explorations that took place between 1865 and 1916

(Mocellin & Suedfeld, 1991). The diaries were divided into four temporal phases, from the shipboard journey to the polar regions until shortly before the return home. Content codes were devised for the physical and social environments and their effects, positive and negative appraisals of experiences, and altered states of consciousness.

Although dreams are seldom described in diaries or interviews, possibly because to do so might contradict the tough and stoic image of the EUE explorer, they are not completely absent from history. Early polar explorers, like other groups in EUEs where food is restricted or sparse, often mentioned dreaming and daydreaming about lavish meals, favorite restaurants, well-loved recipes, and so on. In personal interviews with contemporary EUE personnel, such dreams are seldom mentioned; instead, there are dreams of coming home to find that one's spouse or lover has found another mate or has simply disappeared. This change may be informative as to what was both important and uncertain in the two different eras. In earlier centuries, the explorers' food supply was often uncertain and always monotonous, but relationships were stable and reliable; in our own time, there is usually plenty of nutritious, interesting food and secure resupply; but what is happening at home?

Although most of the comments had to do with the physical environment, the diarists also noted homesickness, self-insight, anxiety, increased sensitivity, and declines in alertness. Dreams (including nightmares) and daydreams, a few visual hallucinations, and religious or transcendental emotions were recorded by 74% of the Arctic and 94% of the Antarctic explorers (but bear in mind the small sample size). Captain Scott, for example, increased his references to God as his journey back from the Pole became increasingly traumatic, as did three spacefarers on *Mir* as they survived one malfunction and emergency after another (Geiger, 2009).

People committed to long-duration EUE or ICE experiences often find themselves in alternating periods of intense, even frantic activity and boring, empty time. This is true of, among others, deployed soldiers, nineteenth-century sailors, search-and-rescue operators, and space station astronauts. During the times of activity, they focus on the task and the goal, whether that be chasing down a harpooned whale, performing an extravehicular activity (EVA) or vehicle docking in space, or charging an enemy formation. Alan Shepard, the first American in space (1961), recounted how he mentally rehearsed what he would have to do if something went wrong during the launch (Shepard interview, 1991); 37 years later, as his Space Shuttle launched, Canadian astronaut Dafydd Williams was concentrating on successfully taking photos out the window, his assigned task (Williams, personal communication).

But the in-between periods are times when thoughts often turn to home and family. Ship's officers and crewmembers wrote about their family and friends at home in diaries and letters, talked about them among themselves and when visiting other ships, and missed them, especially on holidays, birthdays, and anniversaries (Johnson & Suedfeld, 1996). For present-day astronauts, the most popular free-time activity is looking out the window, taking photographs, and identifying places of personal interest: their home, places they had visited, or landmarks of importance (Johnson, 2013). It must be remembered that much of this may have changed with advances in communication technology: both in the polar regions and in space, the Internet and communications satellites have made it possible to see and speak frequently and easily with one's family at home.

These are also times when sensible leaders and home organizations provide activities to stave off boredom. In earlier days, polar expeditions and ships published periodicals, organized athletic contests, encouraged hobbies, held lectures, presented musical shows, and produced theatrical performances. Such distractions remain typical of environments that are lacking in more modern distractors, such as prisoner of war camps. These forms of amusement are still important in polar stations and other ICEs, supplemented by the Internet, along with movie DVDs and home videos. The inventive mind also turns to activities unique to the environment, such as the pranks and ceremonies of the astronauts (Johnson, 2013) and the Antarcticans' 300° Club (dashing naked, except for footwear, from a 200°F sauna out onto the –100°F ice).

Cognitive Phenomena

Both in Antarctica and in space, cognitive activity seems to deteriorate during empty time. South polar sojourners can experience a period colloquially known as "Long Eye: the twenty-foot stare in the ten-foot room." Long Eye is a brief, nonpathological episode of dissociation, in which the individual becomes unaware not only of people and objects in the surrounding environment, but also of his or her own mental processes. It is not a focus on inner experience; there are no ideas, imagery, memories, daydreams, or any other activity—at least none that the person can recall afterward. Some interpretations of mild dissociative reactions view them as coping mechanisms that can reduce the stress of boredom or conflict (Dell & O'Neill, 2009). Long Eye episodes can end spontaneously, or when an external stimulus is intense enough to interrupt them. Interestingly, although it is known as an Antarctic phenomenon, no study has been made of whether it occurs elsewhere.[1]

There is also a phenomenon of temporary cognitive decrements whose effects can range from the trivial to the disastrous. One experienced Antarctic researcher, for example, strapped on his skis and was about to venture out into a blizzard—and certain death—after the weather had confined his group for a week or more in a small shelter. Another story, later denied and relabeled as a joke (as often happens), is that a cosmonaut was about to begin an unscheduled exit from his spacecraft without fastening the tether that would have enabled him to return. He was pulled back at the last minute by his teammate.

In the space community, such lapses of attention and operational errors are known by various names, including "the space stupids," "space fog," and "space dementia." Roscosmos, the Russian space agency, recognizes a syndrome called asthenia, a "weakening of the nervous system" that can lead to fatigue, mood swings, and difficulties in concentration and attention, among other symptoms. The extent to which this is a true, diagnosable syndrome, and if so, whether its cause is psychological or neurological, is moot (Kanas et al., 2013).

The Sensed Presence Phenomenon

A dramatic experience in some EUE/ICE situations has been the feeling, and often the actual visual and auditory perception, of another entity being present. This entity may be another person, and in that case either someone actually familiar, or a supernatural being such as an angel. In a surprising number of cases, the apparition provides suggestions or help to the recipient.

The first episode of this sort was the account of Joshua Slocum, the first man (of well over 200, to date) to circumnavigate the world alone (1895–1898). Figure 40.2 shows him aboard his sloop, *Spray*. At one point during the voyage, Slocum was ill at sea, possibly from food poisoning, when a storm began. He was unable to move, but he also knew that if he could not steer his sloop into the wind, it would likely sink in the rough waters. Suddenly, there was an unknown sailor at the helm, steering the boat through high winds and waves. Slocum identified the stranger as the pilot of one of Christopher Columbus's ships (Slocum had been reading a biography of Columbus). The man assured Slocum that he would keep him safe—which he did, through a 48-hour storm. The "pilot" showed up again during a storm of thunder, lightning, and hail, when Slocum was very tired from working the boat (Slocum, 1900).

Suedfeld and Mocellin (1987) assembled a collection of similar events from a variety of extreme environments. These included the accounts of several other single-handed sailors, the traumatic experiences reported by shipwreck and air crash survivors, climbers and skiers trapped on a mountain, and polar explorers. Of the last, the most famous is the account of a sensed presence described independently by Sir Ernest Shackleton and his two companions on a desperate trek to find succor for other crew members who had been left behind (Shackleton, 1919). It is famous not only because Shackleton was (and is) one of the most admired polar explorers in history, but also because the episode featured in T. S. Eliot's *The Wasteland.* Eliot took some poetic license, writing as though there were only two people present plus the apparition

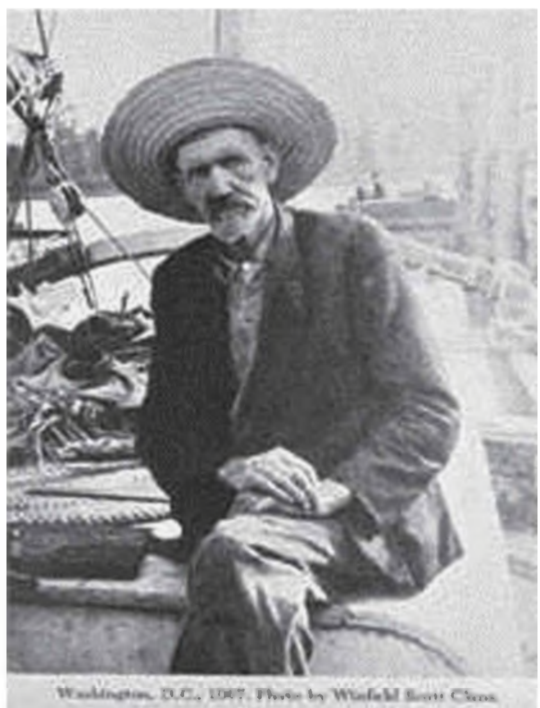

Figure 40.2. Captain Joshua Slocum in his sloop, *Spray*.

("Who is the third who walks always beside you?"), but the allusion was clear.

Later research (Geiger, 2009; Suedfeld & Geiger, 2008) added many more examples of the phenomenon. It has been reported by a fairly large number of shipwrecked sailors and ship passengers, trekkers, and explorers, as well as by trapped survivors of terrorist attacks. Helpfulness may be the criterion that differentiates the sensed presence phenomenon from hallucinations, dreams, delirious images, and so on. However, there has been at least one counterexample. A participant in the Yukon Quest, a long-distance dogsled race, was becoming exhausted when he "met" a fellow racer who suggested that he rest for a while. He agreed, and went into a hotel, where he lay down to sleep in a warm, comfortable bed. Another racer, coming along a little while later, found him sleeping in the snow and managed to revive him before he died of hypothermia. Neither the original encounter nor the hotel was real (Firth, 1998). Table 40.2 shows Suedfeld and Geiger's categorization of the major environmental conditions that are known to produce the sensed presence phenomenon.

In many cases, although not in Shackleton's, the "presence" provided encouragement, instructions, warnings, and other forms of help. The foregoing list implies that the sensed presence phenomenon is evoked when the person is under extreme stress. However, several present-day polar station crewmembers have also reported it. Nevertheless, the precipitating environment seems to require isolation, monotonous surroundings, and frequently some debilitating condition such as fear of imminent death, illness, injury, fatigue, sleep deprivation, hypoxia, or hunger (Geiger, 2009).

Explanations of the phenomenon include dismissing it as mirages, elaborated and misinterpreted actual sensations, or dreams. Theorists who have not dismissed the experience have attributed it to changes in brain functioning, neurochemical and hormonal secretions (Suedfeld & Mocellin, 1987), and regression to an earlier stage of human consciousness, in which spontaneous ideas and emotions were attributed to outside, supernatural forces (Jaynes, 1982).[2] There now seem to be enough anecdotes that a systematic analysis of the phenomenon, its boundary conditions and definitional criteria, should be possible; but none has appeared so far. As one example, the helpfulness of the presence might be a defining characteristic to differentiate it from hallucinations, dreams, and other such experiences.

Table 40.2 Sources of Sensed Presence Reports

Environment	Percentage of Reports
Mountains	41
Oceans (ships, boats, shipwrecks)	21
Polar regions	16
Prisons; POW and concentration camps	9
Air/Space	7
Other	7

Spiritual and Mystical Experiences in EUE/ICEs

> Now and again it is necessary to seclude yourself among deep mountains and hidden valleys to restore your link to the source of life.
>
> —*Morihei Ueshiba, founder of Aikido*

Closely tied to the sensed presence phenomenon discussed in the preceding are the experiences of mystics, spiritual seekers, and members of many indigenous groups who go into environments that fit one or more of the EUE/ICE criteria with the specific goal of making contact with such presences. We can begin by looking at the founders or central figures of several of today's major world religions, as their experiences are recorded in the seminal histories of each religion. The examples in Table 40.3 are listed and described in chronological order; in some cases, especially the oldest, there may not be sufficient factual evidence to establish the accuracy of the information. Nor, of course, are we in a position to judge the accuracy of the accounts as to the individual's encounter with divinity. The table is not meant to imply otherwise.

Spiritual encounters in EUEs are by no means restricted to such towering pioneers as those listed in Table 40.3. Monasticism in some form exists in most major religions, and many believers seek enlightenment or contact with the ineffable by entering EUEs. Solitude in a wilderness or hermitage is perhaps the most common of these. Among the other methods used are rhythmic chanting, drumming, and other kinds of monotonous stimulation, including the Sufi Muslim *semazen*, in colloquial English referred to as the Whirling Dervish. This tradition, begun in the thirteenth century CE, is designed to unite the human mind, heart (emotions), and body as testimony and worship to God (Whirling Dervishes, undated).

Eremite, hermit, and *anchorite* are all Christian terms for individuals who isolate themselves from the world, often in situations of low stimulation and minimal physical comfort, for religious reasons (Kingsley, 1869/2016). Those reasons may be the search for contact with the "source of life," as Ueshiba wrote (in other words, for a transcendental contact); or to concentrate without distractions on prayer, contemplation, or meditation; or to punish oneself for sins committed earlier in life; or because the individual believes that worldly comfort and pleasure lead one away from God.

The Christian Desert Fathers (and a much smaller number of Mothers) who flourished in the Middle Eastern desert in the early centuries after the life of Jesus were ascetics who lived alone or in communities that became the forerunners of the monasteries and nunneries of later eras. Although practices differed, most spent much of the day in prayer and contemplation, and tried to live according to the precepts laid down by Jesus and the Gospels. Eventually, there were thousands of such seekers. Their surviving musings, usually referred to as the sayings of the Desert Fathers (e.g., Wortley, 2013), give clues not only to how they lived, but also to the sensed presences they encountered. These

Table 40.3 EUEs and Religious Enlightenment or Inspiration

Name	Religion	Life	EUE and Seminal Experience
Moses	Judaism	16th–13th Century BCE	Moses fled to the desert of Midian after killing an Egyptian slave-driver. As a shepherd tending his flock on Mount Horeb in the desert, he met God in the form of a burning bush. He was told to return to Egypt, liberate the Hebrews, and convert them to monotheism. After leading his people from Egypt, he again ascended Mt. Horeb, where God gave him the tablets of the Ten Commandments.
Gautama Buddha	Buddhism	6th–4th Century BCE	After sitting and meditating for 49 days under a pipal tree, the Buddha attained Enlightenment, formulated the Four Noble Truths of Buddhism, and encountered both harmful (Mara) and benevolent (Brahma) gods.
Jesus	Christianity	7–2 BCE 30–33 CE	Jesus was tested during 40 days of fasting in the desert ("wilderness"). During that time, the devil appeared and tempted him to perform miracles to prove his divinity, and then offered him kingship over the world if he would worship Satan. Jesus refused each temptation with a quotation from Scripture.
Muhammad	Islam	570–632 CE	Muhammad made repeated retreats alone to a mountain cave, where he was visited by the Archangel Gabriel bearing divine revelations that formed the basis of the *Koran*.
Joseph Smith	Mormonism	1805–1844 CE	God and Jesus appeared to Smith as he knelt in a forest and prayed for divine guidance. He was told that no current religion was the true one, and over time received the tenets of the Book of Mormon.
Mirza Husayn-'Alí ("Bahá'u'lláh")	Bahá'í	1817–1892 CE	Imprisoned in a dungeon as a heretic, he experienced a divine revelation that eventually led to a two-year retreat in the mountains of Kurdistan. During this period he wrote the seminal works of Bahá'í.

included not only God and Jesus, of course, as well as the saints of the Bible and later myths and legends, but also demons and Satan himself. In fact, the most famous Desert Father, St. Antony the Great, encountered so many evil spirits during his lone quest (about 279–356 CE) that he created the taxonomy and science of demonology (Kingsley, 1869/2016). As far as we know, such sensed presence entities did not evidence the compassionate helpfulness of those reported by explorers and sailors on the verge of death.

Another form of mystical seeking is the spirit quest, also known as the vision quest. This was a rite of passage once common to many indigenous cultures, but now in decline. The spirit quest, most standard for male adolescents about to become men, had to be endured stoically to warrant the candidate fit to become a husband, warrior, and full member of the community. Although in some cultures girls had a counterpart process, it was not as common and, where it existed, tended to be less taxing, painful, and dangerous (e.g., Markstrom, 2008).

The male spirit quest usually consisted of a period of isolation, sometimes with other aspirants but sometimes alone, food deprivation, abstinence from pleasant activities, and sometimes the infliction of serious pain. At the end of this time, the boy was sent into whatever the natural environment of the area offered: desert, mountain, forest, or jungle. In some traditions, he would wander around randomly or to visit holy sites; in others, he stayed still in a chosen location.

The quest ended when the boy found what he was questing for. This could be a totemic animal, a sacred dream, a magic song, an ancestor or spirit conferring his adult name on him, or an amulet that would inspire him and keep him safe. This form of the sensed presence experience was the culmination of an extended set of experiences that met some of the criteria we mentioned previously: solitude, weakness from fasting and pain, discomfort and sometimes danger, and fear of failure; and, in addition, the culturally normative expectation that the presence would eventually appear.

The vision quest could also be undertaken later in life, in a search for inspiration and spiritual support. As is often the case in human affairs, unexpected consequences could follow. The case of the Ghost Dance religion is instructive.

Wovoka, a Paiute mystic, having spent four days and nights during a solar eclipse (1889) alone on a mountain, described how he had been guided by God to a village populated by ghosts of Wovoka's deceased relatives. Wovoka announced that the spirits taught him a magic ghost dance, and perhaps—accounts differ as writers with differing sympathies interpret ambivalent stories—told him the secret of a magic ghost shirt that would ward off bullets. Wovoka then preached either a message of indigenous reunion, the alliance of the tribes with the spirits and each other, and a peaceful retreat by the whites who were encroaching on native lands—or the message that the shirt would make warriors bullet-proof when fighting the whites (e.g., Mooney, 1896; Tebbel, 1967).

The Ghost Dance cult spread across the American West (Figure 40.3). Eventually, it reached tribes that were more activist than the Paiute, such as the Oglala Sioux. The increasing popularity of the Ghost Dance and the implications of its bullet-repelling power sparked a heightening of tension, whether as the result of the emboldened natives or the rising fear of the settlers and soldiers that an uprising was imminent (or both). The eventual result was the killing of several hundred Lakota (Sioux) at Wounded Knee in 1890, apparently in response to the accidental discharge of a weapon, which was followed by firing from both sides (Tebbel, 1967).

Adopting and adapting the concept as the original inspiration wanes in aboriginal cultures, there is now a commercial company called Rites of Passage, whose website offers

> Vision Quests, retreats and training programs that bring people into a deep encounter with the natural world, exploring the human-nature connection to reflect and transform the inner world. This work begins with hearing the call to quest, an impulse as ancient as humanity: the path of the hero/ine. It will appeal to men, women and young people in life transition or change, and to those wanting to deepen their spiritual path and sense of purpose. . . . These ceremonies, with their challenges of solitude, fasting and exposure to nature, help us to affirm our inner strengths and capacities, face our fears, and listen to the song of our own soul rather than the world's distracting drumbeat. They will appeal to people who are at a point of change or transition in their lives, and to those who wish to deepen a spiritual or healing path. (Rites of Passage, undated)

A brief excursion from the topics of EUEs and ICEs to a topic that shares one, but not all, of their characteristics may be informative. The virtues of solitude and reduced stimulation for creativity and contemplation have been lauded by many people

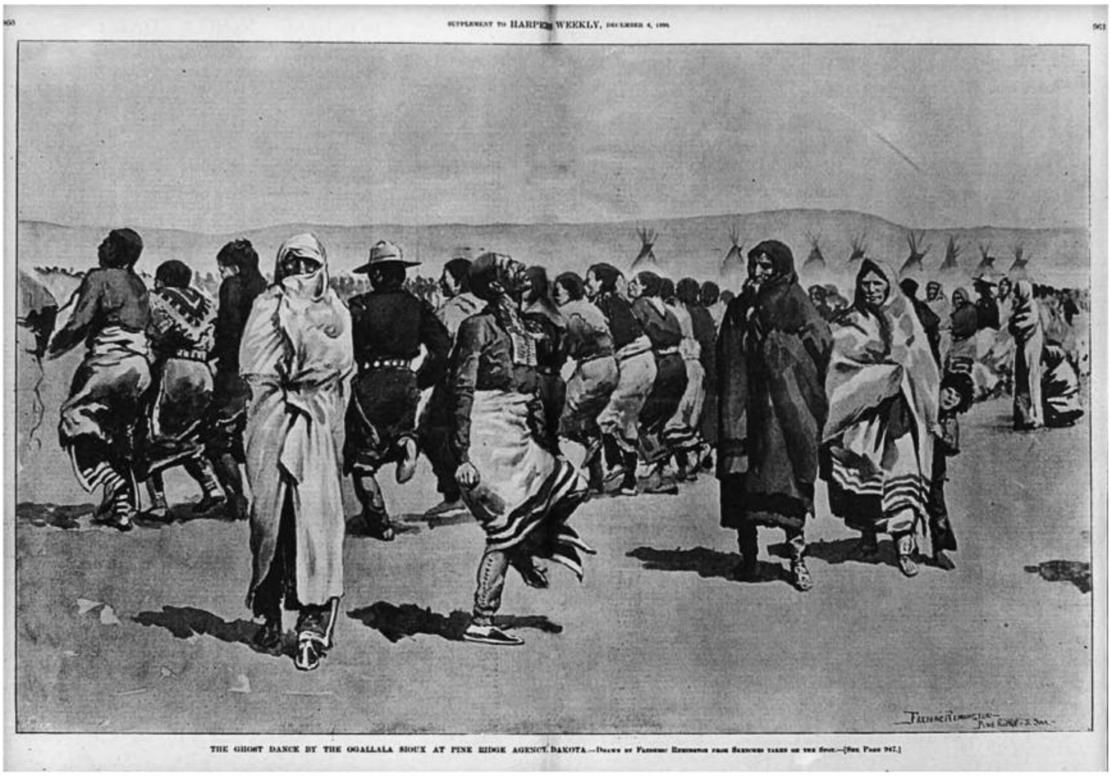

Figure 40.3. The Ghost Dance by the Oglala Lakota at Pine Ridge Agency. Drawn by Frederic Remington from "sketches taken on the spot." Published in *Harper's Weekly*, December 6, 1890, pp. 960–961. Image in the US Library of Congress; in the public domain.

who did not find it necessary to withdraw totally from society (Suedfeld, 1980). The British psychiatrist Anthony Storr (1988) published a compendium of painters, composers, writers, philosophers, and other creative individuals who needed to live and work in isolation. For many, this need went beyond the periods while they were actually engaged in achieving their creations, but permeated their whole life. Imagination, Storr suggested, flourishes best in solitude. Among the writers, musicians, and artists who recorded their views on the benefits of solitude are (in no particular order) Mozart, Picasso ("Without great solitude no serious work is possible"), Goethe, Sandburg, Kafka, Shelley, Gauguin, Aldous Huxley, Emily Dickinson, Thomas Carlyle, and Hermann Hesse. Scientists such as Einstein and Tesla did likewise. We can add to the list Descartes, Rousseau, Virginia Woolf, and—not to neglect creative psychologists—Raymond Cattell (Arieti, 1976; Suedfeld, 1974; Suedfeld, Metcalfe, & Bluck, 1987).

There can be unexpected life-changing experiences in EUEs, even when the person is not seeking them. One of the most surprising examples is the sudden emergence of spirituality and universalism among those who have traveled in space. At least four American astronauts (Eugene Cernan, James Irwin, Edgar Mitchell, and Russell "Rusty" Schweickart) have disclosed such changes (Simpson, 2016).[3] These ranged from a newfound belief in transcendental meditation and telepathic healing at a distance, to accepting UFOs as evidence of extraterrestrial intelligence, and organizing expeditions to look for Noah's Ark. Four astronauts is a small sample, but one must remember three relevant factors. One is that these astronauts were all practical, hard-headed men: military test and fighter pilots and engineers, who had passed the grueling tests of coping ability under stress that piloting high-performance jets and the ingenuity of NASA selectors had administered to them. The second is that NASA, the other astronauts, and the public perception of space explorers did not encourage "mystical" experiences. And last, these three examples are well known because the subsequent changes in the men's values were so dramatic, public, and long-lasting. We do not know how many of their colleagues, Americans and others, had less drastic reactions or remained quiet about them to safeguard their image and space career.

Solitude may be an important component of mental processes in EUEs and ICEs. Although there clearly is a need for human contact, its ubiquity is perhaps overrated in modern society. In a paper published over 40 years ago, I [P. S.] quoted a marginal note written in 1884 in my copy of the book *Solitude*, published 80 years earlier (Zimmerman, 1804). James P. Marsh, the previous owner, had commented: "One must collect his data in the city, he must judge and reason upon that data in solitude." My remark at that time was that the judgment seemed equally valid in 1973 (Suedfeld, 1974); and, in 2016, I still think so.

Stimulus Reduction in the Laboratory and in Therapy

In situations of severely reduced environmental input, human beings experience disruption of their accustomed levels of both stimulation and information. These two aspects are obviously related, although research has shown that they are not synonymous (Jones, 1969). Stimulus hunger leads to physical activity that increases the level of stimulation, such as increased movement or self-stimulation. It may also give rise to increased mental activity, some cognitive, such as trying to think about a life problem or trying to remember exciting events, but others that include some sort of altered state of consciousness: vivid daydreams and dreams, out-of-body experiences, and quasi-hallucinations (Zubek, 1969).

Researchers at McGill University, led by the eminent psychologist Donald O. Hebb, designed a procedure they named "perceptual isolation" in order to study the effects of monotonous and unpatterned stimulation. Experimental participants lay on a bed in a small, enclosed room, experiencing constant diffuse light and noise through the use of a translucent eye-shield and the transmission of white noise. The researchers reported the occurrence of complex and realistic hallucinations, including the iconic and often-quoted "squirrels marching across the visual field" (e.g., Heron, 1957). Strangely, the procedure and its dramatic consequences became known as "sensory deprivation," although in fact the subjects had been exposed to sensory overload. Constant light and noise, 24 hours a day for several days, is far above the normal level of stimulation encountered in ordinary life (Suedfeld, 1980).

Later, overstimulation was replaced by experiments employing a wide variety of techniques to achieve stimulus reduction. The most popular method was the use of dark, soundproof chambers (Figure 40.4). The terminology has also changed, to become more accurate and less anxiety-arousing. The terms *sensory deprivation, perceptual isolation*, and so on, common in the 1950s and 1960s, have generally been replaced by the labels *restricted environmental stimulation technique* or *therapy* (depending on whether the purpose is research or clinical treatment). Both versions are appropriately abbreviated to the acronym REST, which is both more

Figure 40.4. (See Color Insert) REST chamber, University of British Columbia. Photo by Peter Suedfeld.

accurate regarding the environment and free of the negative aura that came to surround the earlier labels (Suedfeld, 1980).

Subjects in REST chambers have reported spontaneous visual and auditory experiences unconnected to any stimulus that is obviously present in the chamber (Zuckerman, 1969). However, these were very different from those reported earlier, and did not meet the criteria for hallucinations: the subjects did not believe them to be real, were able to make them appear and disappear, and so on (Suedfeld & Vernon, 1964).

A more recent method for achieving deep levels of stimulus reduction is the flotation tank (Lilly, 1977). Tanks come in a variety of designs and sizes, but they have some common elements. All reduce the levels of ambient light and sound. Tanks are also located in an environment that itself is dark and sound-reducing—in a way, a REST chamber. They contain a dense, skin-temperature solution of water and Epsom salts, which is about 30 centimeters deep. The solution is thick and buoyant enough to make turning over a major effort, and to enable the participant to float on his or her back, with the face and ventral part of the body out of the water (Figure 40.5).

Floating in the solution has three major physical consequences: after a period of adaptation, the floater loses the sensation of where the skin ends and the ambient environment begins; the pull of gravity becomes imperceptible; and as a consequence of the latter, the muscular tension usually needed to counter the pull of gravity becomes superfluous, and deep muscle relaxation follows. Many floaters

Figure 40.5. (See Color Insert) REST flotation tank. Reproduced by permission of Float On LLC, Portland, OR.

report feeling as though they were floating in interplanetary outer space. Both the chamber and the tank have a range of beneficial effects, and have been widely used for stress management, relaxation, improved learning and athletic performance, and habit modification (Suedfeld, 1980; Suedfeld & Borrie, 1999). Table 40.4 summarizes some of the known aspects of the two major forms of REST.

REST subjects, whether in the chamber or the tank, have reported a great range of sensory experiences. Some of these are connected to the subtle progression between sleep and wakefulness experienced by many: hypnagogic or hypnopompic images, fleeting imagery during micro-sleeps, or actual dreams when the subject was not aware of having been asleep (a common phenomenon in REST). Many participants report pleasant images and memories of varying degrees of complexity, some of which are later recognized as dreams (Suedfeld & Borrie, 1978).

Other sensations are almost certainly due to actual stimuli that permeate the chamber or tank from the surrounding environment due to imperfect sound- or light-proofing. Total darkness can be created in either REST environment, but total silence is more difficult. In both modalities, the removal of salient stimuli would lower the sensory threshold so that normally undetected inputs can suddenly be sensed. In the tank, small ripples of the solution and the smell of the dissolved Epsom salts also provide low-intensity stimulation. Other sensations may have arisen from endogenous stimuli such as bodily noises and spontaneous neural firing behind closed eyelids, sometimes actually keeping the person from falling asleep.

Table 40.4 Established Aspects of Chamber and Flotation REST

Variables	Chamber	Flotation Tank
Research begun	1950s	1970s
Ambient light	None	None
Ambient sound	Residual	Residual, music
Tactile stimuli	Bedding, food, toilet	Epsom salts solution
Standard duration	24 hours	60–90 minutes
Special aspects	Diverse environments	Commercial facilities
Negative connotations	Brainwashing, torture	New age, mysticism
Applications	Learning, recall, habit modification, time out	Stress management, pain relief, motor performance

Many sensations, images, and spontaneous thoughts experienced in REST can be traced back to the subject's concerns in daily life. These, and some exploration of the immediate vicinity of one's body, usually last for the first quarter-hour or so of the session, but some of these thoughts and daydreams become persistent. For example, a mother who was worried about her children "heard" the children's voices, which became more and more insistent and sounded increasingly anxious. Eventually, she became convinced that something was wrong at home, and cut the session short because she could not shake the thought that the children were in danger. A man spending 24 hours in the chamber REST as part of a smoking cessation study kept thinking he smelled cigarette smoke; another, part of a weight-loss study, used the intercom to compliment the monitor on the appetizing aroma of the morning coffee being brewed (which, of course, was not happening). Some people dream about events that break the monotony of the 24-hour chamber session: people coming in to visit, or the subject taking a walk or trip outside (Suedfeld & Borrie, 1978). This can include a dream that the REST session had been terminated, and the individual was back in the customary environment, sometimes feeling frustrated at having had to leave the chamber. A writer who went into the tank in order to write about the experience reported,

> During the first phase of every float, a sort of frantic summary of the immediate conditions of my life intermingles with random, angsty [*sic*] ruminations. The personal blends with the general, the trivial with the profound.
>
> When are tax returns due? Am I eating too much wheat? I'm bored. Is it too hot in here? Everyone I know will one day die. Must remember to buy toilet roll. Should I be putting "all the best" or merely "best" at the end of my emails? Overpopulation. My first kiss. Can I actually muster anything meaningful to say about this for *Aeon*? What *is* the difference between flotsam and jetsam? This is what the dark initially provides. A psychic carnival of just about everything that isn't the eminently worry-free present. (Owen, 2015)

After the first period of exploration and mind-wandering, people tend to settle into a state of relaxed, free-flowing mental process. From the earliest days of REST research, it has been clear that allowing and enjoying this free flow of thought, memory, and imagery is conducive to a pleasant session in the chamber or tank. Personal memories while floating tend to be those that are more frequently retrieved in daily life, and are on the whole culled from the more pleasant items in that storehouse (Suedfeld & Eich, 1995). Some report a meditative state; a Zen master who spent an hour floating in my own laboratory tank told me that although he meditated for several hours every day of his adult life, the depth of meditation that he had achieved in the tank was matched by only three or four that he reached during any year.

Lilly's seminal book (1977) has a section reproducing the remarks of people who floated in his program. Many were veterans of Esalen and other consciousness-expanding projects, sometimes including hallucinogenic drugs, and they prepared for the float by reading Lilly's publications. Some, but not all, of these more than 80 people were famous for their creative work in various fields. This group included the epistemologist and systems theory pioneer Gregory Bateson; the satirical journalist Paul Krassner; human potential guru Werner Erhard; actor and show business entrepreneur Burgess Meredith, who merely found the tank restful; and Louis Jolyon West, the eminent UCLA psychiatrist. A very public and charismatic figure, West studied the "brainwashing" of American prisoners of war in Korea, the forced conversion of kidnap victim Patricia Hearst, hallucinations, sleep deprivation, and the effects of child abuse, and vociferously opposed Scientology, the death penalty, and corporal punishment for children. He gained more notoriety for inadvertently administering a lethal dose of LSD to Tusko, a much-loved Oklahoma City zoo elephant, in the course of an experiment. For such a colorful person, West's response to the tank was bland: "a smoothly unbroken flow of both digital and analog information. . . . Emerged refreshed" (Lilly, 1977, p. 250). On the other hand, physics Nobelist Richard Feynman reported "*the usual* out-of-body or out-of-the-right-time hallucinations" [emphasis mine; P. S.] and judged that "the hallucinations are a delightful and entrancing union of spontaneity of detail with a pattern or set which you have made or can make about their overall character" (Lilly, 1977, pp. 199–200).

Most of Lilly's participants floated for more than the now-standard hour and a half, and more than once. Some had amazing "trips": Myron Glatt, for instance, reported flying past the Orion nebula and then "hitting a few stars and barns and generally getting it on" (p. 204). Auditory sensations also occurred, one floater hearing many voices, coming from different directions—but all of the voices were his own. The range of spontaneous thoughts, emotions, and images is vast, and for the most part within the range of those reported later.

Lilly himself (1977) provided us with detailed, unusual, but probably idiosyncratic introspections about what happens in the flotation tank, based on his neuropsychological and transcendental speculations. He described leaving his own body in the tank and achieving contacts with "guardians": "beings other than himself, not human, in whom he existed and who control him and other human beings" (p. 259). These experiences occurred in experiments combining flotation with LSD, one of several psychotropic drugs that he ingested in the course of flotation studies. In this later work, he rejected attempts to quantify people's experiences in REST, to eliminate artifacts such as expectancy effects, or to incorporate replications or control conditions in his experiments. In general, he disdained the standard parameters of scientific rigor.[4]

Participants in chamber studies tend to think about personal matters, such as their friends, or a specific problem they want to deal with; but the thoughts they rate as the most useful in passing the time in the chamber deal with the future or the past. Other useful mental activities were trying to guess the time, identifying sounds, and "staring at the wall"—presumably meaning just keeping one's eyes open, since the wall would have been invisible in the dark chamber. The same study found that memory for materials learned prior to entering the chamber had improved by the post-session test, confirming previous findings of memory improvement during chamber REST (Suedfeld et al., 1985–1986).

Especially in 24-hour or longer chamber studies, people who try to maintain control over their thoughts frequently find themselves unable to do so for long. Many then relax and enjoy the flow, and even turn it into a creative reverie (as many tank floaters do). Psychoanalysts consider this the result of being comfortable with primary process ideation, the product of the unconscious flow uncontrolled by the reality-oriented ego; individuals who are not comfortable when this happens tend to find the chamber period unpleasant (Goldberger & Holt, 1961). Although this chapter is not the place for a discussion of REST theories, one for which both psychological and neurological evidence exists is that in REST neural processing shifts somewhat, to the advantage of the non-verbal, non-linear functions (Suedfeld et al., 1994).

Attempts have been made to establish whether REST enhances creativity. Several studies of divergent thinking during or after time in the chamber failed to find any consistent pattern; but divergent thinking tests are a questionable measure of creativity. "Real" creative thinking has been studied in a few flotation experiments. Experimenters reported that flotation enhanced conceptual synthesis and scientific thinking among chemistry students (Shore, 1970; Taylor, 1990), and one found that psychology faculty members produced more creative research and theoretical ideas after floating than they did during a session of sitting in their office (Suedfeld et al., 1987). It is interesting that there have been no published studies of changes in artistic, as opposed to scientific, creativity, except for one study. It reported that a small number of music students performing jazz improvisation were rated by their professor as more technically proficient after several floats than a non-floating control group. However, they were not superior in improvisation quality. In other words, floating had improved their perceptual-motor skills, as it has been shown to do in a string of studies on sport performance; but its effect on creativity per se was moot (Vartanian & Suedfeld, 2011).

It may be that the structured procedure of the REST laboratory is not conducive to artistic creativity, or inviting to creative artists. The past few years have seen an amazing proliferation of commercial tank facilities, offering one or two hours of floating at a reasonable cost. There are at least 300 such facilities in North America, with many others spread around the world. Many invite their customers to sit for a while after they leave the tank, and some provide writing materials for them to record their thoughts and feelings. So far, no one has collected and edited the results, but a quick look through some of the folders reveals drawings, poetry, short essays and fiction, profound musings, jokes, limericks, and so on. Vividly described visual imagery is common, as are thoughts about humanity, the Earth, and the universe.

In an innovative project, a float tank operation in the United States recruited 150 artists in its city and offered them floats in exchange for their post-float reactions. The results have been published in an intriguing book (Talley & Jahromi, 2011). The contributions span verbal and graphic art, both abstract and representational. A few of the pages communicate anger or anxiety, but most of the images in both modalities convey a feeling of restfulness (no pun intended). There are many images of water, many recumbent or otherwise clearly relaxed human and supernatural figures, animals (including fish, birds, insects, and a giant snail with two children on its back), and a centering of the physical and psychological self, such as a creation by Cora Pearl, filled with different representations of the word "Breathe," and ending with "I remember now." Another of my favorites is Cori Kindred's page, with small panels around the sides showing drawings of plants, birds, and geometric patterns. The central panel depicts "My heart twinkling in the Dark" (Figure 40.6).

If researchers can't document the spontaneous creative consequences of floating, we may have been overlooking the most promising subject population. But these products of the REST tank were physically created after the session, not during it, so their status as "spontaneous thought in an unusual environment" is arguable; and, just as in the case of Lilly and his project, the nature of the participants leaves unanswered the question of whether flotation enhances creativity in a general population.

"Darkness Therapy"

There have been well over a hundred published reports of REST (both chamber and flotation techniques) being used in therapy. Most concentrate on the reduction of symptoms, but a few have given clients the opportunity to verbalize freely about their REST experience. There has been worldwide publicity about the proliferation of float centers during the past decade, but little attention has been paid to a resurgence of chamber REST, either in research or in applied use. Such a resurgence has been the use of "Darkness Therapy" in several places in Europe, especially in the Czech Republic (e.g., Kupka, Malůš, Kavková, & Němčík, 2014; Urbiš, 2012). Although some participants are seeking a novel experience or a chance for self-exploration, many are clients in stressful life situations. They are looking for an opportunity to relax and regenerate, take time out, and concentrate on problem-solving in a low-demand, low-pressure environment that has been compared to a walk-in Rorschach blot in its freedom to explore the mental landscape. Participants may be seeking a new direction in life, professionally, romantically, or personally, and may view Darkness Therapy as a rite of passage to that new direction. Some use the analogy of the chamber

Figure 40.6. (See Color Insert) Art from the flotation tank. Created by Cori Kindred and reproduced by permission of the publisher and copyright holder, Float On.

being like the womb, from which they emerge into the light and a new life.

Each facility is a small, isolated building divided into at least two rooms, with a sound-reducing and light-proof wall separating the room next to the outside door from the inner space. This is necessary because the participant stays in the room for at least one week, and the antechamber is daily restocked with food and liquids as needed (stimulants and alcohol are barred). When that happens, the participant remains in the back room so that the condition of darkness, silence, and isolation is not disrupted.

Unlike in the much more restrictive REST laboratory, Darkness Therapy clients are free to move about the environment, which contains furniture, exercise equipment, and in some facilities a telephone that connects to a monitoring station. The client can use it to transmit any requests or problems. Unless asked to stay away, the therapist enters the facility every day for a session of interviewing and counseling. Clients and therapists both report that the course and speed of therapeutic progress is facilitated by the experience of darkness, recalling similar observations by clinicians using the older versions of chamber REST (Solomon et al., 1961). One of us (M. M.) hypothesizes that the environment creates an improved connection between the body and the mind, between reality and imagination.

Post-experience growth, analogous to post-traumatic growth, is well supported. For example, a pilot study with a non-clinical Darkness Therapy sample, which administered a questionnaire in a test-retest design, found self-reported increases in the experience of the meaning of life, mindfulness, and self-esteem; and decreases in many psychopathological categories (Kupka et al., 2014).

Visual and auditory sensations are frequent, as are vivid dreams. The connection between mood and endogenous sensation can be vivid, as in the following (translated from the Czech by M. M.):

> With each day spent in the dark, a pallet of colours was growing within me which I perceived and could not get enough of. During the day we see hundreds of shades of vivid colours and it is natural for us. In the dark the colours were toned down and were changing quickly, creating patterns of endless shapes. . . . On the last but one day, the bringer did not bring me the apples I was craving. I was so upset, I was not able to perceive anything. Immediately, there was a thick dark matter around me descending lower and lower, so in a while I had the impression that I had to bow my head so I do not bump it. Because it was on the sixth day, I proudly stood upright and was awaiting what was to happen next. I probably cursed too. Then it occurred to me that I could be cool about it, not getting angry because of a couple of apples, and as I calmed down, everything around me started to brighten. I could see the amazing shapes and their movement again. I accepted it as a great lesson. Don't get upset, be yourself, do not deal with trivialities. And that is great art in normal life. . . . (quoted in Malůš, Kupka, & Kavková, 2013, p. 326)

The Darkness Therapy facility contains materials for clients to record their feelings and thoughts as these occur, as well as for doing that retrospectively. Figure 40.7 shows a work of art produced by one such client.

Analyzing his own Darkness Therapy session, one of the researchers wrote:

> In breaks between individual meditation sessions the process of active imagination started. It was mostly a spontaneous process which was related to key events in my life. From the point of time perspective it dealt with the past. The images of situations and events were vivid and in full detail. It was an authentic "inner film." What was absolutely essential for me was meeting my dead relatives and close people; their understanding, forgiveness and acceptance. Those images were emotionally and behaviourally very strong, with a huge potential for personal and therapeutic growth.

The account continues, combining the personal with the professional:

> Surprisingly, I was able to remember faces and names of my former classmates from primary school, stories with my first friends from the childhood. I remembered family events and stories. They were unpleasant, sometimes embarrassing, anxious, tragic and desperate, and also lovely, funny and inspirational. The years of my life had passed and I realized how rich the life was and what was hidden in it. It came to mind Jung's simile on an iceberg (1994) that we could see only a very small part of a person, that every person is more than he knows about himself and what he can say about himself. Almost all imagination material has an interpersonal component. It is the interpersonal recapitulation that we consider to be therapeutically beneficial. . . . Regarding staying in the darkness, silence and solitude we find it logical it is the solitude that evokes the need to fill the empty space with people. (Malůš et al., 2014, pp. 185–186)

Not everything experienced during the week-long session is necessarily pleasant. One of the current authors (M. M.) was working through a great variety of mental states, including negative emotions, thoughts, and memories, during the fourth day of his first stay in Darkness Therapy. Experiencing many physiological symptoms of arousal and anxiety, he developed a strong feeling that he could see a devil's face with burning red eyes. He was filled with dread of insanity or death. Gradually reinterpreting the image as a rejected part of himself that wanted to be integrated, he came to accept that part of his personality. As a result, he wrote,

> From my existential anxiety I am now experiencing strength, joy, gratitude and love. Is it another piece of the puzzle of my life fitting into its place? . . . I am going to bed, it's time to go to sleep (tomorrow another sizeable portion of my past is going to be purified). I think that the "real" stay in darkness, for which I came, started in earnest (and it was not for free)! (One of the current authors [M.M.])

Conclusion

As we have seen, extreme and unusual environments vary tremendously along a number of both physical and psychological dimensions. Even when we restrict—as we did in this chapter—our

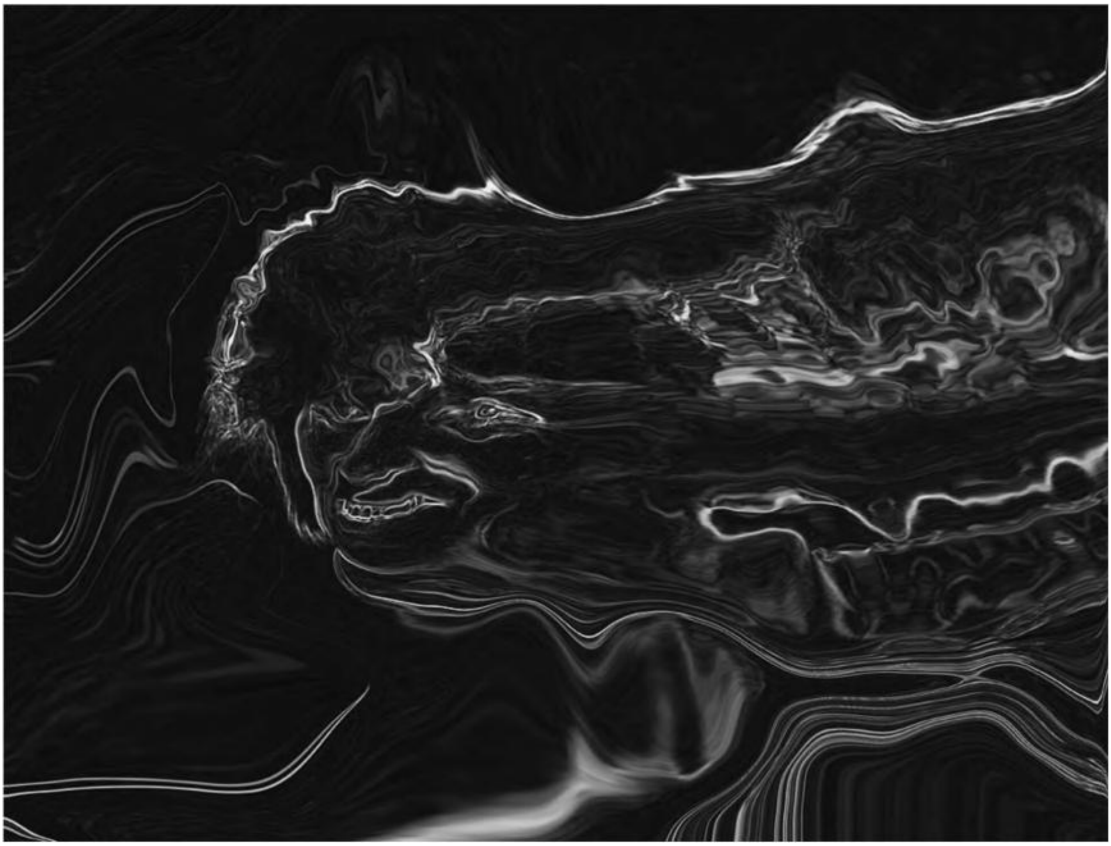

Figure 40.7. (See Color Insert) "Lady Darkness": Art from Dark Therapy.

discussion only to those EUEs that are characterized by relatively low levels of social and sensory stimulation, we are left with the gamut from the immensity of space to the micro-environment of the flotation tank.

Nevertheless, we can draw at least a few conclusions. Perhaps the most striking is that in environments that most people (even human behavior professionals) tend to consider aversive and difficult to tolerate, most actual participants adapt well and even flourish. They also tend to report feelings of post-experience benefits: greater self-confidence, courage, and optimism about the future; stronger belief in their own abilities; increased awareness of love for family and friends, care for human beings in general and for future generations especially.

During their time in the EUE, they can relax with free-flowing ideas, pleasant memories, and various forms of imagery. Some of that can be focused to deal with life problems, enhance performance, make spiritual contact with a transcendental world, and benefit more from counseling or therapy by achieving a deeper understanding of one's own self. Other experiences of this sort may just be enjoyed. The lesson, we think, is that looking at events and experiences from the outside does not give us a trustworthy picture of what those are like for the people actually living through them. The implication of this, in turn, is that although many people deliberately seek out EUEs for these positive experiences, most of them have little sense of what the experience will actually be like—at least not the first time.

This is not to deny that there are also negative experiences. We have discussed the lapses of rational thinking and awareness that can occur in EUEs characterized by monotony and "empty time." Not all of the images conjured up in the course of EUE life are pleasant, and not all of the human interactions are friendly. But as is so often the case, situations and events that look daunting and even traumatic to observers may be felt as much less—or not at all—so by participants.

Among the most intriguing spontaneous reactions is the sensed presence phenomenon. Despite the many reports and competing theories of subjectively similar experiences such as hallucinatory, out-of-body, and near-death reports (see, e.g., Choi, 2011; Persinger & Makarec, 1992), the apparition who actually helps still leaves everyone baffled. There is an old saying that "science is the search for new questions." We leave this one to the reader.

Notes

1. No study; but one of us [P. S.] has had a Long Eye event in an Arctic station after finishing work and while having to wait for several days with nothing to do because bad weather repeatedly delayed the scheduled air-evac flight out.
2. I [P. S.] must add one more hypothesis: out-of-body travel. After I described these cases at an anthropological conference, a member of the audience challenged the theories I had summarized. She said that she was a member of a group that on several nights sensed an urgent need for help or rescue somewhere in the world, left their bodies, traveled to the site of the emergency, and helped in any way they could. They then returned, and next morning woke up physically tired, and sometimes with minor injuries such as scrapes and bruises from handling tools and moving rocks, dirt, construction materials, and so on. When she asked me why I had not mentioned this as the possible explanation of the "presence" phenomenon, all I could say was that it was outside the empirically testable theories that circumscribe my scientific worldview. This paragraph should atone for my earlier omission; note, though, that reports of sensed *groups* are extremely rare.
3. I (P. S.) thank Dr. Gloria Leon for drawing this article to my attention.
4. In fact, he rejected the term "restricted environmental stimulation technique," and came up with his own expansion of "REST": restore energy safely traveling."

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CHAPTER

41 Cultural Neurophenomenology of Psychedelic Thought: Guiding the "Unconstrained" Mind Through Ritual Context

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Abstract

This chapter explores psychedelics as catalysts of spontaneous thought. Classic serotonergic psychedelics such as psilocybin, LSD, and ayahuasca can induce potent alterations in cognition and perception. The chapter reviews research on these substances through the lens of cultural neurophenomenology, which aims to trace how neurobiology and sociocultural factors interact to shape experience. After a decades-long hiatus, the scientific study of psychedelics is rediscovering the potential of these substances to promote creative insight, evoke mystical experiences, and improve clinical outcomes. Moreover, neuroimaging experiments have begun to unravel the influence of psychedelics on large-scale connectivity networks of the human brain. Tapping perspectives from the social sciences, the chapter underscores how culture and context constrain the flexible cognitive states brought about by psychedelics. This integrative approach suggests that seemingly spontaneous psychedelic thought patterns reflect a complex interaction of biological, cognitive, and cultural factors—from pharmacology and brain function to ritual, belief, and expectation.

Key Words: psilocybin, LSD, ayahuasca, psychedelic, cognition, mystical experience, neurophenomenology

Psychedelic substances can profoundly alter the phenomenology of thought. The term *psychedelic* (from the Greek *psychē*, ψυχή, meaning "spirit" or "self," and *dēloun*, δηλοῦν, meaning "to reveal") denotes a broad range of natural and synthetic substances that evoke a variety of culturally mediated experiences, including atypical visual and auditory phenomena, shifts in temporal and spatial perception, and intense emotions ranging from terror to wonder. Although the empirical study of psychedelics began in earnest only in the twentieth century, cultural groups have consumed psychedelic plants in ritualized contexts for millennia (Schultes, 1972). The use of these substances may pose social and psychological risks when ingested without prudence, but they can also be consumed safely (Johansen & Krebs, 2015; Nutt, King, Saulsbury, & Blakemore, 2007). Indeed, psychedelics continue to play a vital role in many spiritual and healing practices around the world (Goldsmith, 2010).

Throughout the history of experimental research on psychedelics, scholars have often emphasized the capacity of these pharmacological agents to loosen the hold of habit over patterns of thought (Busch & Johnson, 1950; Cohen, 1964; Huxley, 1977). A growing body of empirical evidence lends support to this view: experimental findings indicate that classical serotonergic psychedelics such as psilocybin (found in over 200 species of mushrooms), ayahuasca (an Amazonian plant-based brew containing dimethyltryptamine—i.e., DMT—and monoamine oxidase inhibitors), and lysergic acid diethylamide (LSD) can increase the flexibility of human brain function, promote creative insights, foster therapeutic outcomes, and engender mystical experiences (Carhart-Harris, Leech, et al., 2014; Chambers, 2014; Fadiman, 2011; Richards, 2015).

Subjective reports of experiences with psychedelic substances frequently highlight the unconstrained, spontaneous nature of the phenomena, which are often described as involuntary, surprising, and profoundly different from ordinary experience. However, the anthropological literature suggests that psychedelic experiences are strongly constrained by social factors related to culture, context, and individual disposition (Dobkin de Rios, 1972; 1984; Labate & Cavnar, 2014; Langlitz, 2012). Indeed, ethnographic research documents a wide range of ritual practices among diverse cultural groups that aim to evoke specific experiences or to strategically direct the flow of thought stimulated by psychedelics to achieve personal and social benefits (Calabrese, 2013).

In this chapter, we focus on classical psychedelics, which act primarily on the serotonin receptor system, and leave out discussion of other neighboring classes of substances, including dissociative psychedelics (e.g., ketamine) and entactogens (e.g., MDMA). While these other substances are sometimes referred to as psychedelics, they involve distinct albeit overlapping alterations in phenomenology, display different neurochemical binding properties, and likely exert their behavioral and experiential effects through separate mechanisms (Nichols, 2004).

We approach classical serotonergic psychedelics in terms of *cultural neurophenomenology*, which aims to trace how neurobiology and sociocultural knowledge and practice interact to give rise to experience. We synthesize quantitative experimental data with qualitative accounts, including from ethnographic fieldwork by one of the lead authors of this chapter studying a transnational religion centered on the ritual consumption of the ayahuasca brew (Oda Sheiner, 2016). We begin by reviewing research that examines how psychedelics impact functional organization among brain networks related to perception, higher-order control, and spontaneous thought. We then explore the implications of this supposedly unconstrained cognitive state by examining psychedelic effects on creative thinking, mystical experience, and therapeutic practice. In the final sections of this chapter, we incorporate ethnographic and social scientific perspectives to illustrate how culture and context constrain the flexible cognitive states brought about by psychedelics. This approach allows us to explore nuances of interactions between phenomenology and ritual context that complement laboratory findings grounded in behavioral, cognitive, and neuroscientific investigation. The integrative perspective we present suggests that seemingly spontaneous psychedelic thought patterns reflect a complex interaction of biological, cognitive, and cultural factors—from pharmacology and brain function to ritual, belief, and expectations.

Historical Context

Research on psychedelics has been strongly influenced by prevailing cultural attitudes toward substance use. The theoretical models, assumptions, and goals that researchers have historically brought to bear to examine psychedelics have shaped the very experiences they aimed to understand. For example, researchers in the mid-twentieth century typically viewed psychedelic experiences as models or mimics of psychoses, hence the designation of "psychotomimetics" (Dyck, 2006; Hoffer, 1970; Osmond, 1957). Research on psychedelics was pursued because it might shed light on schizophrenia or other psychiatric disorders. Some researchers even encouraged clinicians to try LSD themselves in order to empathize with their patients and obtain a deeper understanding of psychotic experience (Dyck, 2006; Sessa, 2005; Pahnke, Kurland, Unger, Savage, & Grof, 1970).

Although the study of psychedelics as a model for psychosis persists to this day (e.g., Geyer & Vollenweider, 2008; Steeds, Carhart-Harris, & Stone, 2015), it was not long before researchers emphasized important differences between psychedelic and psychotic experiences—most notably, that judicious psychedelic use often yields toward positive experiences, while psychosis is more often marked by distress (Osmond, 1957; for a contemporary study addressing these issues, see Carhart-Harris, Muthukumaraswamy, et al., 2016). Around the same time, researchers began to note the potential for psychedelics to catalyze vivid spiritual and mystical experiences (Huxley, 1954; Panhke, 1963). Moreover, positive subject reports, as well as overlaps between psychedelic experiences and clinical conditions, inspired clinicians to begin experimenting with the use of these substances in therapy (Osmond, 1957; Pahnke et al., 1970).

The striking variety of responses induced via pharmacologically identical agents led early theorists to emphasize the role of contextual factors in shaping psychedelic outcomes (Mogar, 1965). As described in a guidebook penned by a group of Harvard scholars—including Timothy Leary—that promoted psychedelic culture, therapy, and spirituality: "the nature of the experience depends almost entirely on set and setting. Set denotes the preparation of the individual, including his personality structure and his mood at the time. Setting is physical—the weather, the room's atmosphere; social—feelings of persons present towards one another; and cultural—prevailing views as to what is real" (Leary, Metzner, & Alpert, 1964/1971, p. 9).

By the 1960s, more than 40,000 subjects had participated in studies on psychedelics, and more than 1,000 clinical papers had been published (Grinspoon & Bakalar, 1979). Access to psychedelic substances trickled from university and hospital laboratories into the public. Excessive claims and misuses began to surface from both researchers and recreational users, and associations between psychedelics and countercultural movements became increasingly salient. Eventually, prominent members of the medical establishment urged government agencies to tighten regulation of psychedelics. For example, psychiatrist Roy Grinker, then-president of the American Medical Association, accused researchers of "using uncontrolled, unscientific methods. In fact, these professionals are widely known to participate in drug ingestion, rendering their conclusions biased by their own ecstasy. . . . The psychotomimetics are being "bootlegged," and as drugs now under scientific investigation they are being misused" (Grinker, 1964, pp. 768). By the end of the 1960s, recreational use of psychedelics was largely illegal, and research on these substances entered a hiatus (Grinspoon & Bakalar, 1979; Grob, 1994). Following almost three decades of silence, the past 20 years have witnessed a revival of empirical research on psychedelics, with rigorous demonstrations of safety and therapeutic effects, and a growing body of work exploring cognitive and neurobiological mechanisms (Langlitz, 2012; Pollan, 2015; Sessa, 2012).

Spontaneity, Flexibility, and Constraints

Many prominent theoretical models frame psychedelics as substances that loosen or unconstrain cognition by promoting novel, spontaneous connections among thoughts, emotions, and sensations that are typically disparate (Carhart-Harris, Leech, et al., 2014). For example, a hallmark feature of psychedelic phenomenology is synesthesia-like experience, in which perception in one sensory or cognitive modality activates sensation in a different modality (e.g., tasting sound, or seeing colors in response to digits; Luke & Terhune, 2013; Shanon, 2002). Compared to congenital synesthesia, however, synesthesia-like associations induced via psychedelics seem less consistent and not as specific to the triggering stimulus (e.g., after taking LSD, seeing the number seven might sometimes trigger a sense of the color green, but might other times trigger the sense of a different color or no sense of color at all; Terhune et al., 2016). Historically, some psychodynamic clinicians viewed psychedelic substances as "psycholytic" (i.e., mind-loosening) to emphasize their value for unlocking latent associations essential to the course of therapy (Gasser, 1994; Madsen, Øyslebø, & Hoffart, 1996). Contemporary approaches continue to emphasize the fluid associative quality of psychedelic experiences (Letheby, 2015; Majić, Schmidt, & Gallinat, 2015; Shanon, 2002).

But what do we actually mean when we call thought "spontaneous" or "unconstrained"? In the context of the present volume, the notion of spontaneous thought arises from ongoing work in cognitive science that recognizes the importance of studying what the mind and brain do in the absence of, or when tuning out, external stimuli or task demands (Andrews-Hanna, Smallwood, & Spreng, 2014; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007). One leading perspective defines "self-generated" thought as "mental contents that are not derived directly from immediate perceptual input" (Smallwood & Schooler, 2015, p. 489). Cognitive scientists have proposed a variety of terms to delineate this inner world of cognition: spontaneous thought, daydreaming, self-generated thought, mind-wandering, undirected thought, stimulus-independent thought, task-unrelated thought—the list goes on. As the diversity of contributions to this volume attests, these terms encompass a wide spectrum of experiences, from recalling memories and imagining the future to thinking creatively and dreaming. The editors of this book propose a helpful taxonomy that further specifies the spontaneity of thought in terms of types of constraint (Christoff et al., 2016). This framework describes two main types of constraint on the content and flow of thought: (1) *deliberate constraint* by cognitive control, such as when effortfully attempting to recall the name of your first love; and (2) *automatic constraint* operating involuntarily, such as when thoughts about the object of your infatuation intrude during attempts to write a chapter.

How does psychedelic phenomenology map onto this framework? While psychedelic substances may be deliberately ingested, the subsequent thought patterns and sensory experiences are often viewed as unpredictable and largely involuntary. However, as we shall discuss, in many instances of ritualized or therapeutic use a measure of deliberate constraint or control is exerted by explicit instructions or other situational factors. For instance, listening to music plays a key role in many rituals of psychedelic healing (Kaelen et al., 2016; Shanon, 2002). Such external constraints may drive specific content, emotional tone, or even the impression of having no control over the experience. In general, psychedelics likely reduce both deliberate and automatic constraints over the content and flow of thought, as well as over the processing and interpretation of outside stimuli. In terms of phenomenology, psychedelics tend to impede the ability to voluntarily control the content and progression of thought (Shanon, 2002). The stream of psychedelically mediated visions, sounds, and associations is typically experienced as less deliberate and predictable than everyday thinking, sometimes to the point that it seems to flow from an outside source (Oda Sheiner, 2016; Strassman, 2000). As we will see later in this chapter, the reduction of such voluntary and automatic constraints may help foster novel associations in creative thinking, open a space for atypical modes of subjectivity in mystical experience, and help overcome maladaptive patterns of behavior in therapy.

Of course, even when constraints may appear low, our thoughts are inexorably bound to our personal histories and broader sociocultural surroundings. Ethnographic and enactivist perspectives in cognitive science argue that our experiences and expectations—embedded in the narratives, symbols, body practices, and scripts of specific social and cultural contexts—influence the content and process of thought at the most basic levels of attention, sensation, and perception (Barsalou, 2008; Han et al., 2013; Hinton, Howes, & Kirmayer, 2008; Kay & Kempton, 1984; Ramstead, Veissière, & Kirmayer, 2016). No matter how seemingly spontaneous, no thought is completely free from such situational constraints. For example, although psychedelic experiences often involve seemingly self-generated perceptions, the specific content of these manifestations tend to reflect personal stories and cultural concerns—as in the case of religious psychedelic users in Canada, who sometimes report visual and auditory phenomena ascribed to local Aboriginal spirits (Oda Sheiner, 2016). While the influence of individual and cultural context likely holds for most forms of human thinking, it is particularly pertinent in the context of psychedelics. Paradoxically, by virtue of being less constrained by voluntary control and certain automatic cognitive patterns, the psychedelic mind may in fact become more susceptible to the influence of cues arising from individual history and social environment. The psychedelic mind, we propose, is akin to a clay sculpture that, when wet, becomes more pliable and therefore more readily shaped by the forces of culture and context.

Neuroplasticity is basic to learning and adaptation. Many practices of healing may function by inducing cognitive flexibility or an enhanced ability to shift psychological sets (Kashdan, 2010). Flexibility as such, however, is not enough. Interventions that heal seem to do so by at once enhancing flexibility and providing symbolic ritual frameworks that encourage shifts to more positive mental states marked by openness and optimism (Hinton & Kirmayer, 2017). In the case of psychedelics, the unconstrained mental state may be highly labile or volatile. Feelings of overwhelming anxiety, isolation, and confusion surface as readily as experiences of peace, empathy, and insight (Masters & Houston, 2000; Shanon, 2002). While popular notions of spontaneity may bring to mind states of hedonic, free-and-easy play, the spontaneity induced by psychedelics is more capricious. Psychedelic spontaneity is not inherently pleasant, creative, or beneficial; it can at times involve intensely negative imagery and emotions, or the disorganized thought patterns characteristic of psychotic distress (Carhart-Harris, Kaelen, et al., 2016; Osmond, 1957). Thus, promoting healing with psychedelics likely requires constraining the unconstrained mind through symbolic situational cues and embodied rituals that emphasize the potential to move from maladaptive patterns toward constructive states and behaviors. We will return to such rituals later in this chapter. First, we will flesh out the notion of unconstrained cognition in empirical terms, beginning at the level of neurobiology and working our way up to its expression in domains of creativity, mystical experience, and therapeutic practice.

Psychedelics Unconstrain Cognitive Brain Function

A mounting body of neuroscientific evidence supports the general theory that psychedelics unconstrain cognition. In this section, we provide a selective review of the emerging cognitive neuroscience of psychedelics, focusing on findings that concern the flexibility, disorganization, and integration of brain function (for a concise review of these findings accessible to non-experts, see Carhart-Harris, Kaelen, & Nutt, 2014; for more in-depth reviews, see Carhart-Harris, Leech, et al., 2014; Halberstadt, 2015). At the molecular level, converging work with both animal and human models indicate that classical psychedelics (such as psilocybin, LSD, and ayahuasca) function primarily as agonists at the serotonergic 5-HT_{2A} receptor (Nichols, 2004; Vollenweider, Vollenweider-Scherpenhuyzen, Bäbler, Vogel, & Hell, 1998). Studies have associated 5-HT_{2A} receptor signaling with cognitive flexibility (Boulougouris, Glennon, & Robbins, 2008; King, Martin, & Melville, 1974), associative learning (Harvey 2003; Romano et al., 2010) and cortical neuroplasticity (Gewirtz, Chen, Terwilliger, Duman, & Marek, 2002; Vaidya, Marek, Aghajanian, & Duman, 1997). As noted by Carhart-Harris et al. (2015), such findings support the proposal that 5-HT_{2A} signaling via psychedelics may promote the plastic reorganization of neural circuits.

At the systems level, a number of neuroimaging studies have converged on the notion that psychedelics dampen key hubs of cortical integration that are closely tied to self-generated thought processes. In particular, recent studies from multiple independent groups using a variety of imaging techniques (i.e., functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and electroencephalography (EEG) have linked serotonergic psychedelic effects (i.e., intravenous psilocybin and LSD, as well as ingested ayahuasca) to alterations within the default mode network (DMN; Bouso et al., 2015; Carhart-Harris et al., 2012; Carhart-Harris et al., 2016; Kometer, Pokorny, Seifritz, & Vollenweider, 2015; Muthukumaraswamy et al., 2013; Palhano-Fontes et al., 2015). The DMN is a network of brain regions that show increased activity when the person is "at rest" in the scanner, that is, in the absence of external stimuli or task demands (Buckner, Andrews-Hanna, & Schacter, 2008). Behavioral and neuroimaging reports reveal that, when attention is free from external demands, the mind tends to wander spontaneously through internally-directed thoughts that often converge on the sense of self (for a review, see Smallwood & Schooler et al., 2015). DMN activity correlates with such mind-wandering (Mason et al., 2007; Christoff et al., 2009; Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012; Andrews-Hanna et al., 2014; but see Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015). In addition, the DMN activates in response to tasks that recruit an internal locus of attention, including self-referential thought, social cognition, metacognition, and moral decision-making (Buckner et al., 2008). Based on these findings, some theorists have proposed the DMN as a potential neural substrate of narrative selfhood (Qin & Northoff, 2011) or even of the Freudian ego (Carhart-Harris & Friston, 2010).

In line with such perspectives, an MEG study examining the acute effects of psilocybin found that decreases in alpha power localized to the posterior cingulate cortex (a key DMN hub) correlated with first-person reports endorsing the "ego-dissolution" item, "I experienced a disintegration of my 'self' or 'ego'" (Muthukumaraswamy et al., 2013). A more recent multimodal (i.e., MEG and fMRI) imaging study replicated this result with LSD, and further showed that ratings of ego-dissolution were correlated with DMN disintegration—that is, the extent to which regions of the DMN became less functionally connected (Carhart-Harris, Muthukumaraswamy, et al., 2016). In a separate account from the same group, LSD was found to reduce mental time travel to scenarios from the past, and this reduction correlated with the degree of DMN disintegration (Speth et al., 2016). As we will see in more detail later in the chapter, such alterations in self-related thinking and dissolutions of ego boundaries are important facets of classical psychedelic-induced mystical experiences.

Imaging findings examining the effects of ingested ayahuasca are largely consistent with the results concerning intravenous psilocybin and LSD. An fMRI study with the Amazonian brew showed decreased activity within the DMN, as well as decreased connectivity within the posterior cingulate cortex (Palhano-Fontes et al., 2015). However, this study did not replicate the reduction in connectivity between medial prefrontal and posterior cingulate DMN nodes observed in experiments with LSD and psilocybin. A separate morphometric study reported that long-term ritual ayahuasca users displayed thinning of gray matter in posterior cingulate structures, and that the degree of thinning correlated with self-report scores of self-transcendence (Bouso et al., 2015). It is worth noting that the posterior cingulate cortex and other structures of the DMN consume more energy (Raichle & Snyder, 2007) and receive more blood flow (Zou, Wu, Stein, Zang, & Yang, 2009) than any other regions of the brain. Furthermore, the posterior cingulate houses the richest density of cortico-cortical connections in the brain (Hagmann et al., 2008) and has been proposed as a cortical hub facilitating communication among large-scale networks (van den Heuval, Kahn, Goni, & Sporns, 2012). Thus, converging evidence from multiple imaging modalities, pharmacological substances, and methods of administration associates the serotonergic psychedelic experience with decreased activity and connectivity in one of the most important integrative networks of the human brain, the DMN (Bouso et al., 2015; Carhart-Harris et al., 2012; Carhart-Harris, Muthukumaraswamy, et al., 2016; Kometer, Pokorny, Seifritz, & Vollenweider, 2015; Muthukumaraswamy et al., 2013; Palhano-Fontes et al., 2015; Speth et al., 2016; although at least one fMRI report was unable to replicate this predicted DMN effect: Lebedev et al., 2015). At first glance these findings might seem to indicate that psychedelics render the brain less associative (because the DMN connects disparate regions) or less prone to self-generated thinking (because such thinking typically correlates with DMN activity); however, the findings we survey in the next paragraphs suggest that the dampening of activity in this core default network may in fact free up other brain processes related to self-generated thought and encourage the brain to adopt more novel connectivity states.

Cognitive neuroscientists have begun to draw functional distinctions between the DMN core (i.e, posterior cingulate and medial prefrontal cortex) and its subsystems (i.e, medial temporal lobes and lateral parietal regions). Christoff and colleagues (2016) recently proposed that the DMN core may implement automatic constraints on internally oriented thought, which would suggest that reduced activity and connectivity in this core network should result in weaker automatic constraints on thought. This prediction aligns with the imaging results reviewed in the previous paragraph, which reveal that psychedelic states are associated with dampening and disintegration of the core DMN. On the other hand, Christoff and colleagues (2016) propose that the medial-temporal lobe (MTL) subsystem of the DMN may actually be a source of variability in self-generated thought. The MTL—made up of the amygdala, hippocampal and parahippocampal regions, entorhinal cortex, and septal nuclei—plays an important role in memory, thought, and affect. Altered activity in MTL regions has been implicated in REM sleep, psychosis, depersonalization, and dreamlike experiences such as déjà vu and waking hallucinations (see Carhart-Harris, 2007; Carhart-Harris & Nutt, 2014; Zmigrod, Garrison, Carr, & Simons, 2016). In addition, studies dating back to the 1950s and 1960s used intracranial depth-electrodes in humans to demonstrate that ingestion of serotonergic psychedelics including LSD and mescaline was associated with altered activity in the MTL (e.g., Monroe & Heath, 1961; Schwarz, Sem-Jacobsen, & Petersen, 1956).

More recent neuroimaging studies corroborate the link between the MTL and psychedelic experience. One experiment found that psilocybin ingestion led individual brains to show increased temporal variance in the fMRI signal from MTL structures; these MTL changes, moreover, correlated with reports of a feeling of dreaminess (Carhart-Harris, Leech, et al., 2014). In another study, reports of mental imagery while listening to music on LSD were associated with increased effective connectivity (calculated via Bayesian Dynamic Causal Modeling) between the parahippocampus (a key hub of the MTL system) and the primary visual cortex (Kaelen et al., 2016). This specific result accords with the more general finding that reports of mental imagery while under the influence of LSD correlated with increased connectivity between primary visual cortex and a strikingly wide swath of cortical regions (Carhart-Harris, Muthukumaraswamy, et al., 2016). Two additional studies from the same group showed that, following infusion of either psilocybin or LSD, MTL structures functionally decoupled from a variety of neocortical regions including those involved in a sensorimotor network, frontoparietal control network, and salience network (Carhart-Harris, Muthukumaraswamy, et al., 2016; Lebedev et al., 2015). Crucially, in both studies the degree of decoupling between the MTL and neocortical regions correlated with self-reported ratings of ego dissolution (Carhart-Harris, Muthukumaraswamy, et al., 2016; Lebedev et al., 2015).

Based on their findings, Carhart-Harris and colleagues hypothesized that psychedelics may soften constraints implemented by higher-order control regions over activity in the MTL subsystem (Carhart-Harris, Leech, et al., 2014; Lebedev et al., 2015). According to this theoretical proposal, the decoupling of MTL processes from control regions—including from the DMN core—may promote flexibility among thought patterns and may contribute to the sense of ego dissolution common in psychedelic experiences. Another research group recently proposed a related model of psychedelic brain function that also centers on a shift in top-down control mechanisms, albeit operationalized in different brain regions (Alonso, Romero, Mañanas, & Riba, 2015). This group used EEG and a computational measure of information flow called "transfer entropy" to compare brain activity following ayahuasca ingestion versus placebo. They found that during the ayahuasca experience, anterior brain regions reduced their influence (computed in terms of "information transfer") over more posterior regions, while posterior regions increased their influence over frontal regions. Moreover, reductions in information transfer from anterior to posterior regions correlated to subjective ratings of overall intensity of experience. Based on these results, the researchers proposed that ayahuasca may interrupt neural information-processing hierarchies by reducing top-down control (ostensibly implemented in anterior regions) over lower-level perceptual and thought processes (ostensibly implemented in posterior regions). While such theoretical proposals are intriguing, they remain largely speculative.

Beyond alterations in regional and network-localized activity, converging evidence suggests that psychedelics catalyze a more global brain state that is simultaneously disorganized yet highly associative. Multiple analyses indicate that psilocybin and LSD disrupt functional brain architecture by *reducing* connectivity and activity *within* typically robust cortical networks (Carhart-Harris et al., 2012; Carhart-Harris, Muthukumaraswamy, et al., 2016; Lebedev et al., 2015; Muthukumaraswamy et al., 2013). Further supporting the notion of a global functional disorganization, a recent study showed that psilocybin decreased connectivity between cerebral hemispheres (Lebedev et al., 2015). At the level of brain oscillations, which provide a more direct and temporally sensitive index of neural activity, MEG studies showed that psilocybin and LSD desynchronized neuronal populations across multiple frequency bands in a broad array of cortical regions, including anterior and posterior nodes of the DMN (Carhart-Harris, Muthukumaraswamy, et al., 2016; Muthukumaraswamy et al., 2013). On the other hand, psychedelics appear to globally *increase* communication *between* disparate cortical regions and networks (Muthukumaraswamy et al., 2013; Petri et al., 2014; Roseman et al., 2014) and enhance the flexibility of dynamic interactions between networks (Tagliazucchi, Carhart-Harris, Leech, Nutt, & Chialvo, 2014). Altogether, these results suggest that psychedelics cause cortical networks to become functionally less differentiated, more communicative, and more spontaneous in their functional properties.

While potentially illuminating, extant neuroimaging studies of serotonergic psychedelics have important methodological limitations. For one, psychedelics tend to generate a high degree of motion during brain scans. While researchers usually apply stringent compensatory algorithms, motion artifacts nonetheless may systematically influence results. Moreover, sample sizes are small, and most participants in these imaging assays have extensive experience with psychedelics; thus, it remains to be seen how such brain responses generalize to, say, participants and patient populations naïve to these substances. Despite such caveats, the available evidence indicates that serotonergic psychedelics simultaneously disorganize the configuration of large-scale brain networks and increase the extent and variability of communication between these networks. Moreover, some of the key neural indices of these effects correlate with self-reports of ego dissolution and dreamlike imagery during the psychedelic experience. Thus, psychedelics appear to render the brain more flexible and prone to adopting novel patterns of functional integration that may be linked to the classic phenomenological hallmarks of the "unconstrained psychedelic mind" (for reviews of these findings framed in the formal terms of *integrated information theory* and the *free energy principle*, see Gallimore, 2015, and Carhart-Harris, Leech, et al., 2014, respectively).

Such findings may hold important implications for applied domains. Particularly striking is the finding that the unpredictability of the fMRI time series associated with acute LSD experience (i.e., sample entropy—a way of formally measuring the spontaneity of brain function) predicts subsequent increases in the personality trait of Openness two weeks later (Lebedev et al., 2016). Other intriguing findings concern the relationship between the DMN and so-called task-positive attention networks that are normally anti-correlated with the DMN in their temporal fluctuations. One study indicated that four classic task-positive networks (the dorsal attention, salience, right frontoparietal, and auditory networks) become less anti-correlated following psilocybin infusion (Carhart-Harris et al., 2013), similar to patterns observed in individuals at high risk for psychosis (Shim et al., 2010), as well as during certain forms of meditation (Josipovic, Dinstein, Weber, & Heeger, 2012). An independent study examining ayahuasca ingestion, however, was unable to replicate this reduction of anti-correlation between networks (Palhano-Fontes et al., 2015). The discrepancies between the results of these studies (Carhart-Harris et al., 2013; Palhano-Fontes et al., 2015) may reflect the use of different psychedelic substances (ayahuasca vs. psilocybin), analysis methods (seed-based vs. independent component analysis), or regions of interest (focusing exclusively on the frontoparietal control network vs. analyzing a number of task-positive networks). If this anti-correlation finding holds up in other replications, it may prove relevant for modeling aspects of psychosis (Carhart-Harris et al., 2013) as well as in the treatment of depression, where an aberrant relationship between the DMN and frontoparietal network has been linked to maladaptive rumination (Hamilton et al., 2011; Whitfield-Gabrieli, & Ford, 2012; for a general review of psychedelic neuroscience pertaining to the treatment of mood disorders, see Vollenweider & Kometer, 2010). In addition, a few recent studies have reported reduced DMN/frontoparietal network anti-correlation during moments of creative insight and artistic performance (for a review, see Beaty et al., 2016; also Beaty & Jung, Chapter 21 in this volume). Thus, alterations in brain function offer intriguing clues as to the mechanisms that may link psychedelics with creative insight, contemplative experience, as well as pathology and healing (see Fox, Girn, Parro, & Christoff, 2016).

Applying the Unconstrained Mind: Psychedelics in Creativity, Mystical Experience, and Therapy

Creativity

Links between psychedelics and creativity abound in the popular imagination. These substances owe their visibility in mainstream culture to the traces they have left on the work of many of the most prominent artists and personalities of the twentieth century, from the Beatles to Steve Jobs (Rothstein, 2008). Indeed, ethnographic research documents extensive use of psychedelics around the globe in many traditions of spiritual or religious practice that have creative or artistic components (Langlitz, 2012; Schultes, Hofmann, & Rätsch, 2001; Taussig, 1987). Cognitive scientists broadly define creativity as the generation of ideas or novel associations that are at once original or innovative and useful or effective (leading to developments such as scientific theories, solutions to problems, or musical compositions; Sessa, 2008). The creative process also connotes the capacity for divergent thinking, or the ability to produce multiple alternative solutions to a question or problem. This stands in contrast to the application of specific knowledge to achieve a singular, correct solution to a problem—sometimes referred to as convergent thinking (Frecska, Móré, Vargha, & Luna, 2012; Guilford, 1966).

The most comprehensive phenomenological investigation of a psychedelic substance to date documents the stimulating effects of ayahuasca in creative disciplines, including music and art (Shanon, 2002). Unfortunately, the majority of experimental studies investigating the link between psychedelics and creativity were conducted before the 1960s hiatus on research, and thus many of these studies fall short of the methodological standards of contemporary research (e.g., lacking adequate control groups and experimental blinding). Notwithstanding the lack of rigor in early empirical studies, findings from a variety of experimental conditions suggest that psychedelics may bolster associative thought and creativity (for a review, see Krippner, 1985).

An early paradigm designed to probe psychedelic creativity involved recruiting visual artists and asking them to produce art under the influence of specific substances (Berlin et al., 1955; Dobkin de Rios & Janiger, 2003). Subsequently, art critics or instructors would subjectively evaluate the artists' work produced before, compared to during, the psychedelic experience. In one study, an experimenter administered LSD to a diverse group of 60 visual artists over the course of seven years (Dobkin de Rios & Janiger, 2003). These artists submitted over 250 drawings, created before and during the LSD experience, that were evaluated by a professor of art history who judged that the LSD-related works were more impressionistic and aesthetically adventurous, conveyed a heightened sense of emotional excitement, displayed a keener use of color, and were less bound by typical artistic conventions. Janiger also collected numerous qualitative reports from his subjects, who reported without exception that the LSD experience had been both artistically and personally profound (Dobkin de Rios & Janiger, 2003).

Another early study enlisted individuals working in creative disciplines to identify problems of professional interest that required a creative solution, and subsequently administered LSD or mescaline to those individuals in a supportive setting. All participants then completed three objective tests of creativity (Purdue Creativity Test, Miller Object Visualization Test, and Witkin Embedded Figures Test), and attempted to solve the professionally relevant problems they had identified earlier. Participants performed significantly better on all tests of creative ability when under the influence of the psychedelics compared to an earlier baseline assessment (Harman, McKim, Mogar, Fadiman, & Stolaroff, 1966). In addition, participants reported enhancements in their creative process with respect to the problems identified in their professional lives, and attributed these improvements to the psychedelic substance. Creative solutions included a commercial building plan that was subsequently accepted by the client, a new approach to the design of a vibratory microtome, an engineering improvement to a magnetic tape recorder, and the invention of a linear electron accelerator beam-steering device, among other innovations (Harman et al., 1966).

After a half-century hiatus, more recent studies probing the impact of psychedelics on associative thinking and creativity have implemented better experimental designs and measures (Frecska et al., 2012; Humphrey, McKay, Primi, & Kaufman, 2014; Kuypers et al., 2016). For example, a pilot study recruited 40 participants in a two-week-long ayahuasca retreat to complete visual components of the Torrance Tests of Creative Thinking before and two days after the completion of the retreat. The Torrance Tests ask responders to rapidly generate creative images based on a series of geometric shapes. Compared to a control group who did not participate in the retreat, and who did not receive any alternative training, participants who ingested ayahuasca demonstrated a significant increase in the number of highly original solutions to the tests of creative thinking (Frecska et al., 2012). However, one substantial limitation of this study is that, compared to participants in the control group, those in the experimental group were recruited from a different population using different inclusion criteria.

Another recent study recruited 26 participants from two ayahuasca workshops to complete creativity tests before and during the acute psychedelic experience (Kuypers et al., 2016). The researchers found that ayahuasca improved scores of divergent thinking and reduced scores of convergent thinking on one of the two creativity measures—the picture concepts test, which asks participants to identify associations between color images. However, the other creativity measure—the pattern/line meanings test, which asks participants to assign meanings to gray-scale configurations of patterns and lines—yielded no differences in divergent thinking and did not measure convergent thinking. Moreover, the researchers included no control condition and informed participants ahead of time about the aims of their experiment; thus, placebo effects and demand characteristics likely influenced the reported findings.

A recent placebo-controlled study directly tested the influence of LSD on semantic associations using a picture-naming task (Family et al., 2016). In this task, participants saw pictures of objects presented in sequence, and had to name the objects as quickly and accurately as possible. Under the influence of LSD, participants made more naming errors and were more likely to mistakenly substitute semantically related words (e.g., to mistakenly respond "arm" when viewing a picture of a "leg," both of which arise from the semantic category "body parts"). This pattern of results indicates that LSD increased the spread of semantic network activation in a manner that promoted associations between closely related concepts. These preliminary findings align with earlier evidence suggesting that psychedelics may enhance indirect semantic priming, reduce the predictability of speech patterns, and promote free-association (Amarel & Clark, 1965; Landon & Fischer, 1970; Spitzer et al., 1996).

Despite improvements, many recent studies of psychedelic creativity still lack methodological rigor especially in terms of implementing adequate experimental controls. Nevertheless, the cumulative evidence from observational, phenomenological, and preliminary experimental studies suggests that psychedelics can promote creative, associative thinking in a variety of domains (Family et al., 2016; Frecska et al., 2012; Kuypers et al., 2016; Sessa, 2008). Moreover, the connection between psychedelics and creativity may have a plausible neurobiological foundation. As we discussed earlier in this chapter, brain network dynamics associated with psychedelic experience appear to overlap, in some respects, with patterns of brain activity observed in moments of creative insight (see Beaty, Benedek, Silvia, & Schacter, 2016; Fox, Girn, Parro, & Christoff, 2016).

Mystical Experiences

The unconstraining of cognitive patterns via psychedelics can lead to "mystical" experiences that encompass feelings of sacredness, interconnectedness with the world at large, joy, peace, collapse of time and space, ineffability, and a sense of numinous truth (Barrett, Johnson, & Griffiths, 2015; Hood, 2003; Richards, 2015; Stace, 1960). Phenomenological and religious descriptions typically characterize such experiences in terms of a revelatory breakdown of habitual cognitive frameworks that divide the world into categories such as self and other, body and mind, or space and time (Richards, 2015; James, 1902; Roberts, & Winkelman, 2013; Walsh & Vaughan, 1993). An influential early study, referred to by psychedelic researchers as the "Good Friday Experiment," sought to test whether psilocybin could catalyze mystical experiences in a controlled setting at the Marsh Chapel of Boston University (Pahnke, 1963). In this randomized double-blind trial, 20 divinity students received a capsule of either placebo or psilocybin in a single group session. While a retrospective follow-up account identified methodological drawbacks to the original study (including likely breaking of the double-blind due to the use of an active placebo with different physiological side effects), it confirmed and validated many of the original findings—namely that eight of 10 subjects in the psilocybin group reported having a mystical experience, compared to only one subject in the control group (Doblin, 1991; Pahnke, 1963). Moreover, those participants who had a mystical experience reported that significant positive changes in attitude and behavior had persisted on six-month follow-up (Pahnke, 1963). Twenty years after the original findings were published, Rick Doblin—the founder of the Multidisciplinary Association for Psychedelic Studies (MAPS)—tracked down and interviewed seven of the 10 divinity students who had received psilocybin (Doblin, 1991). All seven affirmed that their psychedelic Good Friday experience had made uniquely valuable contributions to their spiritual lives, with positive changes persisting or deepening over time (Doblin, 1991).

Building on these tentative yet promising early efforts, a more recent and rigorous double-blind, placebo-controlled study reported that administering a single moderate-to-high dose of psilocybin in a supportive setting led to full-blown mystical experiences in over half of participants, all of whom had spiritual inclinations but no previous experience with psychedelics (Griffiths, Richards, McCann, & Jesse, 2006). Moreover, these mystical experiences were associated with positive changes in self-reported mood and values over a year later (Griffiths, Richards, Johnson, McCann, & Jesse, 2008). When the researchers pooled data from this study and a subsequent follow-up replication (Griffiths, Johnson, Richards, Richards, McCann, & Jessse, 2011), they observed that a high proportion of participants who reported mystical-type experiences demonstrated enduring changes in the personality factor of Openness (MacLean, Johnson, & Griffiths, 2011). This shift is particularly intriguing given that theorists typically construe such factors as enduring traits that persist in a largely stable manner throughout adulthood (McCrae, 2009; Terracciano, McCrae, Brant, & Costa, 2005; cf. Roberts & Mroczek, 2008). Thus, research raises the possibility that psychedelics can influence structures of cognition and engender mystical-type experiences that appear, in many cases, to leave lasting imprints on core features of personality.

Therapeutic Prospects

The capacity for psychedelics to catalyze dramatic changes in cognition, affect, attitudes, and personality, coupled with emerging psychopharmacological research, suggests that these substances have potential therapeutic applications (for reviews, see dos Santos et al., 2016; Majić et al., 2015). Several independent research groups are currently investigating the prospect of using psychedelic experiences as therapeutic adjuncts in the treatment of clinical conditions including substance addiction, depression, anxiety, and obsessive-compulsive disorder.

In the case of substance use disorders, a meta-analysis of six randomized controlled trials published between 1967 and 1970 found evidence of a beneficial effect of a single-dose LSD session in the treatment of alcoholism (Krebs & Johansen, 2012). More recently, two pilot studies revealed the potential benefits of psilocybin in the treatment of tobacco and alcohol use disorders. When administered moderate-to-high doses of psilocybin in three separate sessions in conjunction with cognitive behavioral therapy, 12 of 15 tobacco-addicted individuals demonstrated smoking abstinence at six-month follow-up, as measured by self-report and urinary cotinine test (Johnson, Garcia-Romeu, Cosimano, & Griffiths, 2014). Similarly, in a proof-of-concept study, 10 alcohol-dependent participants receiving either one or two moderate-to-high-dose psilocybin sessions in addition to motivational enhancement therapy showed significant increases in abstinence 36 weeks later (Bogenschutz et al., 2015).

Beyond addiction, studies have been exploring the potential benefits of psychedelics in the treatment of conditions including anxiety, depression, and obsessive-compulsive disorder. A recent double-blind placebo-controlled study employed a single moderate dose of psilocybin to address anxiety in patients with advanced-stage cancer (Grob et al., 2011). The 12 patients who received psilocybin demonstrated a significant reduction in anxiety at one and three months after treatment and an improvement in depressive mood that reached significance six months after treatment. A study by another group obtained similar placebo-controlled results using two moderate-dose LSD sessions paired with ongoing intensive psychotherapy to treat anxiety associated with terminal cancer (Gasser et al., 2014; Gasser, Kirchner, & Passie, 2015). The 12 participants in the LSD group reported significantly less anxiety and enhanced quality of life compared to the 12 participants in the control condition, with improvements persisting one year after treatment. Another pilot study (which lacked a control group) measured the effectiveness of two psilocybin sessions escalating from low to moderate dosage in 12 patients with moderate-to-severe, treatment-resistant depression (Carhart-Harris, Muthukumaraswamy, et al., 2016). Patients registered no serious or unexpected adverse events in response to the psilocybin, and reported significant reductions in depressive symptoms both one week and three months after treatment. However, the open-label nature of the study limits the conclusiveness of the findings, and about half of the patients still demonstrated significant depressive symptoms at three-month follow-up (see Cowen, 2016; Dikkstra, Jacobs, & Cohen, 2016; Hendrie & Pickles, 2016). Psilocybin has also been explored as a tool for the relief of symptoms of obsessive-compulsive disorder: in a pilot study, nine subjects received psilocybin in up to four sessions of varying dosages ranging from low to high (Moreno, Wiegand, Taitano, Delgado, 2006). Participants showed marked decreases in OCD symptoms, with improvements persisting for 24 hours after ingestion, long after the psychoactive effects had worn off.

While the evidence is promising, we are still in the early stages of establishing the therapeutic value of psychedelics. Results must be interpreted with caution because most data come from small pilot studies that often lack adequate control groups and blinding procedures. As clinical evidence accumulates, however, it becomes easier for researchers to obtain the research funding and ethical approval necessary to conduct further trials. Recent work therefore sets the stage for larger, double-blind, placebo-controlled trials in the near future.

The literature on psychedelic therapy includes substantial debate on the relative contributions to treatment outcomes of pharmacological and psychological mechanisms. In one camp, some researchers suggest that psychedelic substances can generate clinical benefits when given at doses below the threshold for inducing psychedelic experiences (Sewell, Halpern, & Pope, 2006). In the treatment of addiction, for example, researchers have proposed that serotonergic psychedelics exert anti-addictive effects by altering brain circuitry that connects limbic and frontal regions (Ross, 2012). These researchers hope that better understanding the neural and molecular mechanisms of action of these drugs will eventually allow for the development of medications that would provide therapeutic effects while obviating the need for any psychedelic experience as such—especially experiences, including dissociation and depersonalization, that might be undesirable for certain patient populations who could otherwise benefit from the direct pharmacological action of psychedelics (see Vollenweider & Kometer, 2010). In the other camp, many researchers and clinicians attribute the benefits of psychedelic substances to psychological processes that depend on or are marked by specific experiences, including restructuring of pathological cognitive patterns, enhanced empathy or self-understanding, and the adoption of constructive attitudes to one's life circumstances (Majić et al., 2015). Although the debate has tended to frame these as opposing alternatives, it seems likely that pharmacology and psychology interact through bodily, psychological, and social feedback loops to facilitate the therapeutic outcomes associated with psychedelic substances (Raikhel, 2015).

Constraining the Unconstrained Mind Through Ritual and Culture

While a growing body of experimental research has begun to explore how psychedelics reorganize cognition and promote associative, spontaneous dimensions of thought, such scientific approaches have given much less empirical attention to the role of context in shaping the psychedelic experience. When attempting to isolate and examine neurocognitive mechanisms in controlled experiments, scientists often seek a "neutral" setting that avoids biasing participants with expectations about their experience. Of course, any situation conveys suggestions or expectations that may influence outcomes. Thus randomized clinical trials—the gold standard of evidence-based medicine—employ a placebo comparison group to experimentally control for the effects of context or setting on expectations and attitudes (Kaptchuk, 2001; Servick, 2014). The emerging science of placebos underscores how psychosocial parameters such as contextual cues, beliefs, expectations, and empathic rapport profoundly influence many pharmacological outcomes (Brody & Miller, 2011; Finniss, Kaptchuk, Miller, & Benedetti, 2010; Kaptchuk & Miller, 2015; Kirmayer, 2015; Wager & Atlas, 2015). In the rest of this chapter we will explore how such sociocultural variables may influence psychedelic experiences.

A recent meta-analysis highlighted a variety of non-pharmacological factors that shape experiences with psilocybin. Pooling data from 23 controlled experiments involving 409 psilocybin administrations among 261 healthy participants, this analysis revealed that positive and mystical-type experiences were more likely among individuals who scored highly on the personality trait of Absorption, were emotionally excitable immediately before ingestion, and had experienced few psychological problems in the past weeks (Studerus, Gamma, Kometer, & Vollenweider, 2012). Another recent study found that LSD renders individuals acutely more suggestible, intimating that psychosocial influences may play an especially prominent role in determining the effects of psychedelics (Carhart-Harris, Kaelen, et al., 2014). While the neurocognitive mechanisms of suggestion remain poorly understood, neuroimaging findings from the domain of hypnosis implicate altered activity in attention and control processes, including the DMN (Deeley et al., 2012; Jiang et al., 2017; Mazzoni, Venneri, McGeown, & Kirsch, 2013; McGeown, Mazzoni, Vannucci, & Venneri, 2015; McGeown, Mazzoni, Venneri, & Kirsch, 2009)—a pattern that overlaps in some respects with the altered DMN activity associated with psychedelics including psilocybin, LSD, and ayahuasca (Carhart-Harris et al., 2012; Carhart-Harris, Muthukumaraswamy, et al., 2016; Palhano-Fontes et al., 2015). Thus, experimental findings seem to support the idea that the unconstrained neurocognitive state induced via psychedelics may render individuals especially susceptible to the influences of *set* (expectations, mood, or state of mind) and *setting* (including the physical and social environment) on drug experience (Zinberg, 1984).

The Ritual Use of Psychedelics

Social scientific studies of psychedelics place as much emphasis on aspects of historical, cultural, political, and environmental context as they do on the pharmacological properties of a given psychedelic substance (Beyer, 2012; Fernandez, 1982; Labate & Cavnar, 2014). According to ethnographic accounts, traditional and contemporary ritualized uses of psychedelics provide interpretive frameworks that are key to harnessing the pharmacological effects of these substances (Calabrese, 2013; Dobkin de Rios, 1984). The metaphors employed by ritual practitioners corroborate the notion of unconstrained cognition; for example, in the Santo Daime religion we will discuss at length in the following, psychedelics are often said to "open" or "reveal" one's mind (Oda Sheiner, 2016). Moreover, most traditions, including most contemporary approaches to psychedelic therapy, recognize that the states of mind evoked by psychedelics can expose participants to a range of difficult and intimidating emotional and cognitive experiences (Barrett et al., 2015; Strassman, 1984). To mitigate or prevent negative experiences and enhance positive outcomes, many practices use highly structured rituals to guide participants' encounters with psychedelic substances.

In the late 1950s, anthropologist Anthony Wallace noted a discrepancy between the experiential reports of individuals who were administered mescaline in a laboratory environment and the accounts of participants in Native American rituals centered on the consumption of the sacred mescaline-cactus peyote (Wallace, 1959). Based on these observations, Wallace proposed to supplement placebo-controlled pharmaceutical trials with a "method of cultural and situational controls" (1959, p. 84), whereby researchers would modulate the environment and instructions to participants as well as pre-select individuals based on personality, attitude, and cultural background (Langlitz, 2010). While Wallace's notion of culture controls never came to fruition in pharmacology, his early proposal highlights the value of incorporating a more social approach to psychopharmacological research in general, and to the study of psychedelics in particular. In line with this perspective, we will now turn to a discussion of ethnographic data collected by one of the authors of this chapter (Oda Sheiner) to consider how the specific context of a contemporary ayahuasca religion constrains the spontaneity of psychedelic experience through structured rituals and frameworks of interpretation.

Santo Daime and the Ritual Structuring of Psychedelic Experience

Psychedelic substances, consumed as plants or plant decoctions, are central to many cultural practices around the world. Knowledge of the peoples and practices that incorporate these psychedelics is largely a product of twentieth-century scholarship (Schultes, 1972). Yet, ethnobotanists and anthropologists have found evidence in the oral histories and archaeological records of indigenous cultures of the use of a variety of these substances for hundreds, if not thousands, of years (Schultes, 1969). For example, carbon dating suggests that some Native American peoples of North America have used peyote, a psychedelic cactus, for over 5,000 years (El-Seedi, De Smet, Beck, Possnert, & Bruhn, 2005). In discussions of this history and current cultural practices, there is a tendency to portray the psychedelic experience as monolithic—that is, to understand ayahuasca healing or the peyote ceremony as enacted in the much the same way, from one generation to the next, by indigenous healers throughout the global south (cf. Atkinson, 1992). In fact, practices are highly diverse, not only in the use of different plant combinations, but also in terms of the structure of rituals and desired outcomes.

Contemporary ritualized modes of psychedelic practice reflect a blending of traditional cultures and current contexts that influence the psychedelic experience in complex ways. This is well illustrated by Oda Sheiner's (2016) ethnographic analysis of Santo Daime, a Brazilian ayahuasca religion imported to a North American cultural context. Santo Daime is a syncretic Christian religion that originated in the northwestern region of the Brazilian Amazon in the early twentieth century (Dawson, 2013). Members of the religion imbibe a beverage, also called Santo Daime—an ayahuasca decoction made from the *Psychotria viridis* leaf and the *Banisteriopsis caapi* vine, as a sacrament in rituals called *Trabalhos*, or "Works." Although Santo Daime emerged in poor, *mestiço* (indigenous and European mixed-ethnicity) communities in the Amazonian state of Acre, today it is practiced primarily by white, middle-class participants living in cosmopolitan areas throughout Brazil. The religion maintains congregations in more than 30 countries across the world, and as of 2012, an estimated 20,000 individuals participate regularly in Santo Daime Works (Dawson, 2013; Feeney & Labate, 2014). Collaborations between researchers and ayahuasca-using communities such as the Santo Daime have stimulated a growing literature on health outcomes related to ayahuasca use, which report beneficial effects pertaining to substance abuse, psychiatric health, and general well-being (Barbosa, Giglio, & Dalgalarrondo, 2005; Doering-Silveira et al., 2005; Fábregas et al., 2010; Halpern, Sherwood, Passie, Blackwell, & Ruttenber, 2008). Interestingly, in contrast to participants in clinical research with other psychedelic substances, the subjects in studies investigating ayahuasca are typically drawn from communities where highly structured conventions for ayahuasca use are already in place. As such, the efficacy of ayahuasca in these studies is deeply entwined with the effectiveness of the ritual and social contexts in which it is consumed.

The Santo Daime religion hybridizes practices from ayahuasca traditions of South American *mestiço* or *mestizo* communities, Amazonian indigenous ayahuasca rituals, Afro-Brazilian beliefs and practices, European esotericism and, most prominently, Catholicism (Dawson, 2013). Drawing strands from all of these religious traditions, Santo Daime rituals offer adherents a highly structured psychedelic experience designed to reflect the spiritual aspirations of its membership. The structuring of Works ceremonies includes the segregation of participants by gender, and the seating of individuals according to hierarchy within the religious community. Senior members of Santo Daime are typically seated at a central table, while more novice *daimistas*—members of Santo Daime—form separate rows of women and men that radiate outward from a central table. Understood in socio-cognitive terms, this spatial configuration focuses joint attention on the most experienced practitioners, increasing their motivation to enact behaviors commensurate with the expectations of the congregation and providing performative models for less-seasoned practitioners. Ordering the ritual on a visual level, *daimistas* wear simple uniforms with modest symbolic adornments, serving to de-emphasize personal differences in terms of social class or income and to accentuate a sense of collective identity. Ritual spaces are often decorated with images and objects derived from the contributing religious traditions (with a particular emphasis on Christian symbolism). The cues provided by ritual decorations foster expectations among participants as to the character and contents of visions experienced while under the influence of the Daime brew.

Beyond the physical structuring of space, Works follow a regimented timeline. While different Works entail a degree of variation in the contents and sequencing of events, at a rudimentary level, rituals involve the recitation of inaugural prayers, consumption of Daime, silent seated meditation, singing of hymns, coordinated dance, and concluding prayers. Not all Works require these basic elements; still others include additional practices. Beyond the deliberate chronological arrangement of ritual events, participants are expected to sustain a degree of synchrony throughout the Works—whether staying in harmony while singing hymns, keeping the rhythm during dances, or more broadly, maintaining a minimum level of consistency in behavior with other *daimistas* throughout the ritual.

The ordering of ritual time and space structures the psychedelic experience along multiple modalities. On a pragmatic level, it provides the framework and repeatability required for regular religious practice, and codifies Santo Daime such that it can spread to new locations while preserving its core features. On a social level, Santo Daime's structure creates a meritocratic hierarchy of religious seniority, which rewards individuals for their personal growth and their ability to maintain and contribute to the congregation's co-development. On a metaphysical level, according to adherents, the ritual structure allows for the creation of a collectively generated spiritual current, nourished by the combined efforts of *daimistas*, that brings about the individual and communal efficacy of Santo Daime practice, whether it be personal insight, spiritual growth, emotional or physical healing, or any number of other reported benefits. Finally, at the experiential level, Santo Daime hymns and rituals provide *daimistas* with an interpretive framework through which experiences during Works can be constructed, explicated, and integrated into everyday life. Although Santo Daime has developed its idiosyncratic constellations of practice to reflect the values and aspirations of its membership, many other ayahuasca traditions employ analogous customs to help adherents navigate the vagaries of psychedelic experience (Labate & Cavnar, 2014).

Agency, Spontaneity, and Novel Psychedelic Experiences of Intersubjectivity

One of the most striking and ubiquitous sets of phenomena associated with the ritualized ingestion of ayahuasca involves alterations in the sense of control over the stream of consciousness (Shanon, 2002). Under the influence of psychedelics, individuals often experience thoughts and visions as emanating from external sources (Shanon, 2002; Strassman, 2000). In the specific context of Santo Daime, spiritual entities are not only "believed-in" by *daimistas* to the extent that they represent important components of their cosmologies, but they are also experienced as tangible, non-human others in the ritual setting. In-depth interviews collected by Oda Sheiner (2016) support the notion that practitioners relate to the Daime brew as an agent—as a participant in and subject of intersubjective encounters—rather than as an inanimate object. Describing the subject of these perceived relations, participants evoked notions of a being, a spirit, plant voices, and a range of proper nouns referring to specific entities. Many participants identified the specific force who ostensibly animates the Daime decoction as *Juramidam*, a central figure who recurs frequently in Santo Daime hymns and doctrine.

Experienced relations with non-physical entities under the influence of the Daime brew manifest across a range of sensory modalities, including visual apparitions, heard voices, or the felt presence of an entity (cf. Luhrmann, 2011). Oda Sheiner (2016) noted a proclivity among interviewees to use verbs that mark volition when describing experiences with Daime. Participants regularly mentioned being "shown," "told," "instructed," or having "received" information from the brew. This tendency was apparent even among participants who professed an overt skepticism toward the notion of Daime as a sentient being, separate from oneself. For instance, one participant advocated against overly entrenched beliefs about beings encountered in the Daime by way of describing Daime's ability to "bring you out of your belief system, and the more you believe strongly in something, the more it will bump it out for you." Still, whether reflecting implicit beliefs or an adherence to the conventions of the Santo Daime community, the participant later employed locutions that attributed awareness and agency to the Daime decoction by positioning its own intentions as a steering force in the religion's precarious political and legal viability in the future. Beyond the individual sense of agency, therefore, these ethnographic interviews highlighted the importance of Daime, figured as an agent, in collective decision-making in the larger community. When interviewees elaborated on the specifics of different rituals or on the reasons that the Santo Daime congregation adopted a particular stance, the causal chain could often be traced back to an instruction understood to be received by a *daimista* in a vision. It remains an open question whether such alterations in the attribution of agency to thoughts and sensations reflect an intrinsic property of the psychedelic brew, or emerge out of specific interactions with the ritual milieu and doctrines of ayahuasca traditions. Nonetheless, the discourses of Santo Daime, as well as those of other codified ayahuasca practices, normalize and de-stigmatize experiences of altered agency relating to the stream of thought. Indeed, these interpretive frameworks position such experiences as assets for individual and communal growth—and as an experiential fulfillment of the sacrament.

The Culture of Psychedelic Science

Medical and scientific studies of psychedelics do not exist "outside" of culture, but rather represent a response to specific contemporary issues and preoccupations. Recent research tends to operate within the framework of biomedicine, relating psychedelics to other psychopharmacological research questions and priorities, in an effort to legitimize psychedelic substances to relevant regulating agencies (Anderson, 2012; Doblin, 2016; Pollan, 2015). As such, experiments tend to focus on individual therapeutic efficacy, safety, mechanism, and reproducibility, even when the underlying interests may concern broader social or spiritual implications (cf. ongoing studies beginning to explore psychedelics as tools for the study of religion: http://csp.org/religiousleaderstudy). As these laboratory paradigms become popularized through mainstream scientific and popular news outlets, psychedelic research contributes to social and cultural contexts that in turn shape psychedelic experiences through looping effects (Kirmayer & Raikhel, 2009).

Proponents of psychedelic therapy have long appreciated the importance of appropriately framing the experience by way of physical setting, social support, and personal intention (Johnson, Richards, & Griffiths, 2008). A meta-analysis of early trials examining the efficacy of LSD as an adjunct to addiction treatment, for example, emphasized the supportive presence of a therapist as a crucial factor in determining which trials led to beneficial outcomes (Krebs & Johansen, 2012). Dominant therapeutic models of contemporary research on psychedelics are based on an individual-centered approach in which trained guides orient participants (many of whom have little or no experience with psychedelics) by helping them set their expectations and intentions before the experience and subsequently assisting with post-session integration (Majić et al., 2015). During the acute psychedelic experience, guides tend to adopt a passive role and encourage participants to become immersed in their own experience, while remaining physically present and available to intervene when help is needed or requested. Participants typically undergo the experience one at a time, reclining quietly on a couch in a comfortable, living-room style setting while wearing an eyeshade mask and listening to music through headphones. This individualistic, introspective approach stands in stark contrast to many traditional and contemporary psychedelic rituals in spiritual or religious contexts, such as the Santo Daime Works described earlier, which feature a more dynamic environment involving coordinated group activity and an explicit invocation of shared symbols, beliefs, and aspirations.

The peculiarity of psychedelic research contexts becomes even more apparent when we turn from psychotherapy to more basic scientific work centering on cognitive and neurobiological mechanisms. Here, participants (who are typically more seasoned users of psychedelics) spend the peak moments of their experience in a sterile laboratory environment, surrounded by computers, electrical devices, and other accoutrements of modern science. In neuroimaging experiments, participants often sit strapped with scalp electrodes or otherwise lie on their backs, unable to move, in the loud bore of an fMRI scanner. These uncomfortable environments likely influence the psychedelic experience. Whereas one study showed that some of the broad phenomenological characteristics of the psilocybin experience persist in a neuroimaging setting (Carhart-Harris et al., 2011), another study found that neuroimaging contexts increased the likelihood of unpleasant or anxious experiences (Studerus, Gamma, Kometer, & Vollenweider, 2012). Other contextual factors may also influence outcomes; for example, recent findings by Lifshitz and colleagues indicate that body postures (typically supine in fMRI neuroimaging and upright with methods like EEG) alter resting-state brain activity (Lifshitz, Thibault, Roth, & Raz, 2017; Thibault, Lifshitz, Jones, & Raz, 2014; Thibault, Lifshitz, & Raz, 2016). Moreover, the very expectation that one is undergoing a neuroimaging experiment can bias thought patterns and limit critical judgment—a phenomenon we have termed "neuroenchantment" (Ali, Lifshitz, & Raz, 2014). This kind of expectancy effect emphasizes that, far from being neutral, modern clinical and scientific experimental contexts convey a complex set of symbols that have significant cognitive and affective impacts on subjects.

While such contextual considerations may not make their way into the methods sections of cognitive neuroscience papers, they seem to guide, albeit often implicitly, the practices and outcomes of contemporary psychedelic research. For example, in his rich ethnographic work investigating the research practices of a prominent European laboratory studying the neuroscience of psychedelics, anthropologist Nicolas Langlitz (2010, 2012) documents how scientists rearrange and redecorate the space of the laboratory and experimental stimuli, through trial-and-error self-experimentation, to prevent participants from undergoing distracting negative experiences and hence tarnishing their neurocognitive data. Thus, the relevance of context and culture extend beyond traditional ritualistic uses of psychedelics to suffuse even the most "objective" contemporary scientific examinations of these substances. This points to the need for research that approaches these contextual factors not as nuisance variables, but as clues to the dynamics of psychedelic experience in real-world settings.

Conclusion

In this chapter we explored classical serotonergic psychedelics as catalysts of spontaneous thought. Emerging from a decades-long, politically charged hiatus, the scientific study of psychedelics is beginning to rediscover the potential for these pharmacological agents to promote creative insight (Frecska et al., 2012), evoke mystical experiences (Griffiths et al., 2006), and improve clinical outcomes (Majić et al., 2015; dos Santos et al., 2016). Moreover, neuroscientific studies have made some progress in unraveling the brain processes underlying the profound alterations in consciousness associated with serotonergic psychedelics. In particular, a recent series of neuroimaging studies indicates that psychedelics profoundly reconfigure functional brain architecture in a manner that promotes novel connectivity patterns among large-scale cortical networks (Carhart-Harris, Leech, et al., 2014; Carhart-Harris, Muthukumaraswamy, et al., 2016; Kometer et al., 2015; Palhano-Fontes et al., 2015). Preliminary reports are beginning to unravel how such alterations in acute neural function may mold the enduring structure of the brain and personality (Bouso et al., 2015; Lebedev et al., 2016). Thus, the flexibility attributed to psychedelic cognition may be reflected at the level of neurobiology, providing clues for better understanding the mechanisms that underlie the use of these substances in creative, spiritual, and therapeutic domains (Vollenweider & Kometer, 2010).

Contemporary approaches, however, have a long way to go in terms of addressing the contributions of context, suggestion, and culture in co-determining the quality, content, and outcome of psychedelic experiences. Moving beyond psychological and neuroscientific models, we have argued that anthropology and other social sciences can clarify the nature of psychedelic thought as pharmacologically mediated cognition embedded in social and cultural contexts of ritual and community. Ethnographic fieldwork in religion, healing, and ethnobotany point to the importance of personal preparation as well as environmental factors (i.e., set and setting) in shaping psychedelic experiences (Blainey, 2015; Labate & Cavnar, 2014). We illustrated the value of this contextual approach by summarizing some results from an ethnographic study of the use of a psychedelic brew, ayahuasca, in the contemporary syncretic religion of Santo Daime. Our analysis showed how ritualized practice constrains the psychedelically unconstrained mind to limit the volatility of the ayahuasca experience and optimize desired personal and communal outcomes (Oda Sheiner, 2016).

Traditions of psychedelic practice have long recognized that responsible use requires careful preparation and attention to context; with the right preparation and support, even difficult experiences can, at times, contribute to growth and healing (Gow, 1996; Naranjo, 1974; Pendell, 2005). Part of the value of psychedelics stems directly from their ability to reduce habitual constraints on the mind, thereby opening a space for new insights and vivid experiences of great power. The influence of psychedelic substances on thought provides a rich case study for exploring the complex interplay of brain, mind, culture, and neurochemistry. Approached with care, psychedelics may prove to be allies in illuminating the dynamics of spontaneous thought and promoting flexibility of mind in health and illness.

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