Metacognitive Facilitation of Spontaneous Thought Processes: When Metacognition Helps the Wandering Mind Find Its...

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Chapter 12
Metacognitive Facilitation of Spontaneous Thought Processes: When Metacognition Helps the Wandering Mind Find Its Way

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Abstract Mind wandering (MW) and metacognition may give the impression of lying at the opposite poles of the spectrum of human cognition. MW involves undirected, spontaneous thought processes that often occur without our volition and sometimes despite our intentions. Metacognition, by contrast, involves the conscious, often intentional monitoring and evaluation of our own mental processes and behaviors. The neural correlates of MW and metacognition may also appear strictly distinct at first, considering the almost exclusive focus on default network regions' involvement in MW, in contrast to the emphasis on higher order prefrontal regions' role in metacognitive processing. In this chapter, we will argue that despite the apparent gulf between MW and metacognition, some of the most intriguing mental phenomena we humans are capable of experiencing involve an intimate, dynamic interplay between MW and metacognition. According to the standard view of their interaction, metacognition serves to correct the wandering mind, suppressing spontaneous thoughts and bringing attention back to more "worthwhile" tasks. In this chapter, we argue that this "negative" or suppressant view of their interactions represents only a part of the whole picture. Instead, we outline and discuss three examples of positive, facilitative interactions: creative thinking, mindfulness meditation, and lucid dreaming (being aware that one is dreaming while dreaming). We argue that at both the cognitive and neural levels, these phenomena appear to involve an intricate balance whereby spontaneous thought is allowed to arise naturally while at the same time accompanied by

Sound serious thoughts on worthy subjects… cannot be conjured up arbitrarily and at any time. All we can do is to keep the path clear for them… We need only keep the field open to sound ideas and they will come. Therefore whenever we have a free moment with nothing to do, we should not forthwith seize a book, but should for once let our mind become tranquil, and then in it something good may easily arise. Arthur: Schopenhauer [153], p. 54.

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metacognitive monitoring of one's mental content and state of awareness. In ideal cases, this "symbiotic" relationship results in metacognition facilitating or optimizing spontaneous thought processes, so that they become more creative, less intrusive, and more likely to lead to novel conclusion and realizations.

12.1 Introduction

Mind wandering (MW) and metacognition may appear to lie at opposite poles of the spectrum of human cognition. The former calls forth notions of daydreaming, spontaneous thoughts, perhaps even Freud's seething unconscious—a stream of undirected ruminations. In contrast, metacognition, the ability to reflect on and evaluate our own thoughts and behaviors, is often viewed as a high-level, deliberate process, the pinnacle of human thinking and a distinguishing hallmark of our species.

But could there be any overlap and interplay between the seemingly primitive flow of spontaneous and undirected musings, and the lofty self-reflective evaluations of metacognition? One standard view is that the brain networks involved in task-related cognition and in MW operate in an anticorrelated, almost mutually exclusive fashion [64, 65], but the view expressed by Schopenhauer [153] in the epigraph above suggests at least one potential overlap: the process of insight, or creativity. It suggests not only that thoughts and insights arise spontaneously, but that some (and only some) of these thoughts are sound and good—implying that self-generated content must subsequently be subjected to critical metacognitive evaluation.

In this chapter, we will argue that, despite the apparent gulf between MW and metacognition, some of the most intriguing mental processes human beings are capable of experiencing involve an intimate, dynamic interplay between "low-level" spontaneous mental processes and "high-level" metacognitive monitoring. What's more, recent evidence suggests that even MW itself, in the absence of metacognitive awareness, may share neural resources with brain regions traditionally viewed as metacognitive and executive ([31, 32]; Fig. 12.1b).

We begin with a brief overview of behavioral and cognitive neuroscience research that has explored these two cognitive processes independently of one another. We then review the standard view of their interaction, wherein metacognitive monitoring serves to correct the wandering mind, suppressing spontaneous thoughts and bringing attention back to more "worthwhile" tasks. We argue that this "negative" (i.e., suppressant) view of their interactions, although important, represents only a part of the whole picture. We go on to discuss three

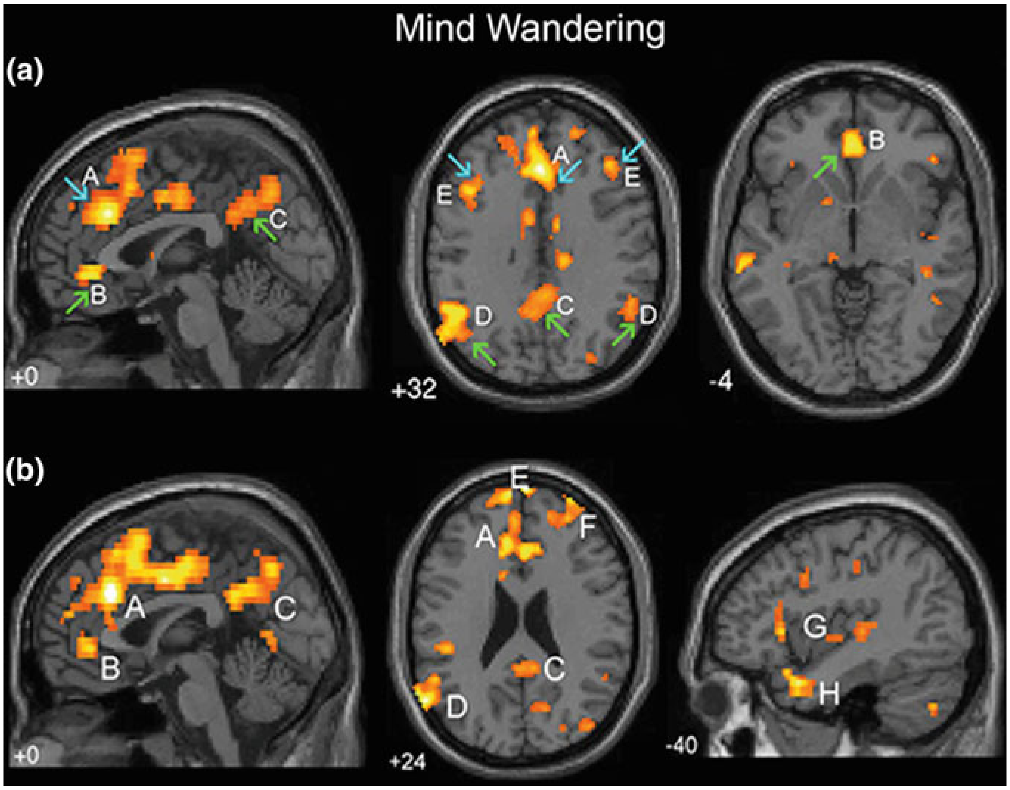

Fig. 12.1 Brain recruitment during mind wandering. **a** Mind wandering simultaneously recruits dorsolateral prefrontal cortex (*E*), anterior cingulate cortex (*A*), medial prefrontal cortex (*B*), inferior parietal lobule (*D*), and posterior cingulate cortex (*C*). **b** Mind wandering without meta-awareness, compared to mind wandering with meta-awareness, recruits a number of traditional metacognitive regions, including RLPFC (*F*) and RMPFC (*E*). Numbers indicate stereotactic coordinates in Montreal Neurological Institute (*MNI*) space. Reproduced with permission from Christoff et al. [31, 32]

examples of positive, facilitative interactions: creative thinking, mindfulness meditation, and lucid dreaming (being aware that one is dreaming while dreaming).

The limited scope of this chapter necessitates broadly defined terms. We therefore use MW in a general sense to refer not only to thoughts that involve deviation from a particular task, but to all forms of undirected or spontaneous thought, such as daydreaming or "zoning out" [27]. On the other hand, by "metacognition" or "metacognitive monitoring" we mean the general "ability to reflect upon, comment about, and report a variety of mental states… [i.e.,] cognition about cognition" [56]. We use these terms not only in the literal sense of "thinking about thinking," but more broadly, to encompass meta-awareness, meta-attention, and metacognitive judgments about perception and performance.

Table 12.1 Core cortical components of the default mode network

Region	Approximate brain areas (BA)
Ventromedial prefrontal cortex	24, 10 m/10 r/10 p, 32 ac
Dorsal medial prefrontal cortex	24, 32 ac, 10 p, 9
Posterior cingulate/retrosplenial cortex	29/30, 23/31
Inferior parietal lobule	39, 40
Lateral temporal cortex	21
Hippocampus	–
Parahippocampus	35, 36
Entorhinal cortex	28, 34

Key cortical brain structures contributing to human default mode network activity, and potentially to the subjective state of mind wandering/spontaneous thought. Adapted from Buckner et al. [18]. *BA* Brodmann area

12.2 The Cognitive Neuroscience of Spontaneous Thought Processes

Extensive first-person reports of spontaneous thought and MW go back nearly a century (e.g., [179]), but it was in the 1960s, 1970s, and 1980s that thorough explorations of the subjective content of spontaneous thought (typically referred to then as "daydreaming") began revealing its complex nature (for reviews and seminal papers, see [6, 33, 61, 98, Singer 1966, Singer and Antrobus 1972, Singer and McCraven 1961]). Based on these studies of content, MW mentation was shown to contain elements of fantasy [96, 97, 99], to be largely audiovisual in terms of sensory content [99], and to be largely based on memories and pre-existing behavioral repertoires [98, 99]. Studies suggest that spontaneous thought occupies a large proportion of our mental lives—anywhere from 30 to 50 % of our waking hours [93, 95, 99]. AQ1

A number of studies have now examined brain activity during "rest" with intriguing results. For example, in an early report, Andreasen et al. [3] found that, compared to a nonmemory task, both autobiographical memory recall and "rest" revealed similar brain activations in numerous regions later found to be part of the "default mode network" (see Table 12.1). When asked what had been going through their minds at "rest," subjects regularly reported recollection of memories, planning for the future, and other thoughts [3]. The study of this "default mode" of brain function [139], and its relation to MW, was refined over time: early studies compared blocked periods of "rest" with blocked task periods (e.g., [3, 35, 158, Raichle et al. 2001]); later work made similar comparisons in a trial-by-trial, event-related fashion (e.g., [31, 32, 178, Shannon 2006]); and the most recent studies have examined functional connectivity (temporally correlated activation and deactivation) across numerous default mode network hubs (e.g., [27, 77]).

Collating data from these three methods has allowed a tentative delineation of core cortical default mode network regions (Table 12.1; [18]). Researchers have hypothesized that activation of the posterior cingulate cortex (PCC) and the anterior medial PFC may reflect the affective, self-relevant nature of spontaneous thoughts

[5]. Medial PFC recruitment may also reflect acts of spontaneous mentalizing, i.e., imagining the thoughts and intentions of other individuals [165]. The temporopolar cortex may also contribute to spontaneous mentalizing [165]. By virtue of its anatomical connectivity with medial temporal lobe (MTL) structures and its role in autobiographical memory [76], the temporopolar cortex may also participate in experiencing spontaneously arising memories [35], especially those memories rich in sensory–perceptual detail [36].

With default mode network regions relatively well-defined, subsequent studies found that both retrospective [120] and online, trial-by-trial [31, 32] self-reported MW predicted increased activity in default mode network hubs (as well as other regions, however—a point to which we will return). Recent work has also found that self-reported intensity of engagement in internally directed thought predicted higher activation in default mode network hubs [178], and that self-reported frequency of thoughts about the past and future predicted the strength of functional connectivity between default mode network regions in MTL memory structures and in other default mode network parietal regions [5]. Taken together, first-person reports have provided a wealth of information about the subjective content of spontaneous thoughts and have tied spontaneous thought to activation of, and functional connectivity within, default mode network regions.

We stress, however, that default mode network activity and spontaneous thought are not merely the objective and subjective aspects (respectively) of a single phenomenon (see also [28]). Though we agree that there is now fairly strong evidence linking MW to recruitment of key default mode network regions (reviewed in [27]), several caveats are in order. Numerous studies noted above have used an a priori region of interest approach, which presupposes a link between the default mode network and MW, and often precludes looking at regions outside the default mode network; others have found activation of numerous regions beyond the default mode network during MW, including traditionally "metacognitive" regions like RLPFC and DLPFC ([31, 32, 120]; Fig. 12.1). Furthermore, multiple forms and definitions of spontaneous thought can be delineated [27]. Thus, although we use default mode network regions (Table 12.1) as a neuromarker for MW-related processes throughout the remainder of this chapter, we do so not out of certainty about the exclusivity of this relationship, but rather out of uncertainty about MW's true neural correlates. It should be emphasized that present evidence suggests [31, 32, 35, 120], and we suspect future work to confirm, that many brain regions outside the default mode network are also key neural substrates of spontaneous thought processes.

12.3 The Cognitive Neuroscience of Metacognition

Metacognition comes in many forms, but all tend to share the notion of a second, "meta" level of cognitive processing or awareness that is to some degree dissociable from a primary (or "object") level involving perception, decision making, or

Table 12.2 Core cortical regions implicated in metacognition

Region	Approximate brain areas (BA)
Anterior prefrontal cortex (RLPFC/RMPFC)	10
Dorsolateral prefrontal cortex (DLPFC)	9/46
Anterior cingulate cortex (ACC)	32/24
Anterior insula	13

BA Brodmann area; *RLPFC* rostrolateral prefrontal cortex; *RMPFC* rostromedial prefrontal cortex

attention [56]. This meta-level can relate, for example, to one's sense of the accuracy of one's own perceptions; certainty about the accuracy of one's decisions or performance; metacognitive evaluation of one's own ideas and theories; or meta-awareness of the quality of one's attention (e.g., focused vs. distracted).

A preliminary understanding of the neural underpinnings of metacognition has implicated rostrolateral, rostomedial, and dorsolateral prefrontal cortices (RLPFC, RMPFC, and DLPFC, respectively) in various metacognitive abilities [29, 30, 55, 57, 72, 73, 121, 140, 145, 150]. There seem to be some finer distinctions between the metacognitive functions carried out by RLPFC and RMPFC, respectively [72, 73]. Metacognitive evaluation in the context of "cognitive" tasks, such as working memory, episodic memory retrieval, and abstract thought [15, 32, 147, 181] appear to involve the lateral PFC rather than RMPFC. On the other hand, reflecting upon one's own emotions activates primarily the medial, rather than lateral, PFC, including RMPFC [105, 133, 134]. An alternative, but not mutually exclusive, subdivision between medial and lateral PFC contributions to metacognitive processing takes into account the temporal focus of metacognitive judgments: on this view, prospective judgments selectively recruit RMPFC, whereas retrospective judgments preferentially recruit RLPFC and DLPFC [55].

A more extended account of metacognition would also involve the anterior insula as an important center subserving conscious meta-awareness of emotions and the state of the body [38, 39, 41], and potentially as a key node relaying such information to higher PFC areas [55]. For example, Farb et al. [48] found a significant correlation between activation in the insula and lateral prefrontal cortex, including RLPFC, in subjects trained in mindfulness meditation (see Sect. 12.5, below) that were asked to become aware of their thoughts, feelings, and body states. Consistent with these results, our group found improved self-regulation of anterior insula activity during a training paradigm that involved meta-awareness of one's own mental states, in parallel with improved RLPFC self-regulation based on real-time fMRI feedback from this region [121].

As with spontaneous thought, we use several regions (Table 12.2) as putative neuromarkers of the involvement of metacognitive processes, with the caveat that these areas are of course only a preliminary estimate of the neural structures central to metacognition, and a necessary simplification for the purposes of this brief chapter. Throughout, we focus specifically on RLPFC/RMPFC and DLPFC due to their basically unequivocal involvement in metacognition, but other regions too, including anterior cingulate cortex (ACC) and anterior insula, are discussed.

12.4 Mind Wandering as Illness, Metacognition as Cure

One kind of interaction between metacognition and MW has a corrective function. This is the case with the primarily suppressive, regulative role metacognition sometimes plays during goal-directed thought and behavior: it can note MW in the form of distractions (e.g., thoughts about competing external stimuli) and can redirect attention to the task at hand [152]. On this view, MW is conceptualized as an unwelcome detriment to the performance of more worthwhile tasks, and metacognition as the sentinel guarding against such costly, occasionally even dangerous, lapses (e.g., [161]).

This "negative" view, which highlights the role of metacognition in the suppression and disengagement from MW, has motivated the majority of research so far. It has led to a substantial number of studies focusing on the detrimental effects of MW on performance during a variety of traditional experimental tasks, such as memory encoding and reading comprehension (for reviews, see [152, 162]). The tendency to mind wander "too much," or too much about "negative" subject matter, has even been linked to clinical pathologies such as depression (reviewed in [161]) and attention-deficit/hyperactivity disorder (e.g., [157]). Such a negative view of MW was recently epitomized in a high-profile study whose title simply declared, "A wandering mind is an unhappy mind"[1] [95].

This focus has been unfortunate, but understandable given our cultural bias toward viewing MW as something negative, even pathological. In contrast to the more desirable pursuit of "rational" thought, MW is often portrayed as undesirable—a wasteful mental diversion and potentially dangerous distraction, a "mere whimsy without body and without subject" [127]—causing motorists to crash their cars [176], students to disregard their studies [183], and readers to skim over whole paragraphs before realizing they have absorbed none of the material on the page in front of them [151].

Overall, our culture values control and effort, and devalues spontaneity and leisure. Since metacognition is often associated with the former and MW with the latter, it is no wonder that research has so far been heavily influenced by this implicit mind-wandering-as-illness, metacognition-as-cure approach. Unfortunately, however, this has left us relatively ignorant of the more positive kinds of interactions through which metacognition may facilitate and even enhance the arising of spontaneous thought, thus enabling beneficial outcomes that would not otherwise be obtained.

[1] The empirical evidence presented by this paper in support of its title's claim is much more controversial than the title suggests. For example, far more spontaneous thoughts were rated as emotionally positive (42.5 %) than negative (26.5 %) [95].

Table 12.3 Three examples of mental phenomena during which metacognition may interact with mind wandering in a positive, facilitative fashion

State	Aspects of mind wandering	Aspects of metacognition
Creative thinking	Spontaneous generation of ideas, imagery, verse, music, solutions, insights, etc.	Evaluation of the novelty, quality, utility, and value of self-generated ideas; monitoring of the effectiveness of the creative process
Mindfulness ("insight") meditation	Arising of spontaneous thoughts; spontaneous "chaining" (elaboration) of thoughts; spontaneous emotional reactions	Monitoring the focus and quality of attention; maintaining a detached, nonelaborative mental stance
Lucid dreaming	Spontaneous generation of visual and auditory imagery, and often a fully immersive dream world resembling physical space; spontaneous construction of narratives, characters with personalities and motives, and theory of mind-like judgments	Recognition that the physical self is actually asleep in bed, and that the perceived "physical" environment is actually a mental representation; directing of the course of the dream and its imagery (rarely)

12.5 When Metacognition Helps the Wandering Mind Find Its Way

Though the "suppressant" MW-metacognition interactions are undoubtedly part of everyday life, in this chapter we aim to make a step toward redressing the imbalance of research focus by concentrating, albeit in a preliminary and speculative fashion, on three phenomena—creative thinking, mindfulness meditation, and lucid dreaming—that we believe represent examples of positive, facilitative interactions between MW and metacognition (Table 12.3).

12.5.1 Creative Thinking: Metacognitive Evaluation of Spontaneous Ideation

Creative thinking is a unique mental ability that relies on the skilled engagement of both deliberate, goal-directed thought and of spontaneous thought [33]. Often defined in terms of its product, creativity is the ability to produce ideas that are both novel (original and unique) and useful (appropriate and meaningful) [17, 69, 168]. In following with this 2-fold definition of the creative product, emphasizing both its novelty and utility, psychological findings have suggested that creative thought involves two main components: the generation of new ideas, on the one hand, and the evaluation of any generated ideas as to their utility and originality, on the other hand [8, 21, 52, 86, 185]. This dichotomy is also present in subjective accounts by artists of their own creative process, which they often describe as alternating between rough sketching and critiquing [42, 63].

Table 12.4 Metacognitive and default mode network regions known to be involved in creative thinking

Metacognitive brain regions	Default mode network regions
DLPFC	Medial PFC
Dorsal ACC	PCC/retrosplenial cortex
RLPFC	IPL/lateral temporal cortex
Anterior insula	Medial temporal lobe (hippocampus, parahippocampus)

ACC anterior cingulate cortex; *DLPFC* dorsolateral prefrontal cortex; *IPL* inferior parietal lobule; *PCC* posterior cingulate cortex; *PFC* prefrontal cortex; *RLPFC* rostrolateral prefrontal cortex

Although somewhat over-simplifying matters, creative evaluation can be seen as heavily relying on metacognition, while creative generation likely relies on spontaneous thought processes. With the recognition that, when engaged simultaneously, metacognition might inhibit spontaneous generation, the optimal creative process is often considered to employ metacognitive evaluation and creative generation sequentially. Although these two components of the creative process certainly can and do occur in parallel, creating a temporal separation between the two is known to increase the creativity of outputs [8, 135]—a principle applied in the practice of "brainstorming." This iterative generation-evaluation process parallels the sequential nature of metacognitive judgments of perceptual decision making, for example confidence judgments about performance on a perceptual task (see [188]).

The facilitating effects of metacognition on creative generation are not, however, limited to simply preventing metacognition from occurring simultaneously with generation. Metacognitive evaluations can also be used to guide future creative generation efforts in directions that have been identified as novel and useful during previous evaluation phases [63]. In this way, metacognition can play a positive, facilitative role in the spontaneous generation of thoughts and ideas during the creative process.

Traditional metacognitive brain regions, as well as default mode network regions, are all known to be involved in the creative process (for a review, see [28]; also Table 12.4). The DLPFC and dorsal ACC are known to be activated during a variety of creative tasks, including piano improvisation, creative story generation, word association, divergent thinking, fluid analogy formation, insight problem solving and visual art design [13, 23, 70, 101, 156]. Similarly, enhanced activations in the area of the inferior parietal lobule (IPL) and lateral temporal cortex (LTC), medial PFC, and PCC/retrosplenial cortex—three key hubs of the default mode network—have been observed during divergent thinking tasks, creative story generation, hypothesis generation, fluid analogy formation, remote associates insight problems, and jazz improvisation [70, 85, 90, 101, 109]. Recruitment of MTL regions such as the hippocampus and the parahippocampus are also observed [47, 50, 102].

What are the neural correlates of creative evaluation versus creative generation, and how do they interact at the neural level? A recent study from our group addressed these questions directly [47]. It revealed, on the one hand, simultaneous recruitment

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Chapter No.: 12 | Date: 21-11-2013 | Page: 10/28

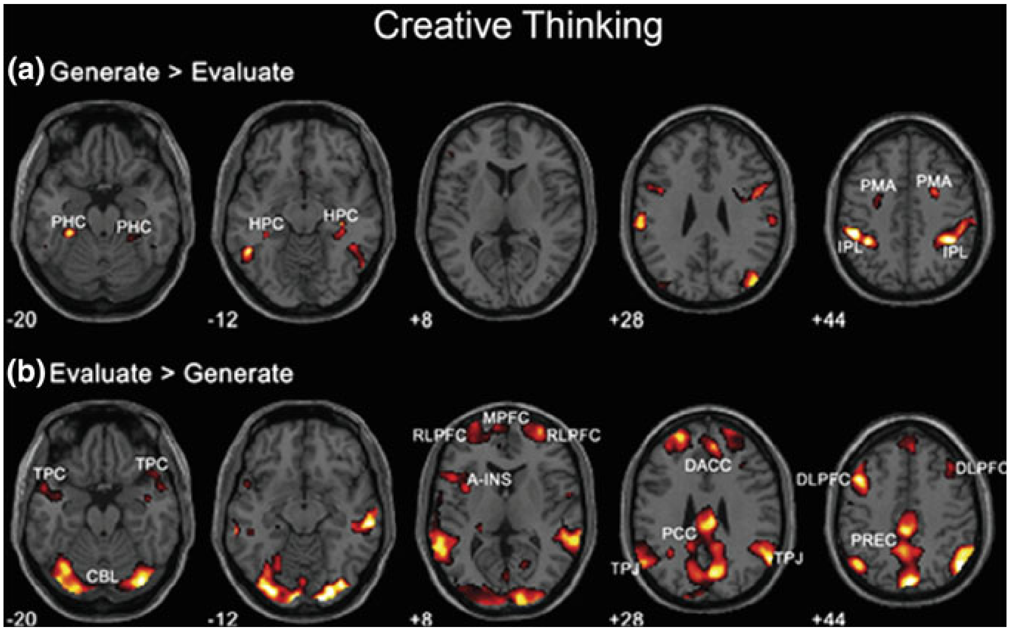

Fig. 12.2 Brain recruitment during the generation and evaluation phases of artistic creativity. Creative thinking recruits hippocampus, parahippocampus, and IPL during the generation of ideas (**a**), and subsequently involves activation of DLPFC, RLPFC, MPFC, and PCC during noetic metacognitive evaluation of one's own thoughts (**b**). Numbers indicate stereotactic coordinates in Montreal Neurological Institute (*MNI*) space. *A-INS* anterior insula; *CBL* cerebellum; *DACC* dorsal anterior cingulate cortex; *DLPFC* dorsolateral prefrontal cortex; *HPC* hippocampus; *IPL* inferior parietal lobule; *MPFC* medial prefrontal cortex; *PCC* posterior cingulate cortex; *PHC* parahippocampus; *PMA* premotor area; *PREC* precuneus; *RLPFC* rostrolateral prefrontal cortex; *TPC* temporopolar cortex; *TPJ* temporoparietal junction. Reproduced with permission from Ellamil et al. [47]

of metacognitive brain regions and default mode network regions during the process of creative evaluation (Fig. 12.2b). Three metacognitive regions—RLPFC, RMPFC, and the anterior insula—were specifically identified as being part of metacognitive creative evaluation, even though they have not been emphasized in terms of their contribution to the creative process in the literature so far.

On the other hand, the results revealed that the process of creative generation is preferentially linked to recruitment of the IPL, as well as the hippocampus and parahippocampus—the two MTL regions that have also been implicated in default mode network functioning (Fig. 12.2a; see also [18]). The parahippocampus may form new, or access old, associations that are then recombined by the hippocampus with other information to construct episodic simulations [149]. Previous studies have also indirectly linked the MTL to the spontaneous generation of thoughts and memories, including the neural replay of memories during rest in rats [59, 170], spontaneous re-activation of memories in humans [71], and spontaneous mental processing during rest [14, 35, 167]. The associative and spontaneous nature of MTL function suggests that it may be important for creative thought by facilitating the generation of novel ideas and associations, as well as the recombination of old ones.

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Chapter No.: 12 | Date: 21-11-2013 | Page: 11/28

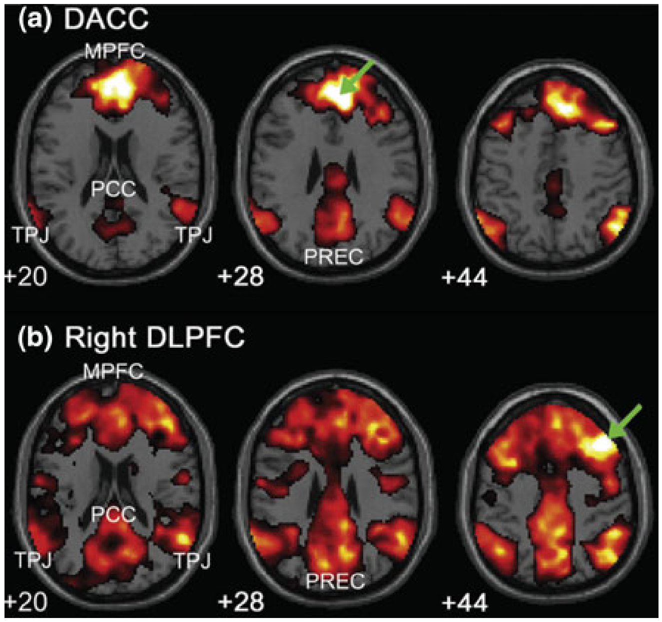

Fig. 12.3 Functional connectivity between metacognitive and default mode network regions during the evaluation phase of creative thinking. Functional connectivity analyses using seed regions in (**a**) dorsal ACC and (**b**) right DLPFC (indicated by *green arrows*) reveal strong positive temporal correlations of activity between default mode network and metacognitive brain regions. *DACC* dorsal anterior cingulate cortex; *DLPFC* dorsolateral prefrontal cortex; *MPFC* medial prefrontal cortex; *PCC* posterior cingulate cortex; *PREC* precuneus; *TPJ* temporoparietal junction. Reproduced with permission from Ellamil et al. [47]

In addition to being co-activated during creative evaluation, metacognitive and default mode network regions also exhibited positive functional connectivity during the creative process (Fig. 12.3). This finding provides specific neural evidence for the existence of temporally coupled, possibly facilitative interactions between these two networks in the process of creative evaluation.

How might metacognition facilitate spontaneous thought during the creative process? First, low levels of metacognitive control during the generation phase may enable an associative mode of information processing that facilitates and ensures the generation of novel ideas [84]. This may allow access to more diverse, nonobvious pieces of information to combine and use as building blocks for novel ideas, or more comprehensive and unusual connections [180]. Second, metacognitive evaluation of already-generated ideas during the evaluation phase may assign positive cognitive and emotional associations to those ideas or directions of creative thought. These positive associations may then be used during subsequent generation phases in order to guide the further generation of novel ideas. Significantly, the metacognitive regions involved in creative evaluation are not limited to strictly cognitive metacognition regions, but also include self- and emotional evaluative regions such the medial PFC and the anterior insula, suggesting the potential importance of affective and visceroceptive forms of evaluative processing during creative thought.

In summary, during creative thinking metacognition appears to facilitate spontaneous thought by first being selectively attenuated during generation phases in order to "make way" for spontaneous thoughts to emerge, and second, by being used during the evaluation phase to identify fruitful directions toward which the generation of spontaneous thought can be directed in subsequent generation phases. One positive outcome of these facilitative interactions may be the arrival at novel conclusions, solutions, and insights that may not otherwise be reached by MW alone, without the positive evaluation and facilitation from meta-awareness.

12.5.2 Mindfulness Meditation as Meta-Awareness of Mind Wandering

Meditation can be thought of as a broad set of mental techniques for focusing and training attention, regulating emotion, enhancing awareness of the body, and various other processes [115, 160]. A crucial component of meditation is a persistent metacognitive monitoring of one's progress in, and execution of, the practices. At the same time, the arising of spontaneous thoughts is a virtually universal experience among practitioners of meditation [75, 174]. In contrast to creative thinking, where spontaneous thought generation and metacognitive evaluation are ideally separated in time, during meditation the two processes ideally occur simultaneously, so that metacognition is present in parallel with any spontaneously arising thoughts.

Two broad strategies can be delineated in response to MW during meditation practice, both of which involve metacognitive monitoring. One common technique involves the simple focusing of attention on the sensations associated with respiration—typically, to the exclusion of all else. The practitioner must also monitor the effectiveness with which they are maintaining attentional stability: laxity (e.g., drowsiness or lack of focus) and outright lapses (e.g., MW) are to be not only noticed, but usually corrected for as well [110]. That is, not only should attention be sustained on a single object, but meta-attention must also be continuously employed [2, 174] during such a "focused attention" meditation [115]. In focused attention meditation, the role of metacognition is in noticing lapses of attention, and then redirecting focus to a chosen object. As such, it strongly resembles the negative, "suppressant" MW-metacognition interaction discussed above.

A second strategy releases the meditator from the need for a single object of focus during practice. Instead, the practitioner maintains an open attentional stance: they neither give preference to, nor attempt suppression of, any stimulus that arises, be it incoming sensation or internal thoughts and emotions. Commonly referred to as "mindfulness" [91], "open monitoring" [115], or "Insight" meditation [106], this practice involves a nonreactive, nonjudgmental, nonelaborative mental stance, during which any object of attention is acceptable so long as metacognitive monitoring of one's stream of thought and emotional reactions is

Table 12.5 Brain regions activated during mindfulness meditation

Metacognitive brain regions	Default mode network brain regions
RLPFC	Posterior cingulate cortex
DLPFC	Inferior parietal lobule
Insula (anterior)	Hippocampal formation

DLPFC dorsolateral prefrontal cortex; *RLPFC* rostrolateral prefrontal cortex

continuously maintained. In contrast to focused attention meditation, during mindfulness meditation the role of metacognition is to maintain detachment from, or restrain elaboration of, thoughts and sensory input, and further to regulate arousal so that one does not become over-involved emotionally [91, 110, 115].

Neuroimaging studies of mindfulness meditation have often shown greater activations in both default mode network and metacognitive brain regions (Table 12.5). The former include greater recruitment during mindfulness of PCC [87], IPL [48] and the hippocampal formation [111]. Activations in metacognitive regions include results in RLPFC [118, 143] and DLPFC [48, 118]. There are exceptions to this trend, however, with some studies showing default mode network or metacognitive region deactivation during mindfulness meditation (e.g., [48, 87]). As noted above (Sect. 12.3), the insula has been hypothesized to play a role in metacognition [55], and so significant insular cortex activations during mindfulness meditation are also of interest [48, 68, 114, 118]. Again, there are exceptions to this observation, too (e.g., [87]).

If meditation practitioners are indeed consistently engaged in metacognitive monitoring, it is possible that this skill may be trained by its persistent engagement [116]. Though the evidence to date remains tentative, work by our own group [62] and others [131, 171] suggests that metacognitive abilities might be enhanced in long-term meditation practitioners. A persistent engagement of metacognitive skills alongside attention to spontaneous thoughts is not only consistent with the functional neuroimaging results discussed above, but would also likely entail a corresponding reorganization of brain structure. Speaking to this possibility, numerous studies have now examined brain structure differences in both long-term meditation practitioners (with thousands of hours of experience) and novices undergoing short-term training. The subjects come from a wide variety of contemplative backgrounds, but essentially all have training in some form of meditation that could be classified as either focused attention or mindfulness. Among many other intriguing differences in both gray and white matter, across cortical and subcortical regions (reviewed in [60]), structural heterogeneities in several default mode network (Table 12.1) and metacognitive (Table 12.2) regions are salient. In 21 structural neuroimaging studies of meditation to date contrasting meditators versus controls, several have found structural enhancement of RLPFC (BA 10) [94, 106, 182], DLPFC [94, 106], and the insula [81, 94, 106, 172]. Default mode network regions are also consistently altered in meditation practitioners, including differences in hippocampus [81, 82, 112, 113] and parahippocampus [94, 108], as well as PCC [82, 83].

These results are part of a large body of as yet fairly disparate findings, however. To address this problem, we recently conducted a review and meta-analysis of all structural neuroimaging studies of meditation. We found meta-analytic clusters of cross-study structural enhancement in RLPFC (BA 10), ACC, anterior insula, and hippocampus (among other regions), suggesting that the structure of metacognitive and default mode network areas is consistently and significantly altered in relation to meditation practice [60].

What might be the benefits of such an open, nonjudgmental metacognitive stance toward spontaneous thought processes? A primary contention in classic Buddhist thought is that mindfulness meditation leads to a gradual lessening of one's identification with passing thoughts and emotions, and thereby to improved well-being (e.g., [2, 174]). This could prove beneficial in the context of negative, depressive thoughts, for instance—such mental phenomena could come to be seen as merely ephemeral experiences, rather than traits that define one's identity. Indeed, such metacognitive detachment from self-identification with negative rumination has been proposed to be a key mechanism underlying the beneficial effects of mindfulness meditation for clinical disorders such as depression and anxiety [37, 173].

A related possibility is that of decreased automaticity in the associations among spontaneous thoughts: although the incidence of spontaneous thoughts per se might not decrease with mindfulness practice, an open, nonjudgmental metacognitive stance might reduce the "chaining" or elaboration of the thoughts that do arise. Reduced elaboration of habitual cognitive and emotional associations might then allow for greater cognitive-emotional flexibility and novel, more adaptive, behavioral responses (e.g., [128]). Furthermore, some spontaneous thoughts—especially those previously judged to be of negative or of a personally "unacceptable" nature—may be suppressed before they reach awareness through a habitual elaborative process that may over time become automatic. The emotional sequelae of those "unconscious" thoughts may affect mood negatively and without the person's awareness. By maintaining an open, nonjudgmental metacognitive mindset, meta-awareness during mindfulness meditation may therefore enable such habitually suppressed thoughts and their emotional consequences to come more fully into conscious awareness, allowing increased insight into the functioning of one's own mind and a greater flexibility in directing mental activity toward personally beneficial goals.

In summary, mindfulness meditation is a unique phenomenon during which brain regions associated with both MW and metacognition appear to be activated, and during which metacognition may occur simultaneously with MW, facilitating and enabling the emergence of spontaneous thoughts that may otherwise not reach awareness. This process may enable the meditator to reach new realizations and conclusions and may allow for improved behavioral and mental flexibility.

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Chapter No.: 12 | Date: 21-11-2013 | Page: 15/28

12.5.3 Lucid Dreaming: Meta-Awareness of the Dream State

Lucid dreaming is perhaps the least researched and most elusive of our examples of potential facilitative interactions between metacognition and spontaneous thought. This seemingly paradoxical phenomenon, wherein one is aware that one is dreaming while in the dream state (and can in some cases direct the dream's course and content), has fascinated humanity for millennia. Ancient written records from both the East and West have elaborated on the notion of lucid dreaming: the Indian scriptures known as the Upanishads [138], for instance, discuss the possibility of maintaining conscious awareness throughout the sleep cycle; Aristotle in his writings on sleep and dreaming [67] noted that, "Often when one is asleep, there is something in consciousness which declares that what then presents itself is but a dream;" and archaic Tibetan Buddhist meditation practice manuals [74, 187] discuss methods of attaining, and beneficial effects of, dream lucidity at length.

As lucid dreaming involves meta-awareness of the true state of the physical self (asleep in bed), as well as recognition that the apparent dreamworld is in fact a projection of the self, it can be considered a form of autonoetic (i.e., self- as opposed to perception-focused) metacognition [92, 122]. But is regular (nonlucid) dreaming a form of spontaneous thought? In a recent review and meta-analysis of the subjective content and neural basis of dreaming, we argue that it likely is [61]. First, the subjective reports from daytime MW and nighttime dreams overlap considerably in terms of sensory content, bizarreness, emotionality, and so on. Second, brain activations during dreaming (compared to waking) show a pattern highly similar to that of the resting state/default mode network [61]. The combined neurophysiological and experiential evidence has led us to propose that nighttime dreaming can be considered as a more intense and immersive version of waking MW or daydreaming [61]. Interestingly, compared to waking rest, nonlucid dreaming typically involves the deactivation of prefrontal cortical regions involved in executive control and metacognitive monitoring, including DLPFC [61, 80, 130], which may explain the lack of meta-awareness during regular dreaming.

If dreaming is an even more immersive form of MW, can the light of metacognitive awareness still penetrate to such depths? Paralleling the ancient accounts mentioned above, some contemporary researchers argue that indeed it can (e.g., [16, 189]), but lucid dreaming continues to meet with considerable skepticism. As the voluntary musculature of the body is paralyzed during rapid eye movement (REM) sleep, when lucid dreaming has been assumed to take place, communicating one's meta-awareness in a verifiable way to outside observers had seemed impossible. It was eventually noted, however, that voluntary control of the muscles of the eyes appeared intact, and that observable eye movements during REM seemed to correlate with direction of gaze in the subjective dream experience [144]. In the early 1980s, a team at Stanford University published the first objective evidence of lucid dreaming by using complex, pre-arranged patterns of eye movements to signal meta-awareness from within verified REM sleep [104].

Layout: T1 Standard SC Book ID: 309393_1_En Book ISBN: 978-3-642-45189-8
Chapter No.: 12 Date: 21-11-2013 Page: 16/28

Further work found other correspondences between subjective reports of lucid dreaming activity and various physiological measures, including increased respiration during dreamed speech and greater electromyographic (EMG) activity during dreamed muscle flexion [49]. Recent work has now complemented these early results by taking advantage of sophisticated methods combining simultaneous electroencephalography (EEG) and fMRI [44].

The latest work has begun to reveal features that distinguish lucid from regular dreaming at the neural level. A recent study employing EEG found that, compared to nonlucid dreaming, lucid dreaming showed greater overall coherence levels across the entire EEG frequency spectrum, as well as greater 40 Hz (γ-band) power localized to frontal and frontolateral regions of the brain (Voss et al. 2009). The finding of high gamma activity is of particular interest, since γ-band ($\sim$30–70 Hz) synchrony has been argued to be a key neural correlate of conscious awareness, with the ensuing capacity for self-reflection (e.g., [40]).

Localization of EEG signals to particular cortical areas is contentious, however, and the gold standard for studying lucid dreaming has long been considered fMRI, due to this method's high temporal and spatial resolution. To date only a single case study of lucid dreaming measured with combined EEG/fMRI has been reported [45]. The results, though highly tentative, are suggestive: lucid REM sleep dreaming, as compared to regular REM dreaming, showed higher activation in numerous cortical regions [45]. Most relevant to the present discussion were activity increases in right DLPFC as well as bilateral RLPFC, both of which have been strongly linked to metacognitive awareness (see Sect. 12.3). Their increased activity was therefore argued to be the basis of the heightened self-reflective awareness present during lucid dreaming [45] (Fig. 12.4). AQ2

But to what end does one engage metacognition during dreaming? The reasons are many and varied. Ancient Tibetan Buddhist texts, for example, view lucid dreaming as a chance to practice deep meditation, and as an aid to understanding the impermanent, partially mind-constructed nature of the waking, physical world [74, 187]. Professional athletes have attempted to use lucid dreaming as an opportunity to rehearse demanding or possibly dangerous physical activities [103]—in line with fairly ample evidence that mental practice, including dreaming of recently learned skills [186], improves actual performance (reviewed in [46]).

Others view lucid dreaming as a potential adjunct to psychotherapy [175]. Many regular (nonlucid) dreams are characterized by negative emotion [132, 154], and intriguingly, the attainment of lucidity is frequently triggered by nightmares [155]. Metacognitive awareness in dreams, then, may also serve to attenuate the high levels of fear and negative emotion in dreams or nightmares [155], while at the same time facilitating the continuation of the spontaneous dream mentation that would otherwise abruptly end if intense negative emotion led to sudden awakening.

Though the cognitive neuroscience of lucid dreaming remains in its infancy, the preliminary work outlined above suggests an intriguing cognitive state that demands rigorous and extensive research. Much work will be required to further understand how immersion in a spontaneously generated, immersive dream world

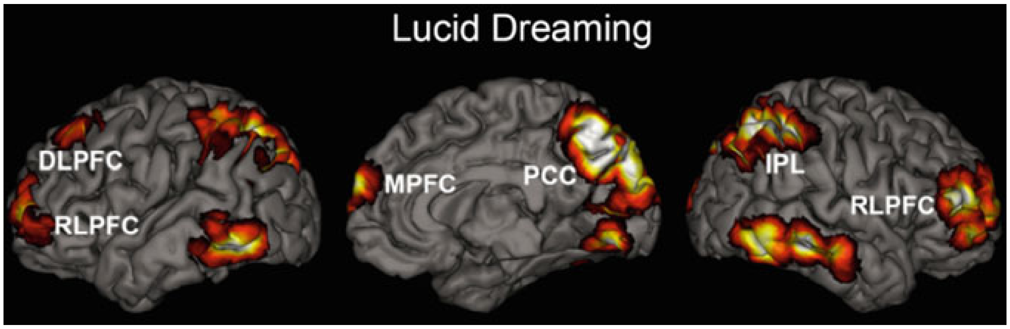

Fig. 12.4 Brain recruitment during lucid dreaming. Lucid dreaming involves simultaneous recruitment of default mode network and metacognitive regions, including rostrolateral (*RLPFC*) and dorsolateral prefrontal cortex (*DLPFC*), as well as medial prefrontal cortex (*MPFC*), inferior parietal lobule (*IPL*), and posterior cingulate cortex (*PCC*). Modified and reproduced with permission from Dresler et al. [45]

can be simultaneously accompanied by metacognitive awareness of the illusory, self-generated nature of one's perceptions and experiences. Just as important will be research into the putative benefits of lucid dreaming, including the potential for mental training, and cultivation of positive emotions and experiences.

12.6 Conclusions and Some Remaining Questions

In this chapter, we focused on the contrast between suppressive and facilitative interactions between metacognition and MW in order to bring more attention to the usually overlooked positive effects of metacognition during MW. But a number of questions still remain: Could the suppressive and facilitative interactions be simply flip sides of the same coin—that of selective pressures exerted by metacognition on spontaneously generated mental contents? Is continuous metacognition, occurring in parallel with the stream of consciousness, possible—and indeed desirable? And are there any other examples of human cognition, in addition to the three we have outlined here, during which there may be positive interactions between metacognition and MW?

12.6.1 Survival of the Fittest in the Cortical Ecosystem?

Nature's profligacy is notorious: a single tree may throw millions of seeds to the wind on the off chance that but one will find fertile ground. So long as slight variations characterize individual units, however, the high cost of such extravagance may conceivably be justified by the immense reward of a single success perpetuating the individual, and possibly the species.

Could the human brain function in a similar fashion, generating an unending array of ideas, plans, and solutions, in order that a single triumph might justify hundreds, perhaps thousands, of failures and mere fantasies? Could metacognition serve to decide among these innumerable ideas and thoughts, and judge their value or utility? This framework was most famously applied by Donald T. Campbell to scientific and artistic creativity, as well as problem solving generally [21, 22, 159]. Campbell's "selectionist" theory of creativity retains enormous influence today. He considered spontaneous thoughts as quasi-random variation of pre-existing ideas and patterns of behavior; metacognitive evaluation as selective pressure; and long-term memory as the substrate allowing for "heritability" or persistence of selected variants.

Such "selectionist" accounts are consistent with the kind of facilitative MW-metacognition interactions we have discussed throughout this chapter, and are certainly worthy of further investigation (cf. [159]). It is worth noting, however, that the analogy with evolutionary selection, albeit useful to some degree, may also obscure other possible facilitative long-term effects that metacognition may have on the spontaneous generation of thoughts. For example, it is possible that by positively evaluating certain spontaneously generated ideas, metacognition makes related ideas more likely to spontaneously arise in the future (as in the case of creative thought). This kind of interaction may be missed if our understanding is framed solely in selectionist terms, which emphasize competition between entities and the "survival of the fittest." In contrast, when it comes to spontaneously generated thoughts and ideas, metacognition may enable an active prospective biasing of certain semantic domains and therefore types of ideas at the neural level, which may then make it more likely for these types of ideas to be spontaneously generated in the future. This prospective biasing would need to be examined and explained in neural rather than evolutionary terms, because of the obvious differences in the way biological species and mental ideas are produced.

12.6.2 Is Continuous Metacognition Possible?

A large body of research suggests that "self-regulation"—the ability to control oneself, delay gratification, and maintain vigilance—is a limited resource ([129]; but see also [88]). It seems plausible that a related higher-order skill like metacognitive monitoring is also subject to "depletion" with continued use, although to our knowledge this remains an unexplored question. As we discuss above, however, it has been suggested that repeated use during, for example, meditation, might not just temporarily deplete metacognitive resources, but may also ameliorate metacognitive skills such as introspection—at least over the long term [62, 116]. Relatedly, advanced meditation practitioners have claimed that with a certain amount of training a qualitative change occurs, after which metacognitive monitoring is effortless and virtually perpetual—attention can be directed to any object, for any length of time, without distraction [184]. As noted above with respect to creativity, metacognition might be a double-edged sword that, if over-applied, can interfere with certain processes, such as creative generation. Whether continuous metacognition is indeed an enviable skill or state remains to us an open question, then. But the plausibility, and indeed desirability, of a continuous state of metacognitive monitoring (not only during MW and meditation, but all thoughts and actions whatsoever) is salient in even the earliest Buddhist scriptures [2]. Although such claims remain highly speculative from a scientific standpoint, we consider them intriguing questions that could be addressed by future work.

12.6.3 Other Constructive Interactions Between Spontaneous Thought and Metacognition

Above we have outlined three processes suggestive of a "positive" or facilitative interaction between metacognition and spontaneous thought processes, but there may of course be others as well. Related to creativity, for example, is the phenomenon of sudden insights or "Aha" moments, during which one is sometimes unaware of the MW process until a "correct" and/or fully formed solution presents itself spontaneously (e.g., [42, 100]). Such sudden presentations of apparently pre-evaluated ideation raise the intriguing possibility that high-level metacognitive evaluation of some kind could also take place semi-unconsciously (for further discussion see, e.g., [7]). Trial-and-error problem solving presents another related case, in which a somewhat more focused, albeit still creative and spontaneous, approach is brought to bear on a particular issue. Here, spontaneous thought processes might be more closely monitored and guided by metacognition (than during, say, artistic creativity) in order to avoid immaterial distractions and ensure a swift solution. Spontaneous musical improvisation (e.g., [109]) seems to be a related case, wherein the two stages of creative thinking are condensed into one, and metacognitive evaluation accompanies spontaneous ideation quasi-simultaneously. Imagining detailed future situations also appears to recruit a combination of default mode network and PFC metacognitive areas (e.g., [1]), suggesting that prospection (thinking about the future) too may involve the spontaneous generation of scenarios with a simultaneous metacognitive valuation of their likelihood or utility (see [20], for a review).

12.6.4 Conclusions

Aside from the everyday interaction whereby metacognition quells or helps us disengage from MW, we have argued here that there are singular mental states during which metacognitive evaluation functions instead to facilitate or guide spontaneous thought processes toward personally relevant, higher-order goals.

These may be goals such as artistic or scientific creativity, improved understanding of a complex problem, insight into the operation of one's own mind, or greater flexibility and adaptability of emotional and behavioral responses. We believe that this "positive" interplay is indicative of some of the most intriguing mental states we as humans are capable of experiencing. We reviewed evidence that neuroscientific measures of these states support the notion of interplay between spontaneous thought and metacognitive judgment or awareness, including both simultaneous and sequential recruitment of midline default mode network and metacognitive brain regions, as well as evidence for positive functional connectivity between the two during processes such as creative thinking. We have also elaborated on some of the possible cognitive mechanisms whereby metacognition may positively interact with MW, facilitating spontaneous mentation and opportunities for arriving at conclusions and realizations that may not otherwise be reached by spontaneous thought processes alone.

Donald Campbell once remarked, "Mental meandering, MW… is an essential process. If you are allowing that mentation to be driven by the radio or the television or other people's conversations, you are just cutting down on… your intellectual exploratory time" (quoted in [42]). Perhaps it is only with the assistance of metacognition that we can make the best use of our mental meanderings and help our wandering mind find its way during those highly valuable, and possibly uniquely human, intellectual explorations.

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