Psychological Bulletin
2010, Vol. 136, No. 2, 202–207

0033-2909/10/$12.00 DOI: 10.1037/a0018673

Why the Global Availability of Mind Wandering Necessitates Resource Competition: Reply to McVay and Kane (2010)

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When the mind wanders, conscious thoughts come to mind that are only loosely related to the task being performed. This phenomenon produces tension within the cognitive sciences because the interfering nature of these thoughts is at odds with the assumption that such processes are functional in daily life. In their comment, McVay and Kane (2010) suggested that failures in executive control can create the conditions that favor mind wandering—a *control-failure hypothesis* that questions whether mind wandering consumes resources. Whether mind wandering always occurs following a control failure, it is always a conscious reportable experience and so is globally available to the system. Such global availability suggests that mind wandering does indeed demand resources, in particular access to a global workspace that supports conscious experience. Although the control-failure view explains the transient occurrence of mind wandering during demanding tasks, the *global availability hypothesis* is consistent with all mind wandering, regardless of context; it is implied by many features of the argument proposed by McVay and Kane (2010). Consideration of these issues leads to the conclusion that when the mind wanders, specific information from the default mode becomes globally available to the system; in this respect, mind wandering is resource demanding inasmuch as it occupies the global workspace necessary for consciousness.

Keywords: mind wandering, default mode, task-unrelated/stimulus-independent thought, consciousness, global workspace

When one is driving home from work, taking a leisurely walk, or completing just about any daily activity, the mind frequently wanders. Although such mind wandering may result in error, it often involves relatively complex trains of thought, associated with the current concerns of the individual (Klinger, 1999, 2009) or upcoming personal events (Smallwood, Nind, & O'Connor, 2009). That a sophisticated form of higher order thought can lead to task failure makes mind wandering a difficult experience to accommodate into the models available to cognitive science. Certain reasons for these difficulties are practical: Perceptual events are more amenable to observation than are internal streams of thought, making the former easier to study. Mind wandering is also spontaneous and consequently harder to induce by the experimenter using a stimulus-evoked paradigm. Setting aside such practical concerns, the question that is posed by the experience of mind wandering is both how and why, at a seemingly unpredictable moment, latent current concerns come to mind.

Despite researchers familiarity with mind wandering, the phenomenon is difficult to pin down for the purposes of research. One way that such experiences are conceptualized is as task-unrelated thought (TUT), which implies that attention has shifted away from the constraints of the primary task. Although amenable to the experience of mind wandering during demanding tasks, TUT seems less applicable in the absence of an obvious task (such as when resting in a scanner). On the other hand, mind wandering has been conceived of as stimulus-independent thought (SIT) to reflect that the experiences are not evoked by the immediate sensory input facing the individual. Whereas SIT seems applicable for daydreaming when the task lacks demands, it fails to distinguish between mind wandering and particular classes of complex tasks (e.g., environments in which task-related cognition is related to a previous piece of unavailable task relevant information, such as when reading a detective novel; Smallwood, Beech, Schooler, & Handy, 2008, or completing a 2-back working memory task). Despite the systematic failure for either SIT or TUT to encompass mind wandering in a satisfactory context-independent manner, for some time theorists have suspected they may share similar underlying processes because they are usually directed to the concerns of the individual (Antrobus, 1999; Klinger, 1999; Singer, 1966). Fortunately, advances in neuroimaging have specified what this similarity is: Both periods of TUT (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; McKiernan, D'Angelo, Kaufman, & Binder, 2006) and SIT (Mason et al., 2007; McGuire, Paulesu, Frackowiak, & Frith, 1996) are associated with activations in the system dubbed the *default-mode network* (Gusnard & Raichle, 2001; Raichle et al., 2001). Together, such data lead to the conclusion that the best way to define the experience of mind wandering is as a state that occurs when information generated by the default mode becomes available to consciousness.

"The Restless Mind" (Smallwood & Schooler, 2006) was an attempt to provide a framework in which to understand mind wandering. Our interest was at least in part to understand how "the waking mind generates and processes information that transcends

I thank Bernard Baars, Ben Baird, Roy Baumeister, Dan Bernstein, Kevin Brown, Mike Franklin, Mike Mrazek, Jonathan W. Schooler, Helga Smallwood, and Christine Tipper for their comments on the ideas contained in this article.

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the limitations of the current context" (Smallwood, Fishman, & Schooler, 2007, p. 235). We argued that executive processes do not trigger mind wandering; instead, such episodes are the product of the activation of unresolved goals (termed *current concerns*). Such a process could be adaptive given that it might help the individual manage multiple goals in his or her life (see Smallwood, O'Connor, Sudberry, & Obonsawin, 2007) and that it is potentiated by (a) the intermittent nature of meta-awareness (Schooler, 2002) and (b) internal states such as low mood (Smallwood, Fitzgerald, Miles, & Phillips, 2009; Smallwood, O'Connor, et al., 2007).

We also suggested that mind wandering shared certain information processes involved in controlled processes. One line of evidence for this claim was that engaging processes such as working memory reduced the frequency of mind wandering (Mason et al., 2007; Smallwood, Baraciaia, Lowe, & Obonsawin, 2003; Smallwood, Obonsawin, & Heim, 2003; Teasdale et al., 1995; Teasdale, Lloyd, Proctor, & Baddeley, 1993). Further evidence that top-down processes are involved came from the observation of a positive relationship between failures in complex tasks and mind wandering (Smallwood, Baraciaia, et al., 2003; Smallwood et al., 2004; Smallwood, Obonsawin, & Heim, 2003; Smallwood, Riby, Heim, & Davies, 2006; Teasdale et al., 1995). Finally, we suggested that during mind wandering, consciousness becomes coupled to internalized processes rather than to the external task environment. Mind wandering was suggested to be a state of decoupled processing, meaning that individuals consciously attend to their thoughts and feelings rather than to information related to the task or to the external environment (see also Smallwood, 2009; Smallwood, O'Connor, et al., 2007). States of decoupled processing can be contrasted with both a purely external attentional focus (such as when individuals are startled) and tasks such as reading in which both internal task-relevant information (known as the situational model) and external information (the current narrative) are coupled together in working memory.

Since 2006, research on mind wandering has increased; as a consequence, researchers' understanding of the phenomenon is now more detailed. In light of this new evidence, the comment by McVay and Kane (2010) provides a timely and thorough reconsideration of the relation between executive processes and mind wandering. In many senses, the hypothesis presented in this comment provides important specifications that were absent from the initial framework. For example, in order to explain the occurrence of mind wandering, we argued that mind wandering itself is not the result of executive processes (Smallwood & Schooler, 2006) and instead that task-unrelated information displaces the task in consciousness. McVay and Kane (2010) made the more specific claim that temporary failures in executive maintenance of goal-relevant information create the circumstances that foster mind wandering. According to this perspective, the lapse in proactive maintenance occurs first, and the mind wanders sometime later; this constitutes an important consideration in research (see, e.g., Cheyne, Solman, Carriere, & Smilek, 2009, for a three-stage model of mind wandering; see also Smallwood et al., 2008). Similarly, in order to explain the occurrence of mind wandering, we suggested that the multiple goals or current concerns of an individual (Klinger, 1999, 2009) provide the content for the TUT. McVay and Kane (2010) took advantage of advances in neuroimaging, suggesting that the current concerns of an individual are represented by the default mode. However, as successful as the control-failure hypothesis is in accounting for aspects of the mind-wandering data, it is unclear whether such evidence necessarily contradicts the view that mind wandering is resource demanding. Does the evidence for the conflict failure view rule out the claim "that mind wandering requires resources" (McVay & Kane, 2010, p. 193)? The answer depends critically on the definition of the resources in question.

As a caveat, it is worth stating that defining what constitutes executive resources is troublesome (Miyake et al., 2000; Monsell, 1996). Indeed, there are many different ways that such processes are conceived by cognitive scientists. The emphasis of the comment is largely on the feature of inhibitory control: Executive processes act to "limit the type of information that gains entry into awareness" (McVay & Kane, 2010, p. 190). McVay and Kane (2010) suggested that such control processes can be divided into two forms: proactive inhibition (maintaining goals in the face of distraction) or retroactive inhibition (resolving conflict when it occurs). Together these abilities combine to control the occurrence of mind wandering

> when control is proactively initiated and maintained in response to task demands (i.e., when the appropriate level of construal is applied) or when control is reactively initiated to block or suppress TUTs as they are activated in response to cues. (p. 191)

An equally plausible and important way to conceive of control processes depends upon the availability of the necessary information to the system in order for successful action to occur. Such global availability is conceived as depending upon the coordination of multimodal information (such as the episodic buffer; Baddeley, 2000). One reasonably well-specified account of global availability is typical of a class of theories called global workspace models (Baars, 1988; Dehaene & Naccache, 2001). Global workspace models generally distinguish between a network of specialized modules, each of which performs subtasks (such as sensory processes). In addition to these specialized processes, a global workspace involves "a distributed set of cortical neurons characterized by their ability to receive from and send back to homologous neurons in other cortical areas horizontal projections through long-range excitatory axons (which may impinge on either excitatory or inhibitory neurons)" (Dehaene, Kerzsberg, & Changeux, 1998, p. 14529). Additionally, the global workspace provides a "distinct internal space, buffered from fast fluctuations in sensory inputs, where information can be shared across a broad variety of processes including evaluation verbal report and long-term memory" (Dehaene, Changeaux, Naccache, Sakur, & Sergent, 2006, p. 205). Global workspace models have been presented for a variety of different attentional states (Baars, Ramsoy, & Laureys, 2003), effortful task performance (Dehaene et al., 1998), and even the competition between internal and external cognition (Dehaene & Changeux, 2005).

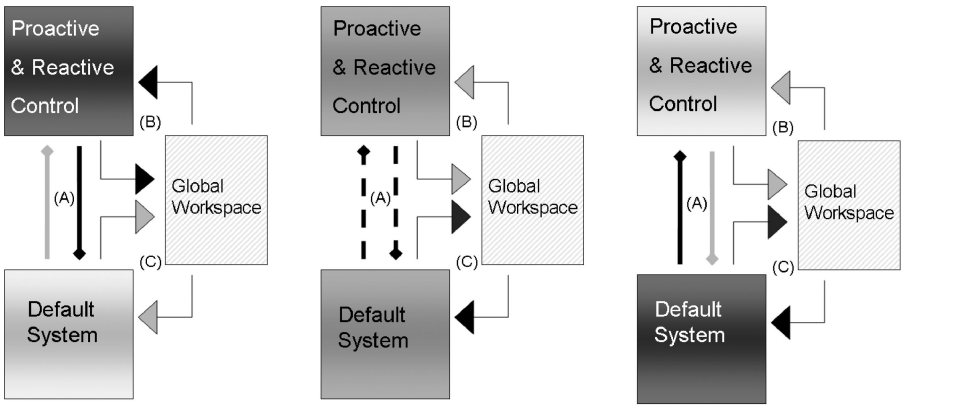
One critical assumption of the global workspace approach is that conscious phenomena are globally available if they can be reported. In such approaches, consciousness is often equated with "information presented to prefrontal executive regions for interpretation, decision-making, and voluntary control" (Baars et al., 2003, p. 673). Once information has gained access to this workspace, it has privileged status because it is able to influence, in a top-down fashion, the more specialized submodules of the brain. In other words, once in consciousness, information becomes ca-

pable of guiding intentional behavior (Dehaene et al., 2006). One important corollary of global availability is that such states are available to self-report.

How do these different features of executive processes (inhibitory control and global availability) relate to the experience of mind wandering? "The Restless Mind" (Smallwood & Schooler, 2006) was rather vague in this regard (although see Smallwood, Fishman, & Schooler, 2007, and Smallwood, 2009, for a more specified account). However, in light of the current debate, it is likely that, at least in principle, both control and global availability are important in mind wandering. For example, the hypothesis that failures in proactive control create condition that lead the mind to wander when engaged in a demanding task is intuitively plausible. However, as noted earlier, the experience of mind wandering is also necessarily conscious; after all, the only way individuals have to study the experience at present is by asking participants. If mind wandering is conscious and so globally available, researchers can conclude that during mind wandering, information from the default network has privileged access to the global workspace. Thus, the fact that mind wandering is a conscious experience implies that such states do entail cognitive resources, at least inasmuch as they occupy and hence block access to a global workspace necessary for consciousness.

Is posing such global availability necessary? After all, it could be simpler and more parsimonious to assume that mind wandering was simply produced by control failure. A critical test is whether the control-failure hypothesis in isolation can reasonably account for all features of the data on mind wandering. Studies of mind wandering can be largely considered to reflect a continuum of contexts from strongly executively demanding tasks (such as verbal fluency; e.g., Smallwood, Baraciaia, et al., 2003) or working memory loads (Smallwood, Nind, & O'Connor, 2009) through automated tasks (e.g., Mason et al., 2007; Teasdale et al., 1995) and ultimately to situations with very few external constraints (such as when passively viewing stimuli—e.g., Smallwood, Nind, & O'Connor, 2009; or the resting state; Raichle et al., 2001). A simple model for how to consider these different data on mind wandering is presented in Figure 1. This diagram emphasizes the nature of information flow through the system in order to dissociate different conscious states (see also Smallwood, 2009; Smallwood, Fishman, & Schooler, 2007). The different boxes on the right represent default and executive-control processes; the global workspace is indicated by the hatched box on the right. The arrows between the boxes indicate the flow of information through the system, and those that are in bold print determine the information that is currently globally available. The lines between default and executive processes represent the negative correlation between these systems (Buckner, Andrews-Hanna, & Schacter, 2008). Each of the different panels can be conceived as states or contexts (Baars, 1988) within which a conscious experience can exist; they should be considered as continua rather than discrete categories. The critical test of the control-failure view is whether in isolation it can account for the available data in each situation, without necessitating the additional property of global availability.

In Panel 1, executive control acts to suppress default processes; under these conditions task-relevant information will gain access to the global workspace. The global availability of this on-task state is likely to be maintained by the engagement of retroactive and proactive control processes on default processes (and other distracting information) as proposed by McVay and Kane (2010). In Panel 2, the suppression of the default mode by the control systems intermittently fails; the default mode becomes globally available in a transient manner. This corresponds to the control-failure example of mind wandering proposed by McVay and Kane



Panel 1: *Low default accessibility.* Control processes constrain default processes and task relevant information gains access to the global workspace.

Panel 2: *Transient default accessibility.* Control processes fail to constrain default processes which subsequently gain **transient** access to the global workspace.

Panel 3: *Sustained default accessibility.* Control processes are not in competition allowing default processes access to the global workspace on a more **sustained** basis.

Figure 1. Presenting a simple model integrating proactive and retroactive control in determining whether task-relevant or default information gains access to the global workspace. The bold arrows indicate the flow of information into the global workspace, and the different degrees of shading represent the intensity in activity in the default and control systems. Consistent with the control-failure hypotheses, executive control can block the default mode access to the global workspace (Panel A), and transient failures in this system can lead to mind wandering (Panel B). The dashed lines in Panel B reflect the transient changes in the contents of consciousness that occur in this context. Critically, whereas the control-failure hypothesis struggles to account for mind wandering in the absence of a demanding task (Panel C), mind wandering is still conscious and is therefore globally available to the system.

(2010) and can be considered to reflect a state of *transient* mind wandering. In both of these demanding contexts, the control-failure hypothesis makes a very clear account for how on-task states are maintained. As noted by McVay and Kane (2010), the conflict hypothesis successfully predicts the link between mind wandering and performance, the association to states such as fatigue and inebriation, and the linkage between attention-deficit/hyperactivity disorder or depression and mind-wandering frequency. It seems reasonable to assume that a significant proportion of episodes of mind wandering in demanding tasks results from a failure in the constraining influence of proactive cognitive control.

Even in the context of strong executive suppression of mind wandering, however, the argument proposed by McVay and Kane (2010) implies a special role for the information that is globally available to the system. For example, in their view mind wandering is produced by the gaining of bottom-up access to consciousness of the associative properties of the default mode (for further discussion, see Smallwood, Baraciaia, et al., 2003; Smallwood, Obonsawin, & Heim, 2003). Such bottom-up influences are consistent with the global workspace accounts of conscious awareness, which arise when bottom-up processes reach a particular threshold and individuals then become aware of them (Dehaene & Changeaux, 2005). In fact, McVay and Kane (2010) suggested that the default network "is continuous and generates a stream of thoughts" (p. 190), examples of which intermittently intrude into awareness, experienced as mind wandering. This is another way of stating that mind wandering occurs when specific examples of default processes become globally available to the system.

Similarly, and perhaps more importantly, McVay and Kane (2010) depended in their account on the notion of global availability for explanations as to why the activations of certain executive structures are observed during unaware mind wandering (Christoff et al., 2009). They have suggested that rather than reflecting the role of the executive system during mind wandering, the activations reflect "control activity to bring their thoughts back on track" (p. 194). Although further research is needed to assess whether this hypothesis is correct, it is critical to recognize that during these periods participants report mind wandering (and not being on task). Given such self-reports, the only way that the control-failure hypothesis interpretation of these data makes sense is to acknowledge that these task-relevant activations are unavailable to consciousness because they are unable to access the global workspace. Indeed, other studies have shown that control processes can be active without being consciously reported during mind wandering. Hester, Foxe, Molholm, Shpaner, and Garavan (2005) demonstrated that whereas absentminded lapses always activate conflict-monitoring structures (including the anterior cingulate), conscious awareness of these lapses (recorded by self-report) occurs only following the additional recruitment of prefrontal areas. In order to accommodate such results, the control-failure hypothesis needs to assume a global workspace that can be both coupled and decoupled from the processes of cognitive control (see also Bekinschtein et al., 2009, for a demonstration of how mind wandering can prevent external information from accessing the global workspace).

It is also important to consider how the global availability hypothesis can account for one study that at first glance seems consistent with the control-failure view of TUT (McVay & Kane, 2009). In this study, a large cohort of individuals performed measures of both working memory capacity (WMC) and the sustained attention to response task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), which is routinely used to study mind wandering because of the sensitivity of errors to mind wandering (Cheyne, Carriere, & Smilek, 2006; Cheyne et al., 2009; Smallwood et al., 2008, 2004; Smallwood, Fitzgerald, et al., 2009; Smallwood, O'Connor, et al., 2007). McVay and Kane (2009) indicated that WMC was strongly related to the tendency both not to lapse and to engage in less TUT, which (as argued in the comment by McVay & Kane, 2010) supports the control-failure view of mind wandering and contradicts the view that resources could be engaged during mind wandering. This conclusion is, however, premature because the SART actually requires that information regarding task performance is continuously globally available to attention. In the initial SART article, Robertson et al. (1997) suggested that "the task would require a high level of continuous attention to responses and be sensitive to transitory reduction in attention or 'lapses,' while keeping to a minimum demands on other cognitive processes such as memory planning and effort" (p. 748). Leaving aside whether the SART is or is not an executive-control task, it seems reasonable that it requires both executive control (as indexed by response inhibition) and that task information is globally available (to guide responses). Furthermore, as McVay and Kane (2010) pointed out, regardless of WMC, TUT was damaging to task performance for all individuals. This lack of a graded relationship between WMC and error on the SART is precisely what would be expected if default mode and task-relevant information were in competition for an all-or-nothing attentional resource (such as a global workspace).

Finally, Panel 3 represents a context in which the need for executive control is low and default processes access the global workspace in a more sustained manner. This panel corresponds to a period of sustained mind wandering, as may occur in daydreaming on a long train journey (or resting in a scanner). Whereas the control-failure account of mind wandering seems a reasonable account of lapses during demanding tasks, it is intuitively least appealing under such less demanding conditions. For example, studies document that under the almost negligible demand of saying a number out loud, most TUTs form connected sequences (Teasdale et al., 1993). Similarly, when participants were asked to decide simply whether occasional colored numbers were odd or even, mind wandering was often future focused (Smallwood, Fitzgerald, et al., 2009). In these high-incidence, mind-wandering conditions, executive-control demands are limited and task performance is high, making it difficult to support the existence of control failures. Finally, it is not even clear why the executive system would set such priority to constraining mind wandering in this context; surely greater value would be provided by allowing rather than suppressing mind wandering. Indeed, the fMRI study by Mitchell et al. (2007) supports precisely this supposition: Neither proactive nor reactive control systems were activated when participants were allowed to experience thoughts about a white bear. Instead, the participants engaged control processes only when asked to suppress the experience of the thought. Despite approximately similar numbers of conscious thoughts of polar bears in both cases, executive control was engaged only when such thoughts were forbidden. Thus, whereas the control-failure hypothesis provides a promising hypothesis of how individuals keep unwanted thoughts out of mind, it simply does not make sense to

view the occurrence of all mind-wandering episodes in trivially demanding contexts (such as rest) as unwanted thoughts. Overall, it seems unnecessary to assume that in nondemanding contexts that mind wandering represents a control failure, when conscious coordinated thought (such as thinking about the future) seems likely to serve at least some uses in daily life (Schacter, Addis, & Buckner, 2007; Tulving, 1985).

It may appear that the nature of mind wandering during nondemanding tasks is a different experience than in contexts in which attention is necessarily constrained to the task. In some senses this differentiation is implied by McVay and Kane (2010) when they stated that "default-mode functions may sometimes be brought under conscious control and directed in a top-down manner" (p. 194). Based on theories such as ironic control (Wegner, 2009), the competition between default and control processes may change significantly depending on the information-processing context. Nonetheless, there are two reasons to suggest that mind-wandering episodes with or without a task should be similar. First, as noted previously, the only *context-independent* way to conceive of mind wandering is to focus on the similarities across different situations (e.g., the global availability of default information), a perspective that is supported by the converging activations in default networks at rest and in high-incidence periods of mind wandering (Christoff et al., 2009; Mason et al., 2007; McKiernan et al., 2006). Second, it is these easy tasks in which mind wandering occurs most frequently, indicating that nondemanding conditions actually encompass the majority of examples of mind wandering on which the theories are built. Because the occurrence of TUT–SIT is what is measured when researchers study mind wandering, it would be peculiar to define the phenomenon in a way that excludes most of the examples.

In conclusion, the central paradox in mind wandering is how, on a momentary basis, one of a multitude of the potential concerns of an individual come to dominate consciousness. It is clear from the control-failure hypothesis that in many complex tasks the transient occurrence of mind wandering can result from a failure in the proactive maintenance of task-relevant phenomena. Nonetheless, by virtue of being conscious, mind wandering is always globally available to the system and thus consumes (at least temporarily) the information-processing resources necessary for consciousness. Not only does the notion of global availability fit well with the definition of mind wandering, but thoughtful consideration of the evidence suggests that the notion is a necessary assumption in the control-failure hypothesis in several key areas. Thus, although the control failure view provides a mechanistic account of how attention can lapse during demanding tasks, a more general definition is that mind wandering occurs when personally relevant goals (presumably represented by the default network) achieve a state of global availability.

Assuming that mind wandering involves aspects of the default mode that gain access to the global workspace of consciousness helps to explain several additional puzzling features of the literature. First, Raichle and Snyder (2007) noted that whereas the default mode is likely to play a role in conscious thought, the extent of activity observed in the default state seems to exceed the resources needed for conscious experiences, which account for a small fraction of total brain activity (Raichle, 2009). Paradoxically, therefore, the extensive nature of the default mode seems to contradict the notion that these structures specifically contribute to internal conscious thought. However, given that the global workspace is subject to resource limitations, then only subsets of the intrinsic processes served by the default mode could become conscious at any given moment. In other words, assuming that default processes compete for access to the global workspace provides one reason why the conscious aspects of the network would necessarily be the tip of the iceberg (Raichle, 2009; Raichle & Snyder, 2007).

Perhaps the most singular implication of the global availability hypothesis is that it helps resolves the tension that mind wandering is a sophisticated form of cognition that interferes with goals of the moment. Not only does global availability necessitate that mind wandering has a specialized status in consciousness, but the ability to broadcast information across the system provides a mechanism that allows information from default networks to have the potential to lead to novel behavior. Given that default-mode processes have been associated with such diverse yet important functions as remembering, prospection, navigation, and theory of mind (Buckner & Carroll, 2007; Spreng, Mar, & Kim, 2009), it seems unlikely that globally broadcasting this information to the system at large would be a disadvantage. After all, given its role in prospection or self-projection (Bar, 2008; Buckner et al., 2008; Buckner & Carroll, 2007; Schacter, Addis, & Buckner, 2008), the default systems goals of today are the executive goals of tomorrow, and the intermittent conscious awareness of such goals when they become available to the system (during mind wandering) is likely to help execute many important life goals. Indeed, if the information from an individual's default network were never available to consciousness, it would be harder for the goals represented by this system to become realized in behavior. Not only does mind wandering engage important attentional resources, it may even provide the seed that allows subsequent executive acts to flourish.

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Received November 11, 2009
Revision received November 30, 2009
Accepted December 1, 2009 ■