

# Mind Wandering and Selective Attention to the External World

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From a cognitive neuroscience perspective, the study of attention has long centered on characterizing the basic systems we have in our brains for selecting what external sensory information to channel to our higher level, capacity-limited processes in cortex. Less understood is how these attentional systems ebb and flow in their selectivity over seconds to minutes in the course of pursuing our daily activities. Toward illuminating this issue, here we review a recent series of studies we have conducted demonstrating that the degree to which our selective attention systems are engaged with the external environment is coordinated over these timescales such that they collectively engage and disengage together as a means of transiently modulating the depth of our cognitive investment in external sensory inputs. Although our studies have primarily focused on mind wandering in healthy, young participants, we suggest that people's ability to comprehensively attenuate their selective attention to the outside world plays a fundamental role in both normal human cognition and its clinical pathology.

*Keywords:* mind wandering, visual attention, executive function, mental simulation

Mind wandering concerns periods of time when our thoughts decouple or drift away from the ongoing task at hand, a regular and periodic human experience that occupies a notable portion of our mental life (e.g., Smallwood & Schooler, 2006). On the assumption that mind wandering has an evolved purpose or adaptive value (e.g., Schooler et al., 2011), much research has centered on understanding the qualitative content of decoupled thoughts and where our minds actually go when they wander (e.g., Killingsworth & Gilbert, 2010). For example, we are more likely to think about the future than the past or present (e.g., Smallwood et al., 2011) and more likely to ponder personal issues instead of unfocused daydreams (e.g., McVay, Kane, & Kwapil, 2009). By providing this dynamic spatiotemporal perspective to our thinking, mind wandering is also believed to promote our problem solving and creativity in general (e.g., Baird et al., 2012; Ellamil, Dobson, Beeman, & Christoff, 2012).

Consistent with these behavioral reports are the patterns of neural network activity that arise when our thoughts drift off task. Mind wandering has been shown to recruit the brain's default mode network—a network that includes medial prefrontal and temporal cortices and the posterior cingulate and that becomes active when attention is directed away from the external task environment—an effect that has been observed in both functional hemodynamics (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007) and electroencephalography phase synchrony (e.g., Kirschner, Kam, Handy, & Ward, 2012). Similarly, mind wandering recruits brain regions associated with

the cortical executive network as well, including dorsolateral prefrontal and posterior parietal regions long implicated in executive functioning (e.g., Christoff, 2012; Christoff et al., 2009). Given that the default mode network has been linked to self-referential thought (e.g., Fingelkurts & Fingelkurts, 2011; Northoff et al., 2006) and autobiographical memory retrieval (e.g., Kim, 2012; Svoboda, McKinnon, & Levine, 2006), its activation during mind-wandering states, in conjunction with coactivation of the cortical executive network, has supported the hypothesis that periods of mind wandering involve decoupling our executive functions from the external task at hand to applying them to task-unrelated, internally generated stimulus content (e.g., Schooler et al., 2011), a hypothesis also consistent with the proposed role of mind wandering in problem solving and creativity (e.g., Baird et al., 2012; Ellamil et al., 2012).

Yet beyond the questions of where the wandering mind goes and what brain networks support its mobility lies a third and equally vital issue of mind wandering that pushes the boundaries of our traditional understanding of selective attention. Namely, implicit in long-standing models of selective attention is the idea that we are always selecting for *something* in the external environment for higher levels of perceptual and cognitive analysis (e.g., Desimone & Duncan, 1995; Posner, 1980; Posner & Petersen, 1990; Treisman & Gelade, 1980). Against this background, mind wandering thus poses a novel question regarding how we may apply or use our neural mechanisms of selective attention: Might periods of mind wandering be associated with turning our so-called attentional spotlights off or selecting for *nothing* from the external environment?

That is, if mind wandering involves decoupling our executive functions from the external task at hand, might we attenuate the prioritization of sensory inputs—the hallmark of attentional selection in cortex—during mind-wandering states? If so, it would indicate that selective attention has a vital role to play in mind wandering and, in particular, dampening selection itself so that our

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higher cognitive processes can focus on something other than the external perceptual milieu.

### External Disengagement: Early Versus Late Selection

We approached this question in our first study using event-related potentials (ERPs). Specifically, the P300 ERP component is a well-known index of cognitive processing of target stimuli; generally speaking, the amplitude of the component positively scales with the depth of cognitive analysis afforded to the ERP-eliciting stimulus (for a review, see Soltani & Knight, 2000). In other words, the less attention paid to a target stimulus, the lower the P300 amplitude it generates. If mind wandering does in fact lead to an attenuation of selective attention, it is thus predicted that the P300 elicited by task-relevant stimuli should be reduced during periods of mind wandering relative to on-task attentional states.

In our study, that is exactly what we found (Smallwood, Beach, Schooler, & Handy, 2008). We had participants perform a sustained attention to response task (SART) wherein a target stimulus requiring a simple detection response was presented on a computer screen every couple of seconds. Interspersed with these appearances were occasional nontargets that acted as catch trials of sorts, or no-go trials, requiring a response to be withheld. As participants performed the task, we stopped them at random, unpredictable intervals and asked them to report on their attentional state just prior to the stoppage—either “on-task,” or “mind wandering”—a method of subjective reporting called *experience sampling* that has shown strong validity in capturing global attentional states (for a review, see Gruberger, Ben-Simon, Levkovitz, Zangen, & Hendlar, 2011). When we then compared the amplitude of the P300 component elicited by targets in the last 12 s prior to mind-wandering versus on-task attentional reports, we found the predicted attenuation for the mind-wandering state.

Our findings were thus consistent with the proposal that mind wandering can in fact be associated with a down-regulation of attentional selection, at least at a comparatively late, cognitive level of selection. However, attentional selection is known to have multiple foci in cortex. It can be invoked at earlier stages of the afferent stimulus-processing stream and, in particular, within sensory-specific cortical regions (e.g., Heinze et al., 1994; Woldorff & Hillyard, 1991). In light of the P300 effects we found, this then raised a new question regarding the impact of mind wandering on our basic mechanisms of selective attention—might mind wandering be associated with attenuation of attentional selection at these relatively earlier processing levels as well?

To address this question, we performed a second study—one that introduced several minor modifications to our original paradigm (Kam et al., 2011). Specifically, in one version, task-irrelevant visual probes were added to the SART, temporally interspersed with the targets, and in a second version, the probes were auditory tones, or brief “beeps,” presented over a speaker. We then looked at the sensory-evoked responses elicited by these task-irrelevant probes as a function of whether they occurred in the 12 s prior to mind-wandering versus on-task attentional reports. Again, we found a significant effect of attentional state. The amplitude of the visual P1 component, which is generated in extrastriate visual cortex (e.g., Heinze et al., 1994), was attenuated during mind-wandering states, as was the auditory N1 component, which is generated in primary auditory cortex (e.g., Woldorff &

Hillyard, 1991). Taken together, our findings and those of others (e.g., Barron, Riby, Greer, & Smallwood, 2011; Braboszcz & Delorme, 2011; O’Connell et al., 2009) indicate that mind wandering can engage mechanisms of selective attention at relatively early afferent processing stages in sensory-level cortical processing.

### External Disengagement: Attention to Performance and Affect

Our initial investigations were thus consistent with the hypothesis that, during periods of mind wandering, there is a dampening of selective attention to the outside world such that our cognitive processing of external stimulus inputs is reduced. In essence, our mechanisms of selective attention appear to select nothing from the external environment during these transient, inward-focused states. To be clear, we are not suggesting that sensory processing itself is turned off but, rather, that the highlighting of specific sensory inputs for higher levels of cognitive analysis—the prioritizing process that has long stood as the functional signature of selective attention in cortical processing (e.g., Heinze et al., 1994; Mangun & Hillyard, 1991; Woldorff & Hillyard, 1991)—is attenuated. Given this initial conclusion, however, we wanted to examine in a new round of studies whether the down-regulation of selective attentional processes during periods of mind wandering extends to other forms of attention.

In one pair of experiments, we considered the attentional processes associated with behavioral performance monitoring, or our ability to adaptively adjust our task-related behavior (Kam et al., 2012). Specifically, we began by asking a set of participants to perform a visuomotor tracking task wherein a small dot moved from left to right across a computer screen while undulating up and down in an unpredictable manner. Using a joystick controller, the task required participants to keep an annulus centered over the moving dot. In this case, the dependent measure was the root mean square tracking error, or an index of how closely the annulus was kept to the moving dot, with greater tracking error indicating worse performance. As with our earlier studies, we stopped participants at random intervals and queried them on whether they were mind wandering or on task just prior to stoppage, and then we examined tracking errors as a function of these reports. Not surprisingly, we found that tracking errors did indeed increase during mind-wandering periods (Kam et al., 2012, Experiment 1).

Given this result, we wanted to determine whether such effects might be attributable to general attenuation of sensory- and cognitive-level processing during mind wandering or if the effects of mind wandering could actually extend to performance-monitoring processes themselves. In this case, we switched to an ERP-based paradigm that had participants perform a simple time-estimation task in which, on each trial, they were asked to estimate the duration of 1 s on hearing a tone via a button press. After each estimate, a visual feedback signal was given indicating whether the estimate was correct or incorrect on the basis of whether the response was within or outside a narrow time window around 1 s (to keep performance relatively constant, the window itself would narrow slightly after each correct response and increase slightly after each incorrect response). As before, we then randomly sampled attentional states—either mind wandering or on task. Our primary dependent measure was the error-related negativity gen-

erated by the feedback signal (or the *fERN*), a component that indexes the extent to which we are monitoring the accuracy of our responses such that its amplitude positively covaries with the magnitude of behavioral assessment (Holroyd & Krigolson, 2007; Krigolson, Pierce, Holroyd, & Tanaka, 2009; Miltner, Braun, & Coles, 1997). We found that whereas the *fERN* was present during on-task attentional states, it was absent during mind-wandering states (Kam et al., 2012, Experiment 2). The conclusion? When our thoughts drift off task, our propensity to monitor our ongoing behavioral performance attenuates.

In a second study, we investigated whether the impacts of mind wandering also extend to our attentional sensitivity to affectively salient stimuli (Kam, Xu, & Handy, 2014). To wit, previous ERP work has shown that the P300 component elicited by visual images is greater in amplitude when an image contains affectively charged content relative to when an image is similar in low-level image properties but affectively neutral in content (Ferrari, Codispoti, Cardinale, & Bradley, 2008; Weinberg & Hajcak, 2011). To determine whether mind wandering can attenuate this affective sensitivity, we asked a cohort of participants to view images of peoples' hands in various contexts, some of which showed them in painful situations (e.g., getting a locker door shut on them) or neutral situations (e.g., next to a locker door), as we recorded the ERPs generated by the images. The task itself required participants to signal via a binary choice response whether the image looked painful or not. Again, we used experience sampling and randomly queried participants as to their global attentional state—either mind wandering or on task. Data analyses revealed that the heightened P300 to the painful images was present during on-task attentional states, but the effect was reduced during mind wandering (Kam et al., 2014, Experiment 1).

To then confirm whether we could really attribute this attenuating effect of mind wandering to changes in affective sensitivity rather than more domain-general cognitive effects as per Smallwood et al. (2008), we conducted a second behavioral experiment that had participants subjectively rate how painful each image looked on a scale of 1 (*not painful*) to 5 (*very painful*). Again using experience sampling, we found that although the subjective ratings of the neutral images were not affected by mind-wandering status, the ratings of the painful images were significantly lower during periods of mind wandering relative to on-task states (Kam et al., 2014, Experiment 2). In other words, conditions associated with decreased P300 responses to affectively charged visual images were also associated with decreases in the subjective sense of the pain conveyed in those images. This supported the conclusion that when we slip into a mind-wandering state, like the drop we observed in behavioral performance monitoring (Kam et al., 2012), our attentional sensitivity to affectively charged stimuli is significantly attenuated.

### Attentional Preservation During External Disengagement

The foregoing studies all converge on the conclusion that mind wandering co-occurs with a broad or widespread attenuation of our attentional engagement with the external world such that multiple mechanisms of selective attention in cortex systematically select for nothing during mind-wandering states. Yet if this is so, it raises a paradoxical question: What allows us to go about our daily

activities while mind wandering? How do we continue to do things like drive down the freeway or walk through the mall with our thoughts off in the clouds? Why aren't we constantly crashing into cars or other people when we mind wander in these situations? These questions are all the more perplexing given the fact that neuroimaging evidence suggests that our executive functions—functions that are presumably critical for maintaining our ongoing task performance—may be recruited away during mind wandering to focus on endogenously generated mental content (e.g., Christoff, 2012; Christoff et al., 2009). In a final pair of studies, we thus sought to determine whether some aspects of attentional selection may actually be preserved during mind-wandering states, thereby facilitating essential aspects of our ongoing behavior.

We first wanted to examine the impacts of mind wandering on executive functions more closely (Kam & Handy, 2014). The fact that we can continue to perform tasks while our thoughts have drifted off suggested that at least some executive functions may remain on task during mind wandering. To test this, we ran three separate experiments, each designed to isolate one core executive function (see Miyake et al., 2000)—response inhibition (assessed via a standard Stroop task; Stroop, 1935), updating of working memory (assessed via a standard *N*-back task; Kirchner, 1958), and set-shifting (assessed via a standard rule-switching task; Rogers & Monsell, 1995). We found that both response inhibition and working memory were negatively affected by mind wandering (Kam & Handy, 2014, Experiments 1 and 2) but that set-shifting was not (Kam & Handy, 2014, Experiment 3). This dissociation between executive functions suggests that one key way in which we can continue task performance while our thoughts drift elsewhere is to maintain a measure of cognitive flexibility—if we need to rapidly snap our attention back to the task at hand, our finding of preserved set-shifting during mind wandering suggests that that capacity persists.

In a second study, we took a more direct look at how attentional control itself is affected by mind wandering (Kam, Dao, Stanculescu, Tildesley, & Handy, 2013). Our first experiment relied on behavioral measures, examining whether mind wandering disrupts our ability to orient or control visuospatial selective attention. Comparing both volitional (e.g., Posner, 1980) and reflexive (e.g., Friesen & Kingstone, 1998) forms of visuospatial orienting in a pair of classic attentional-cuing paradigms, we found that the normal attentional benefits seen for target stimuli at attended locations—in particular, shorter reaction times (RTs) relative to those to targets presented at unattended locations—were absent during periods of mind wandering (Kam et al., 2013, Experiment 1). Notably, these effects of mind wandering on RT, our primary dependent measure, were restricted to targets at attended locations; the RTs to targets at unattended locations were unaffected by mind wandering. This supported the conclusion that task-related visuospatial orienting to external events was indeed abolished during mind wandering, even attentional orienting driven by reflexive mechanisms.

Given this initial finding, we then used ERPs to assess whether our attention to deviant or unusual events may in fact be preserved during mind-wandering states. Specifically, we asked participants to read passages from Francis Bacon's *Essays* while task-irrelevant tones (either 600 or 800 Hz) were played over a speaker that participants were told to ignore. The lower frequency tone was played with .80 probability, making the higher frequency tone the

less-frequent “deviant.” At issue here was whether this deviant tone would be modulated by attentional states in the same manner that task-irrelevant tones were attenuated by mind wandering in an earlier study (Kam et al., 2011). At random intervals, as in all our previous experiments, we would stop participants and ask them to report on their attentional state—either mind wandering or on task. When we then looked at the responses to the deviant tones as a function of attentional state, we found that although the N1 elicited by standard tones was greater when attention was on-task relative to mind wandering, as expected on the basis of the aforementioned study (Kam et al., 2011), the N1 in response to the deviant tones remained unaffected by mind wandering (Kam et al., 2013, Experiment 2). This indicated that despite widespread down-regulation of selective attention during mind wandering, our capacity for processing deviant events in the environment is preserved.

Viewed through an adaptive lens, our findings thus support a preliminary sketch of how we may maintain task performance during disengagement from the external environment. With deviance detection preserved, this would allow us to slip into a more automatic form of behavioral control while retaining the capacity to be vigilant for changes in the external environment that may require more direct, online attentional control. When we are driving down the freeway lost in a haze, for example, we may continue to operate our vehicle somewhat safely if traffic is smooth and easily predictable. However, a context-deviant event such as a car suddenly swerving ahead or brake lights flashing would be expected to trigger a deviance-detection response. With preserved set-shifting and the cognitive flexibility it allows, this would give us the necessary capacity to then rapidly (and adaptively) respond to the deviant event in a strategic, controlled manner.

### Conclusions and Implications

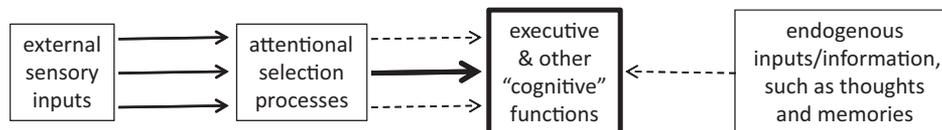
The collective evidence from the studies reviewed here converges on a general model of attentional engagement with the external world that we diagram in Figure 1. We conclude this article by discussing the issues, implications, and questions arising from it.

First and perhaps foremost, our model places selective attention in a broader functional context than has been traditionally taken. Namely, selective attention has long been seen as the necessary gatekeeper for determining what subset of incoming sensory inputs are made available to our capacity-limited cognitive processes (e.g., Desimone & Duncan, 1995; Posner, 1980; Posner & Petersen, 1990; Treisman & Gelade, 1980). This dynamic is captured in Figure 1a by the three most leftward boxes, which diagram how sensory inputs enter into the processes of selective attention equally weighted and then go through a prioritization such that a subset of the sensory inputs are signal amplified, and the remainder of inputs are signal attenuated. By this prioritization, our capacity-limited cognitive processes preferentially operate on the amplified, or selected, signals passed on to them.

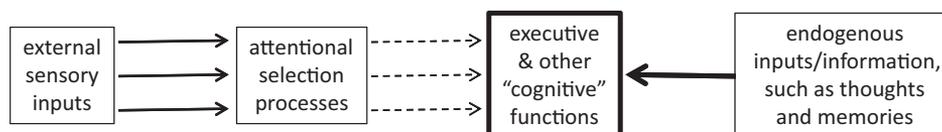
Yet what our model highlights is that our processes of selective attention also have a functional relationship with endogenous or nonsensory sources of information content, as captured by the box on the far right in Figure 1a. In particular, our mechanisms of selective attention provide inputs to a set of capacity-limited executive/cognitive processes that, at any given moment, not only can have inputs from information sources other than just those originating in our ongoing, real-time sensory afferents (e.g., Christoff et al., 2009; Smallwood et al., 2004; Sonuga-Barke & Castellanos, 2007) but also mediate or face a competition between internal and external sources (e.g., Smallwood & Schooler, 2006). Given this functional dynamic, the data reviewed earlier support the hypothesis that selective attention serves not one critical role for our capacity-limited executive/cognitive functions but two—in addition to controlling the prioritization of sensory inputs during what we may call *externally engaged states* (see Figure 1a), our mechanisms of selective attention also serve to facilitate the prioritization of endogenous inputs into our executive/cognitive functions by transiently attenuating sensory signal amplification during what we may call *externally disengaged states* (see Figure 1b).

This model then expands our traditional understanding of selective attention in a second key way. Implicit in traditional models is that we are always selecting for something in the external environment to pass on to our higher level, capacity-limited cognitive

#### a. externally engaged



#### b. externally disengaged



*Figure 1.* A model of how selective attention operates during externally engaged and externally disengaged states. During engaged states, selective attention prioritizes a subset of sensory inputs for further processing by our capacity-limited executive/cognitive functions while endogenous inputs into these processes are attenuated. During disengaged states, selective attention attenuates the prioritization of sensory inputs while endogenous information sources have preferential access to our capacity-limited executive/cognitive functions.

resources. For decades, research and debate in attention has thus focused on how we go about mediating this selection—for instance, whether visual selection is based on spatial locations or object properties (e.g., Desimone & Duncan, 1995; Posner, 1980; Treisman & Gelade, 1980). What we have now uncovered through the study of mind wandering is that, as captured in Figure 1b, there are significant portions of time when we appear to actively select for nothing from the external environment. Or, to update the metaphor made popular by Posner, the attentional spotlight has an on–off switch that is an important part of its functional capacity.

Beyond these issues of selective attention, by deliberately using the labels *externally engaged* and *externally disengaged* to describe the two states in our model, we explicitly recognize that the neurocognitive dynamic it captures is not limited to mind wandering itself. For example, when we are actively recalling an autobiographical memory or performing mental arithmetic, conditions not necessarily tied to mind wandering, we may see a similar pattern of transient external disengagement at the neurocognitive level. Likewise, there are a number of psychological disorders that have been tied to abnormal levels of sensorimotor and cognitive attenuation not dissimilar to the kinds of attentional effects observed during mind wandering (see Kam & Handy, 2013). These include disorders that can be classified as involving excessive maintenance of externally disengaged states—including major depressive disorder (e.g., Spasojević & Alloy, 2001; Watkins & Teasdale, 2001) and the more recently recognized condition of compulsive fantasy (or excessive, structured daydreaming without co-occurring psychopathology; Bigelsen & Schupak, 2011; Schupak & Rosenthal, 2009)—as well as disorders that can be classified as involving excessive maintenance of externally engaged states, most notably attention-deficit/hyperactivity disorder (e.g., Arnsten, 2006; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Fassbender et al., 2009; Sonuga-Barke & Castellanos, 2007). On this view, mind wandering is just one factor influencing whether we are in an externally engaged or disengaged state at any given moment, and thus it shares an underlying neurocognitive mechanism with this set of psychological disorders.

Yet if mind wandering taps into a domain-general neurocognitive dynamic, it is critical to appreciate that mind wandering itself can pose very specific and heretofore unrecognized clinical problems. In one study, for instance, we recently reported that as we age, the prevalence rate of mind wandering drops from approximately 66% of the time (in younger adults) to 33% of the time (in seniors age 65 years and older; Nagamatsu, Kam, Liu-Ambrose, Chan, & Handy, 2013). We hypothesized that as we age, we become less adept in our ability to manage our task performances while externally disengaged, owing to well-known age-related decreases in executive functioning capacities, and so we cognitively compensate by mind wandering less—for example, by giving higher salience or priority to external stimulus inputs. Of clinical importance, however, we found that older individuals with a recent history of falls report mind wandering at rates comparable to younger adults, suggesting that they are failing to compensate for normal age-related changes in executive cognitive functioning. In a more recent study, we found that breast cancer survivors who report cancer-associated cognitive deficits show significantly higher levels of mind wandering relative to demographically matched healthy

counterparts (Kam et al., in press). Given the comprehensive effects mind wandering can have on our attentional engagement with the external environment, the health consequences of engaging in mind wandering at inopportune times—or in inordinate amounts—should not be underestimated.

In closing, we stress that the resolution of our framework here is both coarse and somewhat simplistic. For example, what stands for *selective attention* and *executive/cognitive functions* are grossly underspecified; the role of attention in perception is ignored; and there is no accommodation for the control of behavioral or motor outputs, which are directly affected by what information is shunted to our executive/cognitive processes. Nevertheless, we believe that the general framework provides not just a useful roadmap for explicating how mind-wandering research has advanced our understanding of neurocognitive function but also important questions for further research.

For example, what do the transitions between engaged and disengaged states look like? Are they discrete jumps in time, or are they better characterized as graded shifts? If our mechanisms of selective attention are vital to externally disengaged states, what neural networks control this aspect of their functionality? Elsewhere we have speculated that it may involve the so-called salience network comprising the anterior insula and anterior cingulate cortex (Kam & Handy, 2013), a network believed to be responsible for determining the most salient internal or external stimulus for guiding behavior at any given moment (e.g., Menon & Uddin, 2010). In a similar vein, it has also been suggested that the so-called frontoparietal network—comprising the rostrolateral and dorsolateral prefrontal cortices, the anterior insula, dorsal anterior cingulate cortex, the precuneus, and the anterior inferior parietal lobule—may serve a similar function (e.g., Smallwood, Brown, Baird, & Schooler, 2012). Might both networks be involved, or would the default mode network be a more likely candidate given its known association with mind-wandering states (e.g., Christoff et al., 2009)? More explicitly, our framework captures the basic dynamic that our attention can readily switch from an external to internal focus and back over time. What factors influence this switching, and how might they be categorized with respect to endogenous versus exogenous and volitional versus reflexive triggers? Whatever the answers, we hope our review underscores the importance of continuing to explore the attentional consequences of the wandering mind.

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## Résumé

Dans le domaine de la neuroscience cognitive, l'étude de l'attention a longtemps été centrée sur la caractérisation des systèmes de base du cerveau qui servent à choisir l'information sensorielle externe qui sera portée jusqu'aux processus les plus élevés, et à capacité limitée, dans le cortex. Ce que l'on connaît moins bien est la façon dont les systèmes attentionnels fluctuent dans la durée de leur sélectivité, depuis des secondes jusqu'à des minutes, au cours des activités quotidiennes. Dans le but d'éclaircir le sujet, nous faisons la revue d'études récentes que nous avons réalisées pour montrer que le niveau avec lequel les systèmes d'attention sélective répondent à l'environnement externe est coordonné selon ces délais, de façon à ce qu'ils s'engagent et se désengagent ensemble pour moduler de façon transitoire l'ampleur de l'investissement cognitif à l'égard des

entrées sensorielles externes. Bien que nos études aient principalement porté sur la rêverie chez de jeunes participants en santé, nous suggérons que la capacité des gens à atténuer grandement leur attention sélective à l'égard des stimuli externes joue un rôle fondamental à la fois dans la cognition humaine normale et la pathologie clinique.

**Mots-clés :** rêverie, attention visuelle, fonction exécutif, simulation mentale.

## References

- Arnsten, A. F. T. (2006). Fundamentals of attention-deficit/hyperactivity disorder: Circuits and pathways. *Journal of Clinical Psychiatry*, *67*(Suppl. 8), 7–12.
- Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W. Y., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological Science*, *23*, 1117–1122. <http://dx.doi.org/10.1177/0956797612446024>
- Barron, E., Riby, L. M., Greer, J., & Smallwood, J. (2011). Absorbed in thought: The effect of mind wandering on the processing of relevant and irrelevant events. *Psychological Science*, *22*, 596–601. <http://dx.doi.org/10.1177/0956797611404083>
- Bigelsen, J., & Schupak, C. (2011). Compulsive fantasy: Proposed evidence of an under-reported syndrome through a systematic study of 90 self-identified non-normative fantasizers. *Consciousness and Cognition*, *20*, 1634–1648. <http://dx.doi.org/10.1016/j.concog.2011.08.013>
- Braboszcz, C., & Delorme, A. (2011). Lost in thoughts: Neural markers of low alertness during mind wandering. *NeuroImage*, *54*, 3040–3047. <http://dx.doi.org/10.1016/j.neuroimage.2010.10.008>
- Castellanos, F. X., Sonuga-Barke, E. J. S., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: Beyond executive dysfunction. *Trends in Cognitive Sciences*, *10*, 117–123. <http://dx.doi.org/10.1016/j.tics.2006.01.011>
- Christoff, K. (2012). Undirected thought: Neural determinants and correlates. *Brain Research*, *1428*, 51–59. <http://dx.doi.org/10.1016/j.brainres.2011.09.060>
- Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (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*, 8719–8724. <http://dx.doi.org/10.1073/pnas.0900234106>
- Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, *18*, 193–222. <http://dx.doi.org/10.1146/annurev.ne.18.030195.001205>
- Ellamil, M., Dobson, C., Beeman, M., & Christoff, K. (2012). Evaluative and generative modes of thought during the creative process. *NeuroImage*, *59*, 1783–1794. <http://dx.doi.org/10.1016/j.neuroimage.2011.08.008>
- Fassbender, C., Zhang, H., Buzy, W. M., Cortes, C. R., Mizuiri, D., Beckett, L., & Schweitzer, J. B. (2009). A lack of default network suppression is linked to increased distractibility in ADHD. *Brain Research*, *1273*, 114–128. <http://dx.doi.org/10.1016/j.brainres.2009.02.070>
- Ferrari, V., Codispoti, M., Cardinale, R., & Bradley, M. M. (2008). Directed and motivated attention during processing of natural scenes. *Journal of Cognitive Neuroscience*, *20*, 1753–1761.
- Fingelkurts, A. A., & Fingelkurts, A. A. (2011). Persistent operational synchrony within brain default-mode network and self-processing operations in healthy subjects. *Brain and Cognition*, *75*, 79–90. <http://dx.doi.org/10.1016/j.bandc.2010.11.015>
- Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*, 490–495. <http://dx.doi.org/10.3758/BF03208827>
- Gruberger, M., Ben-Simon, E., Levkovitz, Y., Zangen, A., & Hendlar, T. (2011). Towards a neuroscience of mind-wandering. *Frontiers in Human Neuroscience*, *5*, 56. <http://dx.doi.org/10.3389/fnhum.2011.00056>
- Heinze, H. J., Mangun, G. R., Burchert, W., Hinrichs, H., Scholz, M., Münte, T. F., . . . Hillyard, S. A. (1994, December 8). Combined spatial and temporal imaging of brain activity during visual selective attention in humans. *Nature*, *372*, 543–546. <http://dx.doi.org/10.1038/372543a0>
- Holroyd, C. B., & Krigolson, O. E. (2007). Reward prediction error signals associated with a modified time estimation task. *Psychophysiology*, *44*, 913–917. <http://dx.doi.org/10.1111/j.1469-8986.2007.00561.x>
- Kam, J. W. Y., Brenner, C. A., Handy, T. C., Boyd, L. A., Liu-Ambrose, T. Y. L., Lim, H. J., . . . Campbell, K. L. (in press). Attentional fluctuation abnormalities in breast cancer survivors with cancer-associated cognitive deficits post chemotherapy: An electrophysiological study. *Clinical Neurophysiology*.
- Kam, J. W. Y., Dao, E., Blinn, P., Krigolson, O. E., Boyd, L. A., & Handy, T. C. (2012). Mind wandering and motor control: Off-task thinking disrupts the online adjustment of behavior. *Frontiers in Human Neuroscience*, *6*, 329. <http://dx.doi.org/10.3389/fnhum.2012.00329>
- Kam, J. W. Y., Dao, E., Farley, J., Fitzpatrick, K., Smallwood, J., Schooler, J. W., & Handy, T. C. (2011). Slow fluctuations in attentional control of sensory cortex. *Journal of Cognitive Neuroscience*, *23*, 460–470. <http://dx.doi.org/10.1162/jocn.2010.21443>
- Kam, J. W. Y., Dao, E., Stanculescu, M., Tildesley, H., & Handy, T. C. (2013). Mind wandering and the adaptive control of attentional resources. *Journal of Cognitive Neuroscience*, *25*, 952–960. [http://dx.doi.org/10.1162/jocn\\_a\\_00375](http://dx.doi.org/10.1162/jocn_a_00375)
- Kam, J. W. Y., & Handy, T. C. (2013). The neurocognitive consequences of the wandering mind: A mechanistic account of sensory-motor decoupling. *Frontiers in Perception Science*, *14*, 725. <http://dx.doi.org/10.3389/fpsyg.2013.00725>
- Kam, J. W. Y., & Handy, T. C. (2014). Differential recruitment of executive resources during mind wandering. *Consciousness and Cognition*, *26*, 51–63.
- Kam, J. W. Y., Xu, J., & Handy, T. C. (2014). I don't feel your pain (as much): The desensitizing effect of mind wandering on the perception of others' discomfort. *Cognitive, Affective, & Behavioral Neuroscience*, *14*, 286–296. <http://dx.doi.org/10.3758/s13415-013-0197-z>
- Killingsworth, M. A., & Gilbert, D. T. (2010, November 12). A wandering mind is an unhappy mind. *Science*, *330*, 932. <http://dx.doi.org/10.1126/science.1192439>
- Kim, H. (2012). A dual-subsystem model of the brain's default network: Self-referential processing, memory retrieval processes, and autobiographical memory retrieval. *NeuroImage*, *61*, 966–977. <http://dx.doi.org/10.1016/j.neuroimage.2012.03.025>
- Kirchner, W. K. (1958). Age differences in short-term retention of rapidly changing information. *Journal of Experimental Psychology*, *55*, 352–358. <http://dx.doi.org/10.1037/h0043688>
- Kirschner, A., Kam, J. W. Y., Handy, T. C., & Ward, L. M. (2012). Differential synchronization in default and task-specific networks of the human brain. *Frontiers in Human Neuroscience*, *6*, 139. <http://dx.doi.org/10.3389/fnhum.2012.00139>
- Krigolson, O. E., Pierce, L. J., Holroyd, C. B., & Tanaka, J. W. (2009). Learning to become an expert: Reinforcement learning and the acquisition of perceptual expertise. *Journal of Cognitive Neuroscience*, *21*, 1833–1841. <http://dx.doi.org/10.1162/jocn.2009.21128>
- Mangun, G. R., & Hillyard, S. A. (1991). Modulation of sensory-evoked brain potentials indicate changes in perceptual processing during visual-spatial priming. *Journal of Experimental Psychology: Human Perception and Performance*, *17*, 1057–1074. <http://dx.doi.org/10.1037/0096-1523.17.4.1057>
- Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering Minds: The default network and stimulus-independent thought. *Science*, *315*, 393–395.

- McVay, J. C., Kane, M. J., & Kwapil, T. R. (2009). Tracking the train of thought from the laboratory into everyday life: An experience-sampling study of mind wandering across controlled and ecological contexts. *Psychonomic Bulletin & Review*, *16*, 857–863. <http://dx.doi.org/10.3758/PBR.16.5.857>
- Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: A network model of insula function. *Brain Structure & Function*, *214*, 655–667. <http://dx.doi.org/10.1007/s00429-010-0262-0>
- Miltner, W. H. R., Braun, C. H., & Coles, M. G. H. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: Evidence for a 'generic' neural system for error detection. *Journal of Cognitive Neuroscience*, *9*, 788–798.
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. <http://dx.doi.org/10.1006/cogp.1999.0734>
- Nagamatsu, L. S., Kam, J. W. Y., Liu-Ambrose, T., Chan, A., & Handy, T. C. (2013). Mind-wandering and falls risk in older adults. *Psychology and Aging*, *28*, 685–691. <http://dx.doi.org/10.1037/a0034197>
- Northoff, G., Heinzel, A., de Greck, M., Birmpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—A meta-analysis of imaging studies on the self. *NeuroImage*, *31*, 440–457. <http://dx.doi.org/10.1016/j.neuroimage.2005.12.002>
- O'Connell, R. G., Dockree, P. M., Robertson, I. H., Bellgrove, M. A., Foxe, J. J., & Kelly, S. P. (2009). Uncovering the neural signature of lapsing attention: Electrophysiological signals predict errors up to 20 s before they occur. *Journal of Neuroscience*, *29*, 8604–8611. <http://dx.doi.org/10.1523/JNEUROSCI.5967-08.2009>
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*, 3–25. <http://dx.doi.org/10.1080/00335558008248231>
- Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25–42. <http://dx.doi.org/10.1146/annurev.ne.13.030190.000325>
- Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, *124*, 207–231. <http://dx.doi.org/10.1037/0096-3445.124.2.207>
- Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*, *15*, 319–326.
- Schupak, C., & Rosenthal, J. (2009). Excessive daydreaming: A case history and discussion of mind wandering and high fantasy proneness. *Consciousness and Cognition*, *18*, 290–292. <http://dx.doi.org/10.1016/j.concog.2008.10.002>
- Smallwood, J., Beach, E., Schooler, J. W., & Handy, T. C. (2008). Going AWOL in the brain: Mind wandering reduces cortical analysis of external events. *Journal of Cognitive Neuroscience*, *20*, 458–469.
- Smallwood, J., Brown, K., Baird, B., & Schooler, J. W. (2012). Cooperation between the default mode network and the frontal–parietal network in the production of an internal train of thought. *Brain Research*, *1428*, 60–70. <http://dx.doi.org/10.1016/j.brainres.2011.03.072>
- Smallwood, J., Davies, J. B., Heim, D., Finnigan, F., Sudberry, M., O'Connor, R., & Obonsawin, M. (2004). Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Consciousness and Cognition*, *13*, 657–690. <http://dx.doi.org/10.1016/j.concog.2004.06.003>
- Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*, 946–958. <http://dx.doi.org/10.1037/0033-2909.132.6.946>
- Smallwood, J., Schooler, J. W., Turk, D. J., Cunningham, S. J., Burns, P., Macrae, C. N. (2011). Self-reflection and the temporal focus of the wandering mind. *Consciousness and Cognition*, *20*, 1120–1126.
- Soltani, M., & Knight, R. T. (2000). Neural origins of the P300. *Clinical Reviews of Neurobiology*, *14*, 199–224.
- Sonuga-Barke, E. J., & Castellanos, F. X. (2007). Spontaneous attentional fluctuations in impaired states and pathological conditions: A neurobiological hypothesis. *Neuroscience and Biobehavioral Reviews*, *31*, 977–986. <http://dx.doi.org/10.1016/j.neubiorev.2007.02.005>
- Spasojević, J., & Alloy, L. B. (2001). Rumination as a common mechanism relating depressive risk factors to depression. *Emotion*, *1*, 25–37. <http://dx.doi.org/10.1037/1528-3542.1.1.25>
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643–662. <http://dx.doi.org/10.1037/h0054651>
- Svoboda, E., McKinnon, M. C., & Levine, B. (2006). The functional neuroanatomy of autobiographical memory: A meta-analysis. *Neuropsychologia*, *44*, 2189–2208. <http://dx.doi.org/10.1016/j.neuropsychologia.2006.05.023>
- Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*, 97–136. [http://dx.doi.org/10.1016/0010-0285\(80\)90005-5](http://dx.doi.org/10.1016/0010-0285(80)90005-5)
- Watkins, E., & Teasdale, J. D. (2001). Rumination and overgeneral memory in depression: Effects of self-focus and analytic thinking. *Journal of Abnormal Psychology*, *110*, 353–357. <http://dx.doi.org/10.1037/0021-843X.110.2.333>
- Weinberg, A., & Hajcak, G. (2011). The late positive potential predicts subsequent interference with target processing. *Journal of Cognitive Neuroscience*, *23*, 2994–3007. <http://dx.doi.org/10.1162/jocn.2011.21630>
- Woldorff, M. G., & Hillyard, S. A. (1991). Modulation of early auditory processing during selective listening to rapidly presented tones. *Electroencephalography & Clinical Neurophysiology*, *79*, 170–191. [http://dx.doi.org/10.1016/0013-4694\(91\)90136-R](http://dx.doi.org/10.1016/0013-4694(91)90136-R)

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