Insights from Quiet Minds: The Converging Fields of Mindfulness and Mind-Wandering

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Abstract Our lives are filled with an endless array of perceptions, thoughts, and feelings, and our attention usually darts back and forth between them. Yet meditative traditions have long valued the capacity to remain undistracted from our immediate experience, and countless individuals make a practice of stabilizing their awareness in the here and now. What are the implications of anchoring our usually restless minds? Could stabilizing our attention provide an informative lens into the dynamics of the human brain? Here we review recent research that situates mindfulness as an opposing construct to mind-wandering and a remedy for wandering minds. We then review empirical intersections between mindfulness and mind-wandering from recent neuroimaging studies.

Mindfulness and Non-Distraction

The word mindfulness is used with a growing sense of familiarity, but there is ongoing disagreement as to the most privileged and useful definition of this construct (Grossman and Van Dam 2011) or even whether the act of defining mindfulness is appropriate (Schmidt, this volume). Some meditative traditions have defined mindfulness as sustained non-distraction (Brown and Ryan 2003; Wallace and Shapiro 2006; Dreyfus 2011), whereas multifactor conceptualizations of mindfulness emphasize additional qualities as well, such as an orientation toward one's experiences characterized by curiosity, openness, and acceptance (Bishop et al. 2004; Baer et al. 2006).

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These definitions are by no means exhaustive and there are many traditions of mindfulness practice that have evolved over millennia and offer further delineation.

Amid this disagreement, there is nevertheless consensus from meditative traditions that sustained attentiveness represents a fundamental element of mindfulness. Accordingly, we have largely focused our investigations into mindfulness by examining the capacity for non-distraction.[1] Our focus on non-distraction as a central element of mindfulness is not intended to devalue other qualities sometimes ascribed to mindfulness, such as intentionality, non-judgment, awareness, openness, and curiosity. There is continued disagreement as to whether each of these various capacities are sufficient or necessary constituents of mindfulness, or even whether they might be understood as precursors, concomitants, or consequences of mindfulness, rather than aspects of mindfulness per se. Fortunately, empirical investigation into mindfulness can continue despite these disagreements so long as researchers are explicit about their conceptual and operational definitions.

Mind-Wandering as Task-Unrelated Thought

In direct contrast to mindfulness, which entails a capacity to avoid distraction, mind-wandering is characteristically described as the interruption of task-focus by task-unrelated thought (TUT; Smallwood and Schooler 2006). Unlike the struggle to identify a validated and widely accepted measure of mindfulness, there has been somewhat greater consensus with respect to operational definitions of mind-wandering. The most widely used measure is straightforward: periodically interrupting individuals during a task and asking them to report the extent to which their attention was on the task or on task-unrelated concerns, a procedure known as "thought-sampling", which measures "probe-caught" mind-wandering. There is a broad literature validating the self-report measures of mind-wandering obtained through thought-sampling by using behavioral (Smallwood et al. 2004), event-related potential (ERP; Smallwood et al. 2008c), and fMRI methodologies (Christoff et al. 2009). Such studies suggest that individuals are able to accurately report whether they have been mind-wandering – and even whether they have been aware of it – as revealed by distinct patterns of task performance and neural activation in association with self-reported mind-wandering (for a recent review see Schooler et al. 2011). Additionally, studies using retrospective reports of mind-wandering after a task has been finished typically find results that are similar to those obtained with thought-sampling during the task (Mrazek et al. 2011). This not only provides convergent validity for thought

[1] It is worth noting that this definition of non-distraction always exists with reference to a particular activity. For example, if your goal is to engage in a task, but instead you become deeply focused on off-task concerns, this would not be an example of mindfulness even though your off-task focus may be undistracted.

sampling, but also suggests that asking participants to intermittently report their mind-wandering does not substantially alter their behavior or performance in at least some task contexts (Mrazek et al. 2012; Barron et al. 2011).

Another common measure of mind-wandering involves asking participants to indicate every time they notice that they have been mind-wandering. This measures "self-caught" mind-wandering, providing a straightforward assessment of mind-wandering episodes that have reached meta-awareness as an explicit re-representation of the contents of one's own consciousness (Schooler 2002). By contrast, thought-sampling queries participants at unpredictable intervals and does not require participants to attend to their thoughts independently of an external prompt. However, because thought-sampling probes occur at varying and unpredictable times during a primary task, this method can be used in conjunction with the self-catching measure to catch people mind-wandering before they notice it themselves (Schooler and Schreiber 2004).

Several indirect markers of mind-wandering are also available, including those derived from performance markers of inattention in the Sustained Attention to Response Task (SART; Smallwood et al. 2004, 2007a, b, 2008b; McVay and Kane 2009; Cheyne et al. 2009). The SART is a GO/NOGO task in which participants are asked to respond with a key press as quickly as possible to frequent non-targets and to refrain from responding to rare targets. Different performance markers in this task, such as response times (RTs) or different kinds of errors, have been associated with varying degrees of task disengagement (Cheyne et al. 2009). For example, failures to respond to rare targets (errors of omission) generally indicate a more pronounced state of disengagement than a large coefficient of variability (CV) for RTs (the CV is the standard deviation of RTs divided by the mean). RT CV has been associated with a state of mind-wandering that emerges from a minimally disruptive disengagement of attention characterized by a periodic speeding and slowing of RTs as attention fluctuates slightly (Cheyne et al. 2009; Smallwood et al. 2008b).

Mindfulness and Mind-Wandering as Opposing Constructs

Many behavioral markers of mind-wandering have a distinctly mindless quality, such as rapid and automatic responding during SART (Smallwood et al. 2004), absent-minded forgetting (Smallwood et al. 2003), and eye-movements during reading that are less sensitive to lexical or linguistic properties of what is being read (Reichle et al. 2010). Furthermore, ERP studies have demonstrated that instances of mind-wandering are characterized by a reduced awareness and/or sensory processing of task stimuli and other objects in the external environment (Barron et al. 2011; Smallwood et al. 2008c; Kam et al. 2010). The ability to remain mindfully focused on a task therefore appears to be in direct opposition to the tendency for attention to wander to task-unrelated thoughts. Starting from this observation, we began our ongoing series of investigations into the relationship between mindfulness and mind-wandering by first examining whether we could find empirical support for this intuitive notion that mind-wandering and mindfulness are opposing constructs.[2]

Existing work that links mindfulness and mind-wandering has relied heavily on the Mindful Awareness Attention Scale (MAAS; Brown and Ryan 2003), the most widely used dispositional measure of mindfulness. This scale addresses the extent to which an individual attends to present experience without distraction (e.g., I find myself listening to someone with one ear, doing something else at the same time; reverse scored). Low self-reported mindfulness as measured by the MAAS is associated with fast and error-prone responding in the SART (Cheyne et al. 2006, 2009). These results show that the measurement of trait-mindfulness by the MAAS can predict behavioral concomitants of real-time mind-wandering observed during performance of a task in the lab.

We recently conducted a more comprehensive investigation into the relationship between the MAAS and several convergent measures of mind-wandering (Mrazek et al. 2011). All participants completed the MAAS, a 10-min mindful breathing task with thought-sampling probes, a 10-min mindful breathing task requiring self-catching of mind-wandering, a 10-min SART, and a self-report measure of trait daydreaming that has been widely used to study mind-wandering (Mason et al. 2007). We found that individuals who reported high levels of mindfulness during daily life also reported less daydreaming. Furthermore, high levels of trait-mindfulness were also associated with less mind-wandering as measured by self-reported TUT during mindful breathing, fewer errors of commission during the SART, and lower RT variability. These results provide converging evidence suggesting that – at least based on their most common operational definitions – mindfulness and mind-wandering are indeed opposing constructs.

Mindfulness as a Tool for Reducing Mind-Wandering

If mindfulness and mind-wandering are inversely related, it follows that mind-wandering and its disruptive effects on task performance (e.g. Smallwood et al. 2003, 2004, 2007a, b, 2008a; Smallwood 2011a; Reichle et al. 2010) should be reduced by interventions that increase mindfulness. While mindfulness training has been demonstrated to improve executive attention, perceptual sensitivity, and sustained attention (Tang et al. 2007; MacLean et al. 2010), the direct impact of mindfulness training on mind-wandering has until recently been less carefully examined. In fact, to date there has been little progress in developing empirically proven strategies for reducing mind-wandering.

[2] Our selection of non-distraction as a central feature of mindfulness strongly influences our interpretation of the opposing nature of mindfulness and mind-wandering. More inclusive conceptualizations of mindfulness might lead to different perspectives. For instance, although there may be wide agreement that episodes of mind-wandering are not instances of mindfulness, the absence of mind-wandering may not guarantee the presence of mindfulness. One might be undistracted, but lack other qualities sometimes espoused to be essential to mindfulness (non-judgment, openness, curiosity, etc.).

We recently examined whether a brief mindfulness exercise can reduce mind-wandering, thereby both introducing a potential antidote to mind-wandering and establishing a causal relationship between the presence of mindfulness and the absence of mind-wandering. This expectation is consistent with the many well-documented benefits of mindfulness training (for a review see Brown et al. 2007). However, many prior studies have utilized intensive meditation training lasting months or years, limiting the applicability of observed improvements for most societal and educational contexts (Brefczynski-Lewis et al. 2007; MacLean et al. 2010). Furthermore, from a methodological perspective, mindfulness intervention studies typically include so many different aspects of intervention that it is difficult to discern which specific element is responsible for any observed changes. What is useful in discerning the causal role of mindfulness in mitigating mind-wandering is a simple manipulation that directly and specifically targets individuals' ability to remain mindful. Accordingly, we used an 8-min mindful breathing intervention that provides a simple and widely accessible intervention that also affords a high degree of experimental control.

In this investigation, participants were randomly assigned to conditions in which they completed either 8 min of mindful breathing or one of two control conditions: passive relaxation or reading. Expectation effects and demand characteristics were minimized by informing all participants that they were participating in a study designed to examine effects of relaxation on attention. In the mindful breathing condition, participants were instructed to sit in an upright position while focusing their attention on the sensations of their breath without trying to control the rate of respiration. Participants were asked to return their attention to the breath anytime they became distracted. Participants in the reading condition were asked to browse a popular local newspaper, while those in the passive rest condition were asked to relax without falling asleep. Subsequently, all participants completed a 10-min version of the SART. Relative to the two control conditions, those who first completed 8-min of mindful breathing exhibited enhanced performance as measured by behavioral markers of inattention commonly associated with mind-wandering (fewer errors of commission and lower RT variability). The effectiveness of this intervention establishes a causal relationship between the cultivation of mindfulness and subsequent reduction in mind-wandering.

Building on the finding that a brief mindfulness exercise could reduce mind-wandering, we next examined whether a more thorough introduction to mindfulness could reduce mind-wandering in a manner that would enhance working memory capacity (WMC) and reading comprehension. In a recent randomized controlled investigation, we examined whether a 2 week mindfulness training course would be more effective than a comparably demanding nutrition program in decreasing mind-wandering and improving cognitive performance among undergraduates (Mrazek et al. 2013). We found that mindfulness training improved performance on both the measure of WMC and the test of reading comprehension (an adapted version of the Graduate Record Examination; GRE). Mindfulness training also reduced mind-wandering during these tasks as assessed by thought sampling, self-catching, and a validated scale measuring retrospective task-unrelated thought. Notably, improvements in WMC and GRE performance following mindfulness training were mediated by reduced mind-wandering specifically for those who were most prone to distraction at pre-testing. This suggests that mindfulness-based interventions do not only benefit individuals who are already proficient at attentional control, and that training to enhance attentional focus may be a key to unlocking latent cognitive skills that were until recently viewed as immutable.

Brain Dynamics Through the Lens of Mind-Wandering and Mindfulness

The task-positive and task-negative networks of the human brain – together comprising a substantial portion of the human cerebral cortex – are engaged in an endless back-and-forth. As we engage with a task, task-positive brain regions dedicated to attention and control are activated. This task positive network is also referred to as the dorsal attention network, and it includes brain regions involved in orienting attention and executive control. When our minds wander, a different set of task-negative brain regions activate (these regions are also known as the default mode network). These two networks usually operate in opposition, yet under some circumstances they activate simultaneously (Smallwood et al. 2011b). Understanding the functions and dynamics of these respective networks remains an area of focused investigation. Here we illustrate how the intrinsically related constructs of mindfulness and mind-wandering may provide an informative lens when thinking about the potentially nuanced relationship between the task-positive and task-negative networks.

Neural Correlates of Mind-Wandering

Over the last decade, accumulating evidence has suggested that activation of the task-negative or default-mode network (DMN) may serve as an fMRI marker of mind-wandering (for a review see Gruberger et al. 2011). The DMN is a collection of brain regions that typically show greater activation at rest than during task performance. Direct evidence that the DMN is associated with mind-wandering comes from studies that link this network to reports of task-unrelated thoughts. One approach involves linking retrospective measures of mind-wandering to brain activity (e.g. Andrews-Hanna et al. 2010). Other studies have documented that situations that are associated with greater mind-wandering reports (as assessed outside of the scanner) also lead to greater activity in many of the key elements of the DMN (Mason et al. 2007; McKiernan et al. 2006). Furthermore, Christoff and colleagues (2009) combined experience sampling with fMRI while participants engaged in the Sustained Attention to Response Task. During periods of off-task thought, DMN activity was higher than when participants were focused on the task, an observation that has been replicated by Stawarczyk and colleagues (2011). Importantly, Christoff and colleagues also demonstrated that DMN activity increased prior to performance errors that have themselves been linked to greater mind-wandering. In summary, although DMN activity may underlie more than just task-unrelated thoughts, a growing body of evidence clearly indicates that DMN regions are more active during mind-wandering than during focused task-engagement.

Neural Correlates of Mindfulness

What happens in the brain when someone meditates, and does this depend on expertise? If mind-wandering and mindfulness are opposing constructs, neural markers of mind-wandering should decrease during the practice of mindfulness. This topic has been approached largely through investigations with experienced meditators. The accumulated practice of experienced practitioners might be expected to produce stronger contrasts between rest and meditation, though it is also possible that these individuals' resting state is largely characterized by an ongoing mindfulness (see discussion below of Froeliger et al. 2012). It can also be informative to investigate the underlying neural correlates of mindfulness among individuals without prior training. This second approach is helpful because attempts to identify the neural processes of distinct aspects of mindfulness (like non-distraction) can be obscured by the divergence in how mindfulness is defined and practiced. In fact, researchers often study experienced meditators who have undertaken considerable training in a number of related but potentially dissociable practices: non-distraction, non-judgment, non-reactivity, non-attachment, etc.[3] From this vantage point, investigating the neural mechanisms supporting mindfulness among non-meditators helps control for prior history with mindfulness that may not align with the experimenter's operational definition. Here we review selected research that addresses what happens in the brain during periods of focused-attention meditation in both inexperienced and experienced meditation practitioners, with an emphasis on how this research illuminates the intersection between mind-wandering and mindfulness.[4]

A recent investigation focused specifically on neural correlates of mindfulness among non-meditators (Dickenson et al. 2012). This study used an fMRI block

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[3] One could argue that a genuine instance of mindfulness must be characterized by the presence of non-distraction, non-judgment, curiosity, and openness, and therefore, that investigations pertaining to a single quality of mindfulness will be insufficient in their ability to draw conclusions about the construct in its totality. Although more focused research into specific features of mindfulness risks not fully representing the more inclusive characterizations of the construct, they do allow for more tractable empirical investigations. It is considerably more feasible to operationally define and measure non-distraction than it would be to integrate measurements of curiosity, openness, non-judgment, awareness, and non-distraction to ensure that all these elements are present simultaneously.

[4] Focused-attention meditation may not represent an instance of mindfulness within multi-factor frameworks of mindfulness that would require the presence of some constellation of additional qualities besides non-distraction.

design in which participants alternated between 50 s of focused-attention meditation and a control task in which they were provided with the instructions: "let your mind take you wherever it goes as you normally would throughout the day." Relative to the control task, there was increased activation of a variety of regions associated with the task-positive network during meditation. Specifically, significant increases were found in superior parietal lobule (SPL), temporal-parietal junction (TPJ), pre-supplementary motor area, dorsal anterior cingulate gyrus, and the insula. Meditation also led to a decrease in activation of a coherent subset of the default mode network, including medial PFC, dorsomedial PFC, angular gyrus, and precuneus. This study clearly demonstrates that focused-attention meditation can activate brain regions associated with control of attention, even among non-meditators. However, it remains unclear whether the activation of task-positive regions represent focused attention, the *attempt* to focus attention, or both. Regardless, the combination of increased activation of the task-positive network with reduced activation of default-mode network regions is consistent with the notion that individuals are at least attempting to engage their attention on their breath while suppressing the distraction of mind-wandering. This is also broadly consistent with evidence that functional connectivity between task-positive and default mode networks should change during meditation – a topic we return to shortly.

Although Dickenson and colleagues (2012) found clear activation changes during meditation that could be interpreted as reduced mind-wandering, another study employing a similar methodology found only partially consistent findings. Brewer and colleagues (2011) examined differences in neural activation during meditation among both non-meditators and experienced meditators who had an average of over 10,000 h of practice. As part of a larger investigation, participants completed two 4.5-min focused-attention meditations in which they were asked to pay attention to the sensations of breathing. During baseline scans that preceded the meditations, participants were instructed: "please close your eyes and don't think of anything in particular". Unlike Dickenson and colleagues (2012), this investigation did not find meditation-induced reductions in activation of key default mode regions (PCC and mPFC) or any changes in task-positive network regions among non-meditators. By contrast, experienced meditators showed reduced activation in both PCC and mPFC. A between-groups contrast revealed that during focused-attention meditation, meditators showed significantly less activation in PCC and left angular gyrus compared to non-meditators. In sum, advanced meditators showed the expected pattern of reduced default mode network activation, whereas non-meditators showed no significant changes. This complete absence of activation changes that Brewer and colleagues (2011) found in non-meditators is striking, and might be explained by the combination of a small sample size and a long-block design that the authors suggest may have de-optimized their analyses. Additionally, novice meditators may rapidly alternate between attempts to focus, focused attention, and lapses of attention. This could lead to a less consistent activation of brain regions during the focused-attention meditation, although participants in Dickenson et al. (2012) would have been subject to similar fluctuations of attention and yet that investigation revealed several predicted effects.

Although there is some inconsistency with respect to non-meditators, the results across these studies are generally consistent with the notion that brain regions associated with mind-wandering are relatively deactivated during focused-attention meditation. The inconsistency across studies could be a consequence of the variations in block design, meditation instructions, and control/baseline task instructions. It is also worth mentioning that in each study, participants repeatedly alternated between meditation and control tasks. Given that even brief mindfulness inductions can result in subsequently altered performance (Mrazek et al. 2011), there is some risk that meditation-related neural changes could bleed into control tasks. One alternative strategy would be to have all participants first complete a control task and then complete a meditation task, though this design is also not without limitations (i.e. order effects).

Neural Activation Versus Functional Connectivity

Experienced meditators tend to show greater activation of task-positive regions and decreased activation of DMN regions during meditation, indicating that mindfulness practice influences the magnitude of activity within various brain regions. Given that the brain operates as a highly complex system, it is plausible that these changes in the magnitude of neuronal activity are coupled to changes in the interactions between brain areas (and their associated networks). Functional connectivity analysis of fMRI data has recently gained traction as an informative approach toward understanding the dynamics of the brain and the extent to which different brain areas are functionally connected to one another. Functional connectedness, in the context of fMRI data, is measured by examining the strength of correlations between the time-courses of neuronal activity across different brain regions. Brain regions are functionally connected to the extent that their respective activation patterns are correlated during a particular task or context, regardless of whether those regions are adjacent or structurally connected. Importantly, functional connectivity is present between brain regions even if they exhibit highly anti-correlated (i.e., negatively correlated) patterns of activation; such anti-correlations suggest inhibitory or control processes that are likely just as important to brain function as co-activations of brain areas. Here we review the impact of mindfulness training on functional connectivity both within and between the default-mode and task-positive networks.

Mindfulness and Functional Dynamics Within the Default Mode Network

Jang and colleagues (2011) examined the differences in functional connectivity within the DMN during the resting-state between 35 experienced meditators and 33 controls without prior meditation experience. Separate analyses were conducted using either the medial prefrontal cortex (MPFC) or the posterior cingulate cortex (PCC) as seed regions (both of these regions are considered to be primary hubs of the DMN; see Buckner et al. 2008 for evidence supporting this claim). While the patterns of connectivity were similar for either seed region – including MPFC, PCC, inferior parietal cortices, and lateral temporal cortices for both seed maps – the experienced meditators exhibited greater functional connectivity within the medial prefrontal region than controls. Activation of the medial prefrontal cortex has been associated with concentrating on internal focus and sensations (so-called "internalized attention", Hölzel et al. 2011); these results therefore suggest that meditation practice may produce changes in functional connectivity within anterior DMN regions that may afford enhanced concentration or self-awareness.

Whereas Jang and colleagues (2011) found increased DMN functional connectivity within the MPFC (an anterior DMN region) among experienced meditators, self-reported mindfulness during daily life among non-meditators has also been associated with increased functional connectivity in more posterior portions of the DMN (i.e., the precuneus (Pcu) and the posterior cingulate cortex (PCC)) (Prakash et al. 2012). Although there is a discrepancy regarding the specific region(s) involved, the existing literature therefore indicates that mindfulness is associated with increased functional connectivity within key DMN regions. On appearance, this is difficult to reconcile with the previously reviewed evidence that mindfulness practice leads to less DMN activation. If mindfulness is associated with lower levels of DMN activity, then why should training in mindfulness act to strengthen the functional connections within this network? One potential answer may lie in the relationship between the anterior and posterior regions of the DMN. Jang and colleagues (2011) found greater functional connectivity within an anterior portion of the DMN (i.e., MPFC) while Prakash and colleagues (2012) found greater connectivity within posterior regions (i.e., Pcu and PCC), but recent research suggests that the functional connectivity between these anterior and posterior regions may in fact decrease with mindfulness/meditation training. Hasenkamp and Barsalou (2012), in a study comparing trained vs. novice meditators, found that the trained meditators exhibited decreased functional connectivity between a regional cluster containing portions of the MPFC and anterior cingulate cortex (ACC) and a cluster containing the PCC. Thus, these mindfulness-trained individuals exhibited less anterior-posterior functional coherence within the DMN (a similar connectivity relationship between the ACC and PCC was also observed by Kilpatrick et al. 2011). As such, it is plausible that mindfulness training may improve the intrinsic functioning of this task-negative system overall (as indicated by the observed increase in connectivity within specific regions of the DMN). However, by means of reducing the functional connectivity between anterior and posterior regions, mindfulness may reduce the likelihood of intrusive mind-wandering (e.g., rumination, prospection, etc.), the content of which is provided by the more posterior regions of the DMN (in their DMN review, Buckner et al. (2008) suggest that the DMN, particularly the PCC, is chiefly involved in internal mentations such as episodic remembering, prospection, and theory of mind).

Mindfulness and Between-Network Functional Dynamics

Hypothetically, mindfulness training may be expected to produce several key changes in the way the brain operates, both at rest and also under task constraints. For instance, individuals who have been trained in mindfulness techniques may be able to exert more attentional control over their thoughts, and as such they may be expected to display heightened coherence in brain networks associated with attentional control, especially during task settings in which such control is most critical. In a recent study, Froeliger and colleagues (2012) examined whether mindfulness-trained individuals indeed display these characteristics. They compared meditation-trained individuals with a control group and found that during a resting-state fMRI scan the meditation-trained group displayed higher functional connectivity within the task-positive network, suggesting a heightened control over the direction of attention for these individuals, even outside of the context of meditation. Additionally, those trained in meditation exhibited higher functional connectivity between the task-positive network and the DMN when meditating than when at rest, perhaps indicating a greater level of executive control in these individuals.

Several additional studies have provided converging evidence that mindfulness training enhances connectivity between DMN and task-positive regions. Brewer et al. (2011) reported that meditators (compared to controls) exhibited greater functional connectivity between DMN regions (including the PCC) and task-positive regions (specifically, the DLPFC). Hasenkamp and Barsalou (2012) also found a similar trend in functional connectivity patterns, namely that meditation-trained participants exhibited greater functional connectivity between a key anterior DMN region (e.g., the ventro-medial prefrontal cortex; VMPFC) and a key task-positive region, the inferior parietal lobule (IPL). As the IPL has been functionally associated with attentional disengagement processes (e.g., Posner et al. 1984), the authors suggest that this increased connectivity in meditators better allows for these individuals to disengage from mind-wandering states and re-engage in their meditative practices. This increased coherence between DMN areas and areas involved in attentional control has also been documented by Taylor and colleagues (2012), who compared experienced vs. novice meditators and found, similarly, that experienced meditators displayed higher functional connectivity between the IPL and the VMPFC during the resting-state.

In summary, the existing literature suggests that mindfulness training is associated with increased functional connectivity (i) within key default-mode regions (e.g., MPFC), (ii) within the task-positive network (e.g., DLPFC), and (iii) between default-mode and task-positive regions. How does mind-wandering fit into this picture? In considering this, it is important to keep in mind that functional connectivity does not distinguish between neural recruitment and inhibition. The fact that DMN regions are temporally coupled to task-positive regions in mindful individuals may therefore reflect the fact that these control regions are now, as a result of training, better able to exert inhibitory or reactive influence on these DMN regions, thus preventing mind-wandering from disrupting periods of mindfulness. This interpretation is bolstered by the finding that, overall, DMN activity is lower during meditation for experienced mindfulness practitioners (Brewer et al. 2011).

Future Directions

This review suggests that one important direction for future research is to integrate these various observations about mindfulness training, mind-wandering, and brain dynamics into a single cohesive training study. We now know that mindfulness training can reduce mind-wandering and that individuals with extensive meditation experience show functional changes within and between task-positive and default-mode regions that are consistent with less mind-wandering. A clear next step would be to determine whether these changes in underlying neural activity mediate the improvements in task-focus.

Future research must also keep potential benefits of mind-wandering in view. After all, there are circumstances in which diverting attention away from the "here and now" is beneficial. Thinking about the past or planning the future can of course be done deliberately, but research has indicated that even spontaneous mind-wandering that occurs when we are occupied with another task can be useful in some circumstances. For instance, recent findings suggest that mind-wandering can promote future planning (Baird et al. 2011) and enhance creative incubation (Baird et al. 2012). Yet the accumulating evidence for the positive outcomes of mindfulness might be interpreted to suggest that mind-wandering is of no benefit, especially within a framework that places these constructs in direct opposition. In contrast, the potential benefits of mind-wandering could be interpreted to suggest a downside to mindfulness. For instance, a practice of mindfulness that eliminated mind-wandering might lead to neglect of distal goals like retirement planning (even though it would not eliminate the opportunity for more deliberate goal-oriented planning). It may therefore be that mindfulness is most helpful when it affords a degree of control over mind-wandering that allows for its benefits while minimizing its costs. With mindfulness individuals might become better able to mind-wander at the right times (e.g. when primary task demands are relatively modest) and on the right topics (e.g. on productive issues that can foster future planning or creativity).

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References

Andrews-Hanna, J.R., J.S. Reidler, C. Huang, and R.L. Buckner. 2010. Evidence for the default network's role in spontaneous cognition. *Journal of Neurophysiology* 104(1): 322–335.

Baer, R.A., G.T. Smith, J. Hopkins, J. Krietemeyer, and L. Toney. 2006. Using self-report assessment methods to explore facets of mindfulness. *Assessment* 13(1): 27–45. doi:10.1177/1073191105283504.

Baird, B., J. Smallwood, and J.W. Schooler. 2011. Back to the future: Autobiographical planning and the functionality of mind-wandering. *Consciousness and Cognition* 20(4): 1604–1611.

Baird, B., J. Smallwood, M.D. Mrazek, J.W. Kam, M.S. Franklin, and J.W. Schooler. 2012. Inspired by distraction mind wandering facilitates creative incubation. *Psychological Science* 23(10): 1117–1122.

Barron, E., L.M. Riby, J. Greer, and J. Smallwood. 2011. Absorbed in thought: The effect of mind-wandering on the processing of relevant and irrelevant events. *Psychological Science* 22(5): 596–601. doi:10.1177/0956797611404083.

Bishop, S.R., M. Lau, S. Shapiro, L. Carlson, N.D. Anderson, J. Carmody, et al. 2004. Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice* 11(3): 230–241. doi:10.1093/clipsy.bph077.

Brefczynski-Lewis, J.A., A. Lutz, H.S. Schaefer, D.B. Levinson, and R.J. Davidson. 2007. Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences* 104(27): 11483–11488. doi:10.1073/pnas.0606552104.

Brewer, J.A., P.D. Worhunsky, J.R. Gray, Y.-Y. Tang, J. Weber, and H. Kober. 2011. Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences* 108(50): 20254–20259. doi:10.1073/pnas.1112029108.

Brown, K.W., and R.M. Ryan. 2003. The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology* 84(4): 822–848. doi:10.1037/0022-3514.84.4.822.

Brown, K.W., R.M. Ryan, and J.D. Creswell. 2007. Mindfulness: Theoretical foundations and evidence for its salutary effects. *Psychological Inquiry* 18(4): 211–237. doi:10.1080/10478400701598298.

Buckner, R.L., J.R. Andrews-Hanna, and D.L. Schachter. 2008. The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences* 1124: 1–38.

Cheyne, J.A., J.S.A. Carriere, and D. Smilek. 2006. Absent-mindedness: Lapses of conscious awareness and everyday cognitive failures. *Consciousness and Cognition* 15(3): 578–592. doi:10.1016/j.concog.2005.11.009.

Cheyne, J., G.J.F. Solman, J.S.A. Carriere, and D. Smilek. 2009. Anatomy of an error: A bidirectional state model of task engagement/disengagement and attention-related errors. *Cognition* 111(1): 98–113. doi:10.1016/j.cognition.2008.12.009.

Christoff, K., A.M. Gordon, J. Smallwood, R. Smith, and J.W. Schooler. 2009. Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences of the United States of America* 106(21): 8719–8724.

Dickenson, J., E.T. Berkman, J. Arch, and M.D. Lieberman. 2012. Neural correlates of focused attention during a brief mindfulness induction. *Social Cognitive and Affective Neuroscience* 8(1): 40–47. doi:10.1093/scan/nss030.

Dreyfus, G. 2011. Is mindfulness present-centered and non-judgmental? A discussion of the cognitive dimensions of mindfulness. *Contemporary Buddhism* 12(1): 41–54.

Froeliger, B., E.L. Garland, R.V. Kozink, L.A. Modlin, N.-K. Chen, F.J. McClernon, et al. 2012. Meditation-state functional connectivity (msFC): Strengthening of the dorsal attention network and beyond. *Evidence-Based Complementary and Alternative Medicine* 2012: 1–9. doi:10.1155/2012/680407.

Grossman, P., and N.T. Van Dam. 2011. Mindfulness, by any other name…: Trials and tribulations of sati in western psychology and science. *Contemporary Buddhism* 12(1): 219–239. doi:10.1080/14639947.2011.564841.

Gruberger, M., E. Ben-Simon, Y. Levkovitz, A. Zangen, and T. Hendler. 2011. Towards a neuroscience of mind-wandering. *Frontiers in Human Neuroscience* 5: 56.

Hasenkamp, W., and L.W. Barsalou. 2012. Effects of meditation experience on functional connectivity of distributed brain networks. *Frontiers in Human Neuroscience* 6: 38. doi:10.3389/fnhum.2012.00038.

Hölzel, B.K., S.W. Lazar, T. Gard, Z. Schuman-Olivier, D.R. Vago, and U. Ott. 2011. How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science* 6(6): 537–559. doi:10.1177/1745691611419671.

Jang, J.H., W.H. Jung, D.-H. Kang, M.S. Byun, S.J. Kwon, C.-H. Choi, et al. 2011. Increased default mode network connectivity associated with meditation. *Neuroscience Letters* 487(3): 358–362. doi:10.1016/j.neulet.2010.10.056.

Kam, J.W.Y., E. Dao, J. Farley, K. Fitzpatrick, J. Smallwood, J.W. Schooler, et al. 2010. Slow fluctuations in attentional control of sensory cortex. *Journal of Cognitive Neuroscience* 23(2): 460–470. doi:10.1162/jocn.2010.21443.

Kilpatrick, L.A., B.Y. Suyenobu, S.R. Smith, J.A. Bueller, T. Goodman, J.D. Creswell, et al. 2011. Impact of mindfulness-based stress reduction training on intrinsic brain connectivity. *NeuroImage* 56(1): 290–298. doi:10.1016/j.neuroimage.2011.02.034.

MacLean, K.A., E. Ferrer, S.R. Aichele, D.A. Bridwell, A.P. Zanesco, T.L. Jacobs, et al. 2010. Intensive meditation training improves perceptual discrimination and sustained attention. *Psychological Science* 21(6): 829–839.

Mason, M.F., M.I. Norton, J.D. Van Horn, D.M. Wegner, S.T. Grafton, and C.N. Macrae. 2007. Wandering minds: The default network and stimulus-independent thought. *Science* 315(5810): 393–395. doi:10.1126/science.1131295.

McKiernan, K.A., B.R. D'Angelo, J.N. Kaufman, and J.R. Binder. 2006. Interrupting the "stream of consciousness": An fMRI investigation. *NeuroImage* 29(4): 1185–1191.

McVay, J.C., and M.J. Kane. 2009. Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology. Learning, Memory, and Cognition* 35(1): 196–204. doi:10.1037/a0014104.

Mrazek, M.D., J.M. Chin, T. Schmader, K.A. Hartson, J. Smallwood, and J.W. Schooler. 2011. Threatened to distraction: Mind-wandering as a consequence of stereotype threat. *Journal of Experimental Social Psychology* 47: 1243–1248.

Mrazek, M.D., J. Smallwood, M.S. Franklin, B. Baird, J.M. Chin, and J.W. Schooler. 2012. The role of mind-wandering in measurements of general aptitude. *Journal of Experimental Psychology: General* 141(4): 788–798. doi:10.1037/a0027968.

Mrazek, M.D., M.S. Franklin, D.T. Phillips, B. Baird, and J.W. Schooler. 2013. Mindfulness training improves working memory capacity and GRE performance while reducing mind-wandering. *Psychological Science* 24(5): 776–781.

Posner, M.I., J.A. Walker, F.J. Friedrich, and R.D. Rafal. 1984. Effects of parietal injury on covert orienting of attention. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience* 4(7): 1863–1874.

Prakash, R.S., A.A. De Leon, M. Klatt, W. Malarkey, and B. Patterson. 2012. Mindfulness disposition and default-mode network connectivity in older adults. *Social Cognitive and Affective Neuroscience* 8(1): 112–117. doi:10.1093/scan/nss115.

Reichle, E.D., A.E. Reineberg, and J.W. Schooler. 2010. Eye movements during mindless reading. *Psychological Science* 21(9): 1300–1310. doi:10.1177/0956797610378686.

Schooler, J.W. 2002. Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in Cognitive Sciences* 6(8): 339–344. doi:10.1016/S1364-6613(02)01949-6.

Schooler, J., and C.A. Schreiber. 2004. Experience, meta-consciousness, and the paradox of introspection. *Journal of Consciousness Studies* 11(7–8): 7–8.

Schooler, J.W., J. Smallwood, K. Christoff, T.C. Handy, E.D. Reichle, and M.A. Sayette. 2011. Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences* 15(7): 319–326. doi:10.1016/j.tics.2011.05.006.

Smallwood, J., and J.W. Schooler. 2006. The restless mind. *Psychological Bulletin* 132(6): 946–958. doi:10.1037/0033-2909.132.6.946.

Smallwood, J.M., S.F. Baracaia, M. Lowe, and M. Obonsawin. 2003. Task unrelated thought whilst encoding information. *Consciousness and Cognition* 12(3): 452–484. doi:10.1016/S1053-8100(03)00018-7.

Smallwood, J., J.B. Davies, D. Heim, F. Finnigan, M. Sudberry, R. O'Connor, et al. 2004. Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Consciousness and Cognition* 13(4): 657–690. doi:10.1016/j.concog.2004.06.003.

Smallwood, J., D.J. Fishman, and J.W. Schooler. 2007a. Counting the cost of an absent mind: Mind wandering as an underrecognized influence on educational performance. *Psychonomic Bulletin and Review* 14(2): 230–236.

Smallwood, J., M. McSpadden, and J.W. Schooler. 2007b. The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin and Review* 14(3): 527–533.

Smallwood, J., M. McSpadden, and J.W. Schooler. 2008a. When attention matters: The curious incident of the wandering mind. *Memory and Cognition* 36(6): 1144–1150. doi:10.3758/MC.36.6.1144.

Smallwood, J., M. McSpadden, B. Luus, and J. Schooler. 2008b. Segmenting the stream of consciousness: The psychological correlates of temporal structures in the time series data of a continuous performance task. *Brain and Cognition* 66: 50–56. doi:10.1016/j.bandc.2007.05.004.

Smallwood, J., E. Beach, J.W. Schooler, and T.C. Handy. 2008c. Going AWOL in the brain: Mind wandering reduces cortical analysis of external events. *Journal of Cognitive Neuroscience* 20(3): 458–469. doi:10.1162/jocn.2008.20037.

Smallwood, J., M.D. Mrazek, and J.W. Schooler. 2011a. Medicine for the wandering mind: Mind wandering in medical practice. *Medical Education* 45(11): 1072–1080.

Smallwood, J.M., K. Brown, B. Baird, and J.W. Schooler. 2011b. Cooperation between the default mode network and the fronto-parietal network in the production of an internal train of thought. *Brain Research* 1428: 60–70. doi:10.1016/j.brainres.2011.03.072.

Stawarczyk, D., S. Majerus, P. Maquet, and A. D'Argembeau. 2011. Neural correlates of ongoing conscious experience: both task-unrelatedness and stimulus-independence are related to default network activity. *PloS One* 6(2): e16997.

Tang, Y.Y., Y. Ma, J. Wang, Y. Fan, S. Feng, Q. Lu, et al. 2007. Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences* 104(43): 17152.

Taylor, V.A., V. Daneault, J. Grant, G. Scavone, E. Breton, S. Roffe-Vidal, et al. 2012. Impact of meditation training on the default mode network during a restful state. *Social Cognitive and Affective Neuroscience* 8(1): 4–14. doi:10.1093/scan/nsr087.

Wallace, B.A., and S.L. Shapiro. 2006. Mental balance and well-being: Building bridges between Buddhism and Western psychology. *American Psychologist* 61(7): 690–701.