Catching the wandering mind:

Meditation as a window into spontaneous thought

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To appear in *The Oxford Handbook of Spontaneous Thought*, K.C.R. Fox and K. Christoff (Editors), forthcoming (2017). New York: Oxford University Press.

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 by combining detailed subjective reports from experienced meditators with rigorous objective physiological measures, we can advance our understanding of human consciousness.

Keywords: 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, both scientific and 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 towards 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 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 1.

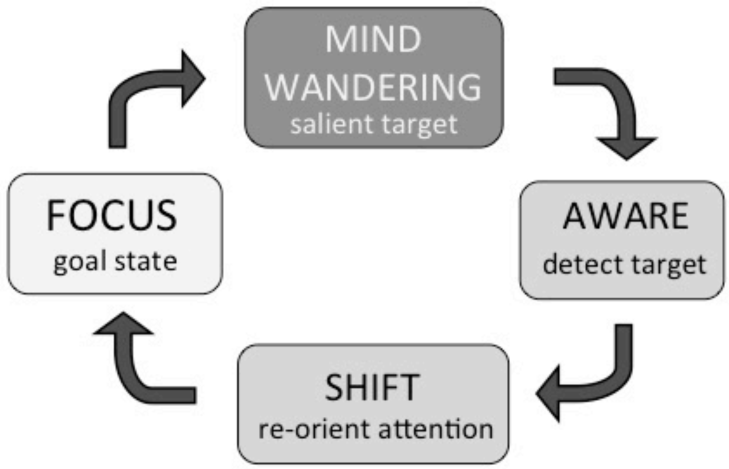

Figure 1: Cognitive dynamics of FA meditation. A session of FA meditation is an iterative cycle of mental states including object-focused attention (FOCUS), mind wandering (MW), awareness of mind wandering (AWARE), and shifting attention back to the object (SHIFT). The FOCUS state is the intended "goal," 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).

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 importantly—of monitoring and recognizing naturally arising mental states or spontaneous thoughts (AWARE), as well as disengaging and re-directing 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 an 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 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 4 distinct phases (3 sec each) corresponding to the cognitive model in Figure 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

[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 s/he 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).

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 below). 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 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 re-orienting 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.

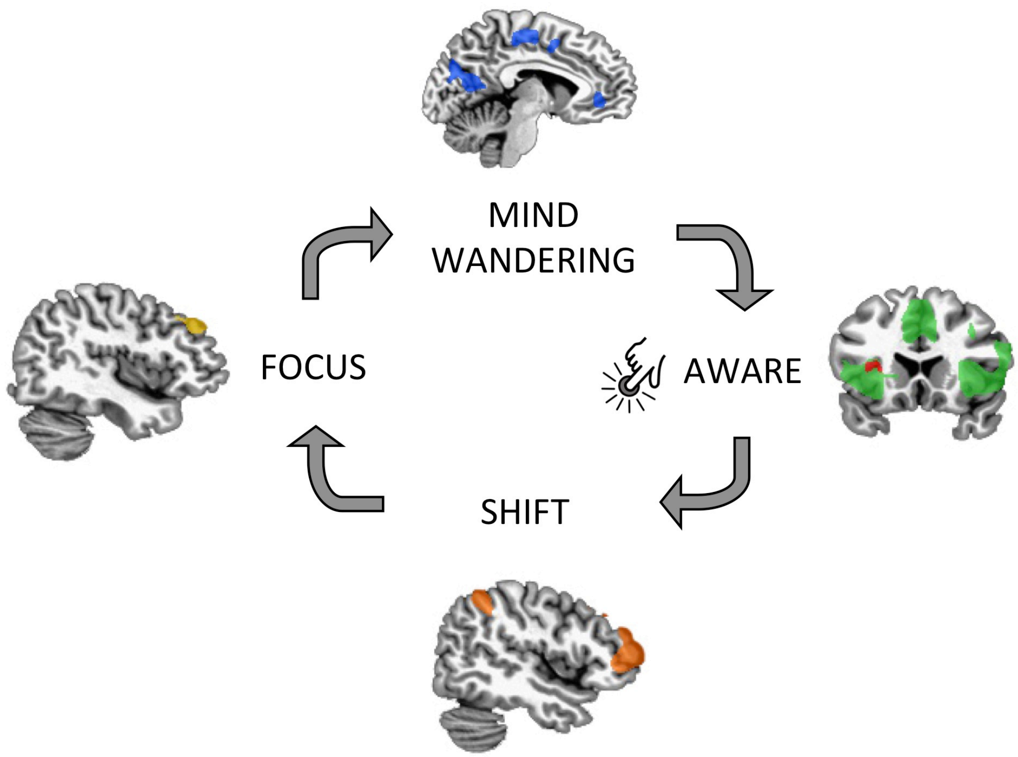

Figure 2: Brain networks involved in FA meditation. Using a button-press from the participant to mark the moment of awareness, four brief cognitive phases were defined around this time point, and neural activity was analyzed accordingly. These results show activity during the FOCUS, AWARE, and SHIFT 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).

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 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 meta-cognitive 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 SART task (Jha et al.,

[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 2, with insula activity bridging default mode and executive network activity.

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-

[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.

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 and 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) 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 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 3A). In other 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 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 end point 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,

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[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).

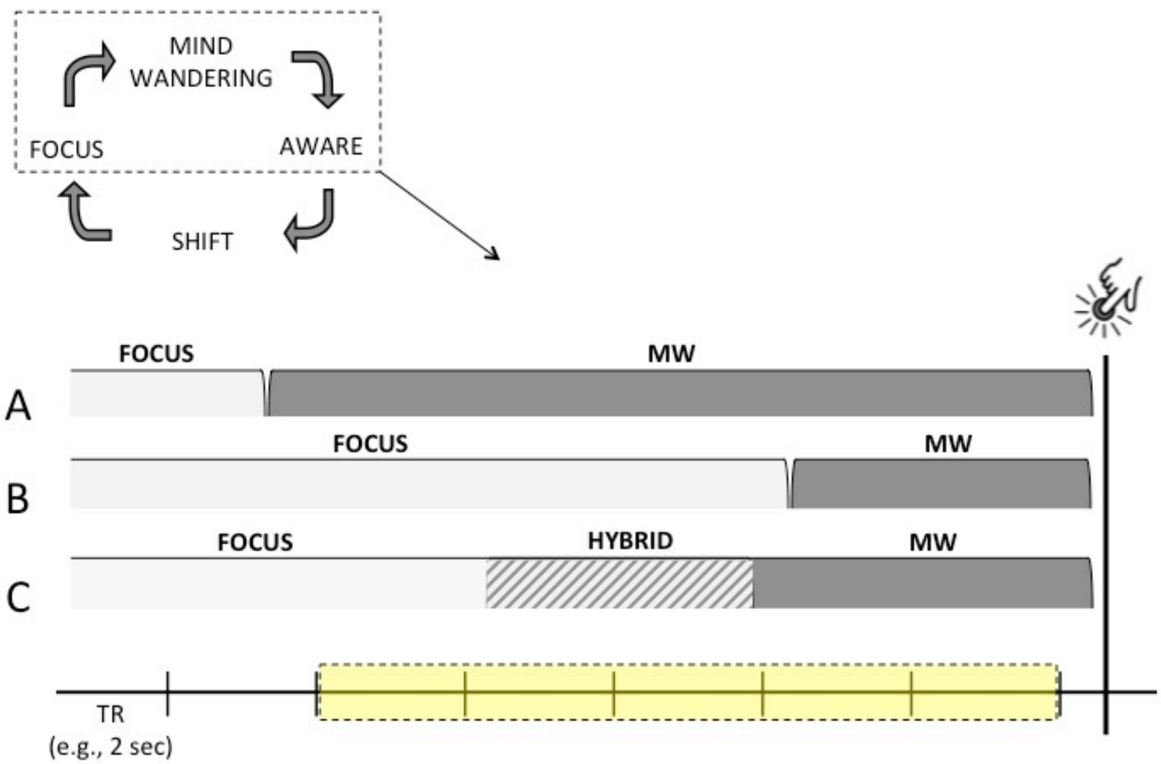

Figure 3: Defining the temporal window of analysis. This schematic depicts three hypothetical cognitive scenarios and related window of analysis for a neuroimaging study of self-caught mind wandering. Tick marks denote TRs (the fMRI scanner's sampling rate, here 2 seconds each), and the yellow bar represents 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.

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 3C).[7] Splitting of attention has been

[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 above, 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

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 end point* (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).

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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.

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, Thompson, & Rosch, 1992; 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." Below, 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 vs. 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 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 where 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.

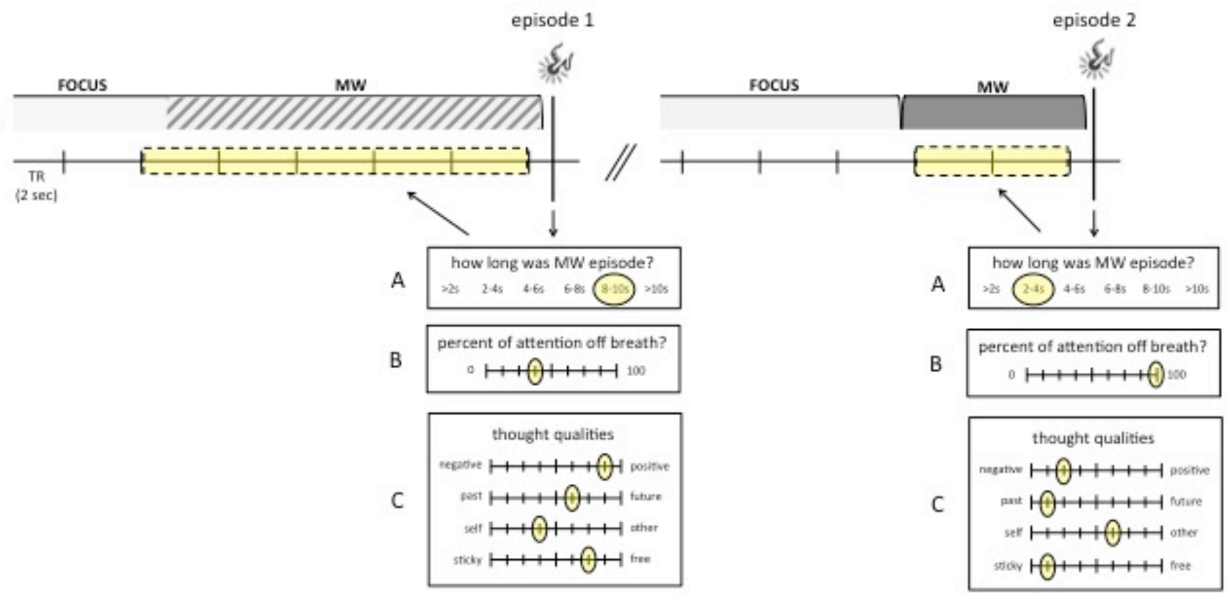

Figure 4: Possible characterization of individual thought episodes through first-person reports during FA meditation. This schematic shows two temporally and phenomenally different episodes of mind wandering that could occur during the course of FA meditation. In this kind of design, each time the practitioner becomes aware of mind wandering, s/he 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.

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 4A). Using a trial-by-trial approach with the help of such skilled participants, researchers may thus be able to construct very fine-grained and 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 above (Figure 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 4C).

Participant selection. While this suggested approach assumes 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 above 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.

Conclusions

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.

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