

I don't feel your pain (as much): The desensitizing effect of mind wandering on the perception of others' discomfort

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Abstract Mind wandering reduces both the sensory and cognitive processing of affectively neutral stimuli, but whether it also modulates the processing of affectively salient stimuli remains unclear. In particular, we examined whether mind wandering attenuates one's sensitivity to observing mild pain in others. In the first experiment, we recorded event-related potentials (ERPs) as participants viewed images of hands in either painful or neutral situations, while being prompted at random intervals to report whether their thoughts were on task or mind wandering. We found that the brain's later response to painful images was significantly reduced immediately preceding "mind-wandering" versus "on-task" reports, as measured via amplitude decreases in a frontal–central positivity beginning approximately 300 ms poststimulus. In a second, control experiment using behavioral measures, we wanted to confirm whether the subjective sense of pain observed in others does in fact decrease during mind wandering. Accordingly, we asked participants to rate how painful the hand images looked on a 5-point Likert scale, again while taking reports of their mind-wandering states at unpredictable intervals. Consistent with our ERP data, we found that the ratings for painful images were significantly reduced immediately preceding mind-wandering reports. Additional control analyses suggested that the effect could not simply be ascribed to general habituation in the affective response to painful images over time. Collectively, our findings demonstrate that mind wandering can directly modulate the cortical processing of affectively salient stimulus inputs, serving in this case to reduce sensitivity to the physical discomfort of others.

Keywords Mind wandering · Affective saliency · Attention · Empathy · ERP

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Mind wandering is the ubiquitous phenomenon of our thoughts drifting away from the external environment to focus on the internal milieu (see, e.g., Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011; Smallwood & Schooler, 2006). For example, we may often find ourselves thinking about plans for the weekend when reading the newspaper, or brainstorming destinations for your next trip while watching the television. Given that we mind wander frequently (Killingsworth & Gilbert, 2010) and that mind wandering appears to be integral to normal human brain function (Smallwood & Schooler, 2006), researchers have become increasingly interested in understanding the functional consequences of the wandering mind, and specifically, in elucidating how our neurocognitive processes change as our thoughts drift away from the current task at hand.

In this regard, mind wandering can be seen as having two primary effects at the neural level. First, modern neuroimaging methods have revealed that a core set of networks in the brain oscillate in their activity over time, depending on the nature of the task being performed and other key variables (e.g., Corbetta & Shulman, 2002; Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008; Gusnard & Raichle, 2001). As we now know, mind wandering is one of these core determinants, in that it up-regulates activity in the default mode network (DMN; Gusnard & Raichle, 2001), an effect that has been shown using both fMRI (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason, Norton, Van Horn, Wegner, Grafton, & Macrae, 2007; Starwarczyk, Majerus, Maquet, & D'Argembeau, 2011) and electroencephalographic synchrony (e.g., Kirschner, Kam, Handy, & Ward, 2012). Moreover, activity is anticorrelated between the DMN and task-related networks (e.g., Fox, Snyder, Vincent, Corbetta, Van Essen, & Raichle, 2005), a finding that supports the hypothesis that the DMN may facilitate mind wandering and the internal trains of thought it generates by actively disengaging our attention from the external environment (e.g., Schooler et al., 2011).

Second, and more directly related to our study, mind wandering also actively attenuates the neural processing of external sensory inputs, an effect that goes hand-in-hand with up-regulation of activity in the DMN. For example, sensory-evoked responses to task-irrelevant stimuli decrease in both visual and auditory cortex (e.g., Braboszcz & Delorme, 2011; Kam, Dao, Farley, Fitzpatrick, Smallwood, Schooler, & Handy, 2011), suggesting that, like top-down attention, mind wandering has a direct impact on cortical sensory gain control. Farther upstream, our cognitive analysis of target events also diminishes (e.g., Barron, Riby, Greer, & Smallwood, 2011; O'Connell, Dockree, Robertson, Bellgrove, Foxe, & Kelly, 2009), an effect that is independent of any concomitant sensory attenuation (Smallwood, Beach, Schooler, & Handy, 2008). Likewise, our adjustment of behavior is also disrupted while mind wandering, in terms of both online motor control and monitoring of performance feedback (Kam, Dao, Blinn, Krigolson, Boyd, & Handy, 2012). These disruptions in processing, which co-occur with DMN up-regulation, effectively shut out the external world and allow our thoughts to drift off to other times, places, and events—the cognitive hallmarks of the subjective mind-wandering state (e.g., Smallwood & Schooler, 2006; Smallwood, Schooler, Turk, Cunningham, Burns, & Macrae, 2011).

Given these neural effects, a key unanswered question concerns whether the qualitative nature of the incoming stimulation itself affects its extent of attenuation during mind wandering. In particular, the stimuli used to examine these attenuating sensory and cognitive effects of mind wandering have been relatively impoverished, so far, with respect to their contextual representation or information content; for instance, numbers and letters have been used in the sustained-attention-to-response task (e.g., Kam et al., 2011; Smallwood, Beach, et al., 2008), and colored, geometrically patterned visual stimuli in oddball (e.g., Barron et al., 2011) and continuous temporal expectancy (e.g., O'Connell et al., 2009) tasks. Yet the extent to which—and perhaps whether—the qualitative content of task-relevant stimuli influences how they are attenuated during mind wandering remains unknown. Our goal here was to examine whether the attenuating effects of mind wandering extend to more naturalistic stimulus inputs—specifically, those having some measure of affective saliency.

To address this question, we chose a stimulus set that was both comparatively high in ecological validity and had a moderate degree of affective content (Fan & Han, 2008; Gu & Han, 2007). This set contained pictures of hands in the first-person perspective in painful or neutral situations (see Fig. 1). In asking participants to rate these pictures while recording the event-related potentials (ERPs) that they engendered, Fan and Han not only identified two successive stages of neural processing that were engaged by the painful versus neutral pictures, they also found differential affective associations with each of these stages. Specifically, the earlier, more automatic stage of

processing was found to index the emotional sharing of the painful experience, which correlated with subjective ratings of unpleasantness. Alternatively, the later, more controlled stage of processing was found to index the cognitive or contextual evaluation of the experience, which appeared to be directly modulated by both task demands (Fan & Han, 2008) and shifts in the visual perspectives that participants took during the task, or whether they adopted a first-person or third-person perspective (Li & Han, 2010). This dissociation in the two stages of processing triggered by painful images was ideal for our study, in that we could investigate whether mind wandering would affect either or both levels of stimulus processing.

Importantly, the two-stage response engendered by Fan and Han's (2008) images is consistent with the two-stage (bottom-up and top-down) processing model of the empathy response (Decety & Lamm, 2006; de Vignemont & Singer, 2006). This model of empathy—the capacity to understand the emotional experience of other individuals—purports that whereas emotional cues automatically elicit sensory simulation of the observed emotional state (i.e., bottom-up processes), contextual information is evaluated subsequently to regulate this vicarious emotional state (i.e., top-down-controlled processes). In particular, the bottom-up stage involves an automatic process of emotional sharing. For example, the perception of others' emotions and the generation of one's own emotion activate similar networks of neural regions (Botvinick, Jha, Bylsma, Fabian, Solomon, & Prkachin, 2005; Singer, Seymour, O'Doherty, Kaube, Dolan, & Frith, 2004). Furthermore, the relationship between the participant and the observed image did not modulate the empathy-related response (Botvinick et al., 2005; Jackson, Meltzoff, & Decety, 2005), suggesting that empathy is automatically activated upon observing pain in others. Alternatively, top-down processes appear to involve a cognitive evaluation that may inhibit or facilitate the emotional experience. For instance, a prior painful experience more readily elicits an empathetic response when one is observing a similar experience (Jackson et al., 2005). Likewise, knowledge of one's emotional experiences also helps facilitate the empathetic response (Rimé, Herbet, & Corsini, 2004). Both findings support the notion that cognitive processes related to intentionality and expectancy can modulate the empathetic response (Goubert, Craig, Vervoort, Morley, Sullivan, de C. Williams, & Crombez, 2005). Of interest here is whether these kinds of affect-related responses are immune to the impacts of mind wandering, or whether being disengaged from the external environment leads to transient reductions in our proclivity for sensitivity to perceived pain.

Given the available evidence from the affective literature, the possible effect of mind wandering on the processing of painful images remains uncertain. On the one hand, emotional stimuli appear to automatically elicit or trigger heightened attention (Armony & Dolan, 2002; Frank & Sabatinelli 2012). For example, emotional stimuli improved contrast

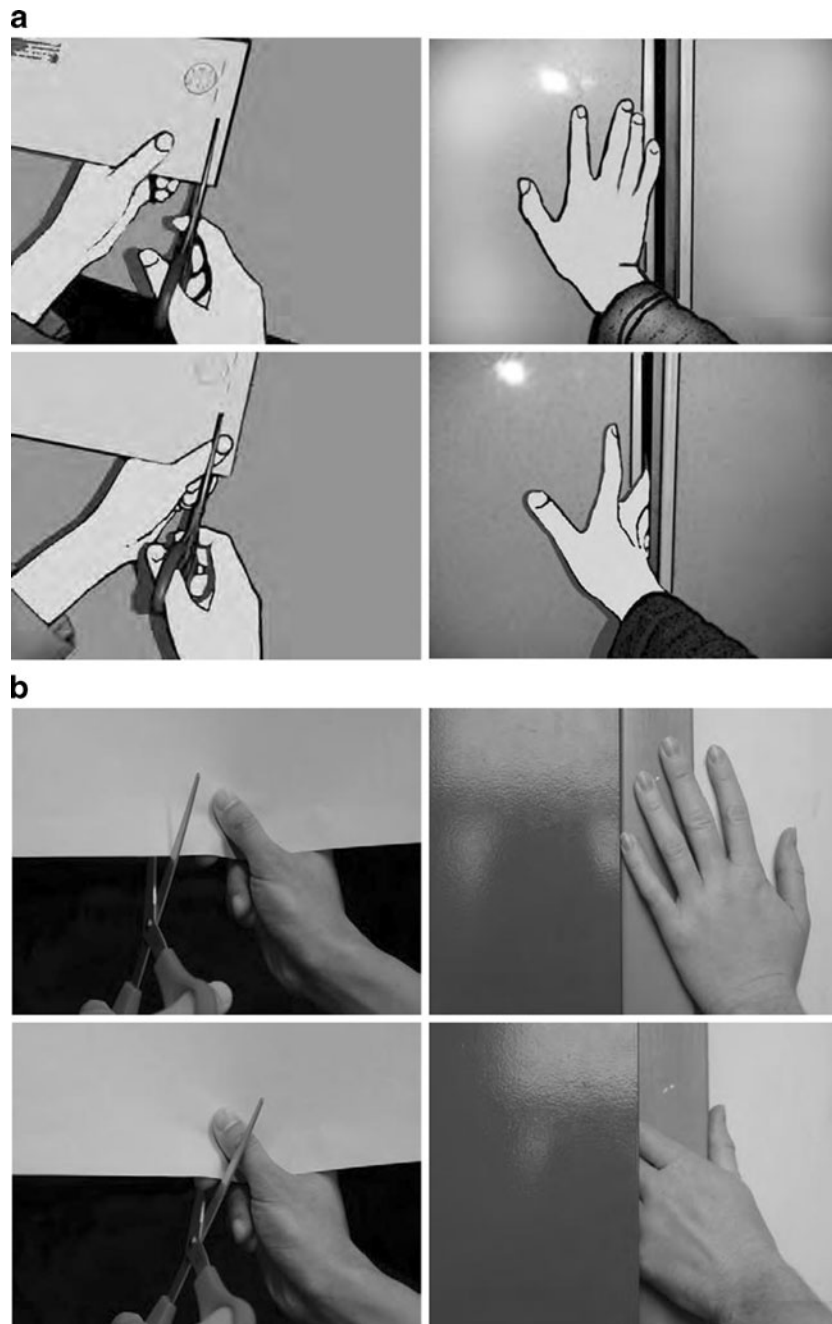


Fig. 1 Visual stimuli in Experiments 1 and 2. Examples are shown of (a) the cartoon-ized images of hands in painful and pain-neutral situations used in Experiment 1, and (b) the similar but naturalistic images used in Experiment 2

sensitivity in an ongoing task (Phelps, Ling, & Carrasco, 2006), increased ERP responses relative to neutral stimuli (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Foti, Hajcak, & Dien, 2009), and enhanced the fMRI BOLD signal in neural regions involved in emotional processing (Kensinger & Schacter, 2006; Morris, Friston, Büchel, Frith, Young, Calder, & Dolan, 1998). This suggests that stimuli having emotional content may have privileged access to neural processing relative to affectively neutral stimuli. On the other hand, previous studies have also revealed top-down

modulation of our neural response to perceived pain in others (Fan & Han, 2008; Gu & Han, 2007). That is, top-down attentional control appears to impact the strength of the late but not the early ERP response to the perceived pain of others (Fan & Han, 2008; Li & Han, 2010), a finding that the authors ascribed to a direct effect of attention on the empathetic response to the observed pain. Of relevance, the question of interest for us concerned whether mind wandering would modulate this later empathy response in a manner akin to top-down attentional control. Given the similarities between the effects of mind

wandering and top-down control (cf. Smallwood, Brown, Baird, & Schooler, 2012), we hypothesized that mind wandering would attenuate the response to painful images in a manner similar to the modulatory effects of top-down attention; that is, the effect would be present in the late but not in the early ERP response to painful images.

In the first experiment, we thus recorded ERPs while participants viewed a serial stream of visual images of hands pictured from a first-person perspective, which were in either a painful or a comparable neutral situation (e.g., shut in a drawer vs. next to a drawer). During the task, participants were also prompted at random intervals to report on their attention state as being either “on task” or “mind wandering.” To determine the impact of mind wandering on the sensitivity to others in pain, we compared the ERP responses to painful and neutral images in the interval immediately preceding “on-task” versus “mind-wandering” reports. At issue was whether the early versus late responses to perceived pain, as defined by Fan and Han (2008), would selectively attenuate during mind wandering. If so, this would indicate that our responses to affectively salient stimuli are in fact labile to control by slow fluctuations in task-related attention states.

Experiment 1

Methods

Participants A total of 19 individuals (12 females, seven males; $M = 22.63$ years old, $SD = 4.89$) participated in the study. All were right handed, had normal or corrected-to-normal vision, gave written informed consent, and received \$20 for their participation. All procedures and protocols of this study were approved by the UBC Behavioral Review Ethics Board.

Stimuli and paradigm The visual stimuli and primary task replicated those of Fan and Han (2008). The stimuli consisted of 40 cartoon-ized images of one or two hands viewed from a first-person perspective in everyday situations (see Fig. 1a). Half of these images showed the hand(s) in painful situations, and the other half showed the hand(s) in similar, but pain-neutral, situations. Each image was 10.6×11.2 cm and was viewed on an 18-in. color monitor at a distance of 80 cm. Each trial began with an image presented for 300 ms, followed by a randomly jittered intertrial interval between 1,500 and 1,900 ms. During that time, participants made a two-choice, forced choice decision regarding whether the images showed hands in a painful or pain-neutral situation; their responses were made with the two thumbs, with the response mappings counterbalanced between participants.

Task-related attention Our approach to determining whether or not participants were in a mind-wandering state at any given

moment was based on “experience sampling.” Considered to be a “direct” measure of mind wandering, experience sampling relies on our ability to reliably report whether or not our attention is focused on the task at hand (e.g., McKiernan, D’Angelo, Kaufman, & Binder, 2006; Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Smallwood, McSpadden, & Schooler, 2008; see Gruberger, Ben-Simon, Levkovitz, Zangen, & Hendler, 2011, for a review). In this method, participants were instructed to verbally report their attention state when prompted as either being “on task” or “mind wandering.” To facilitate this, participants were provided with descriptions of these attention states prior to testing; “on-task” states were defined as when one’s attention is firmly directed toward the task, and “mind-wandering” states were defined as when one’s attention has drifted away from the task.

We used the experience sampling method because in using the report to categorize a participant’s attentional state in the 10–15 s immediately prior to the report, the methodology has been used to demonstrate reliable and replicable differences in neurocognitive functioning between “on-task” and “mind-wandering” states (e.g., Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Franklin, Smallwood, & Schooler, 2011; Kam et al., 2011; Kirschner et al., 2012; Mason et al., 2007; McKiernan et al., 2006; Smallwood, Beach, et al., 2008; Starwarczyk et al., 2011). Specifically, this dichotomous self-report classification of attentional state has shown a systematic down-regulation of both sensory (e.g., Kam et al., 2011) and cognitive processing (e.g., Smallwood, Beach, et al., 2008) during mind-wandering versus on-task states, and furthermore, an up-regulation of activity in the brain’s DMN (e.g., Christoff et al., 2009; Kirschner et al., 2012; Starwarczyk et al., 2011)—a brain network that has been linked to mind wandering via indirect mind-wandering measures as well (e.g., Mason et al., 2007).

Accordingly, our question in the present study was whether comparable down-regulation of the processing of affectively salient stimulus also occurs when this mind-wandering self-report criterion is used to classify attentional state. Attentional reports were thus recorded at the conclusion of each trial block by the investigator, and these reports were then used to sort ERP data on the basis of on-task versus mind-wandering states. In order to maximize the variability of attention states and minimize predictability of when an attentional report would be required, the duration of each trial block was randomly varied between 30 and 90 s, or 15 to 45 trials (cf. Kam et al., 2012; Kam et al., 2011; Smallwood, Beach, et al., 2008).

Electrophysiological recording and analysis During task performance, electroencephalograms (EEGs) were recorded from 64 active electrodes mounted on a cap in accordance to the International 10–20 system using a Biosemi Active-Two amplifier system. Two additional electrodes located over medial-parietal cortex (common mode sense and driven right leg)

were used as ground electrodes. All EEG activities were amplified with a band-pass filter of 0.1–30 Hz, digitized online at a sampling rate of 256 samples per second. To ensure proper eye fixation and allow for the removal of events associated with eye movement artifacts, vertical and horizontal electrooculograms (EOGs) were also recorded—the vertical EOGs from an electrode inferior to the right eye, and the horizontal EOGs from two electrodes on the right and left outer canthus. Offline, computerized artifact rejection was used to eliminate trials during which detectable eye movements and blinks occurred. These eye artifacts were detected by identifying the minimum and maximum voltage values on all recorded EOG channels from –200 to 800 ms poststimulus for each event epoch, and then removing the trial from subsequent signal averaging if that value exceeded 200 μV , a value calibrated to capture all blinks, saccades and other eye movements exceeding approximately 1 deg of visual angle. An average of 29% of the total number of trials across participants were rejected due to these signal artifacts. The percentage of trials rejected did not significantly differ between painful and neutral images ($p = .508$), nor did they significantly differ between on-task and mind-wandering states ($p = .122$).

All ERP data analyses reported below were based on mean amplitude measures using repeated measures ANOVAs, with specific time-windows of analyses centered on the components of interest as identified in the grand-averaged waveforms. These measures were all taken relative to a –200- to 0-ms prestimulus baseline. To compare ERP responses between on-task and mind-wandering states, we only included the 6 images in our ERP averages that were presented in the 12 s preceding each attention report (on task vs. mind wandering)—a time window we have used previously with ERP data (e.g., Kam et al., 2012; Kam et al., 2011; Kam et al., 2013; Kirschner et al., 2012; Smallwood, Beach, et al., 2008) that is designed to maximize the number of events that can be included in the ERP averages while still maintaining a reasonable fidelity to the actual attentional report (i.e., as the time window increases, the signal-to-noise ratio of the ERP averages improves, but the validity of the attention report for individual events decreases). In particular, we averaged separately the painful and neutral images occurring within this time period.

Results

Behavior Participants completed an average of 48 trial blocks (approximately 1440 trials), of which 57% ended with an “on-task” report, and 43% ended with a “mind-wandering” report. The verbal report of attention states may have increased the risk of demand characteristics, thereby potentially affecting the validity of the reports. Nevertheless, the proportions of on-task versus mind-wandering reports have been consistent across studies, regardless of the methodology used, whether

participants provided a response verbally or via buttonpress (Christoff et al., 2009; Kam et al., 2011; Kirschner et al., 2012; Smallwood, Beach, et al., 2008). And, importantly, neuroimaging evidence revealed systematic differences between these attention states.

Toward confirming that the painful images were in fact perceived as painful, participants responded “painful” on 84% of the painful images presented, but only 12% of the neutral images presented. We also examined the extent to which these judgments varied as a function of whether attention was on task (painful, $M = 85.8$, $SD = 7.0$; neutral, $M = 90.1$, $SD = 9.0$) or off task (painful, $M = 84.2$, $SD = 9.5$; neutral, $M = 87.7$, $SD = 11.6$) and found that the accuracy of the ratings did not significantly differ between attention states for either image type ($p > .05$).

Electrophysiology ERP waveforms are shown in Fig. 2. Our ERP data analyses focused a priori on two portions of these waveforms—an initial positive-going response to painful images, beginning by 140 ms poststimulus at frontal/central midline electrode sites, and the subsequent P3 response, beginning about 300 ms poststimulus, consistent with Fan and Han’s (2008) “early” and “late” responses to pain, respectively. In examining our waveforms, we observed that the “late” response appeared in two parts: (1) the ascending phase of the P3 at frontal/central midline sites, in line with Fan and Han’s (2008) choice of electrode sites and time window for their cartoonized stimuli, and (2) the P3 component itself, which was maximal over central/parietal midline sites. Repeated measures analyses of variance (ANOVAs) included the factors Attention State (on task vs. mind wandering) and Image Type (painful vs. neutral), as well as Electrodes and Subjects; however, for brevity, no main effects or interactions involving electrode or subjects are reported.

The mean amplitudes and standard errors of the means for the initial response to painful images across a 140- to 180-ms poststimulus time window at electrode sites Fz, FCz, and Cz are shown in Table 1. The main effects of neither attention nor image type were significant ($p > .50$). Consistent with our hypothesis, the interaction was also not significant [$F(1, 18) = 1.56$, $p = .227$].

The mean amplitudes and standard errors of the means for both parts of the later response to painful images across the 300- to 500-ms poststimulus time window at Fz, FCz, and Cz, as well as across the 550- to 700-ms poststimulus time window at electrode sites Cz, CPz, and Pz, are also shown in Table 1. In examining the ascending phase of the later response at 300–500 ms, a significant positive-going response in this time window appeared that was specific to painful images in the on-task condition. This data pattern was confirmed by an omnibus ANOVA that revealed significant main effects of attention state [$F(1, 18) = 7.26$, $p = .015$] and image type [$F(1, 18) = 7.08$, $p = .016$], as well as a significant

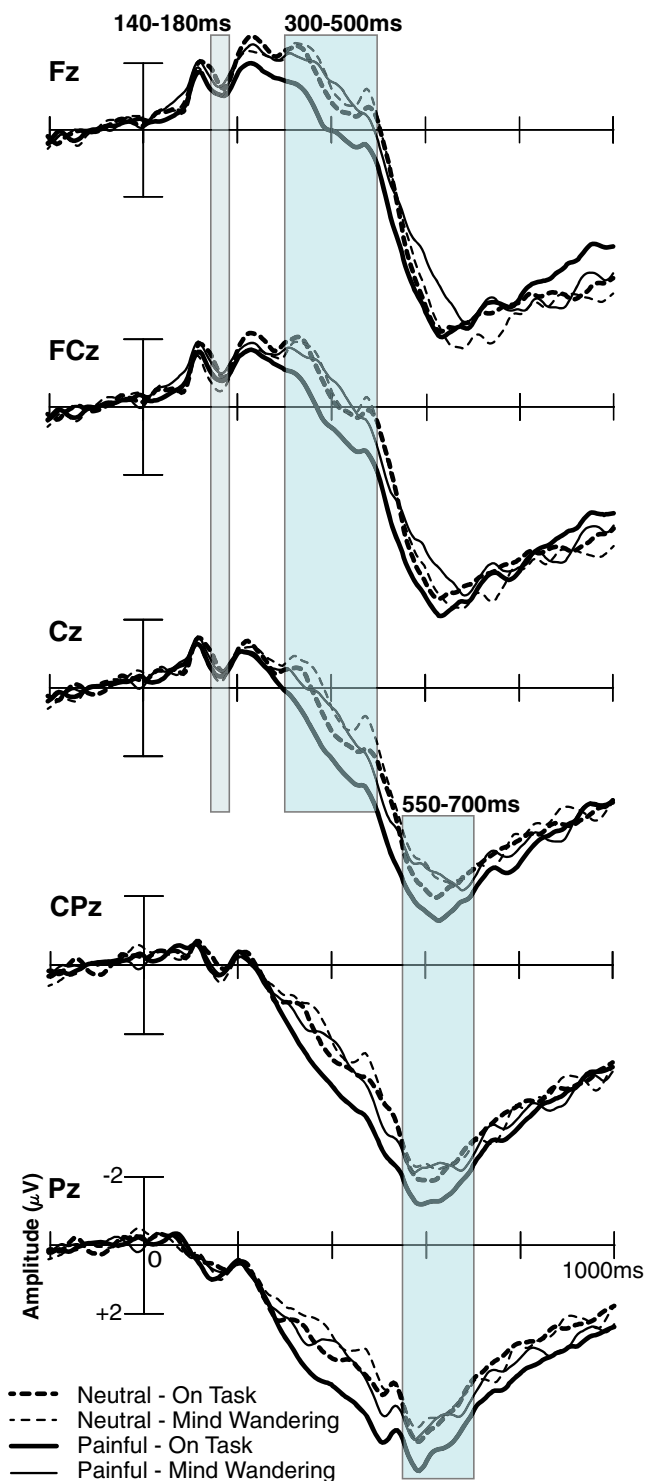


Fig. 2 Event-related potential (ERP) waveforms in response to painful and neutral images in Experiment 1. Averaged ERP waveforms for each image type are presented as a function of on-task and mind-wandering states at electrode sites Fz, FCz, Cz, CPz, and Pz. Only the ascending phase of the later component (300–500 ms) elicited by painful stimuli was significantly attenuated during periods of mind wandering relative to being on task; however, this was not observed for neutral stimuli

interaction [$F(1, 18) = 7.57, p = .013$]. Follow-up analyses demonstrated an effect of attention state for painful [$F(1, 18) =$

Table 1 Amplitudes of ERP components in response to painful and neutral images in Experiment 1

Component	Stimuli	Electrodes	Attention State	
			On Task	Mind Wandering
Early (140–180 ms)	Painful	Fz	−1.07 (0.330)	−1.45 (0.487)
		FCz	−0.86 (0.327)	−1.11 (0.507)
		Cz	−0.44 (0.296)	−0.57 (0.514)
	Neutral	Fz	−1.44 (0.483)	−1.18 (0.441)
		FCz	−1.10 (0.460)	−0.64 (0.445)
		Cz	−0.65 (0.417)	−0.43 (0.419)
Late, ascending slope (300–500 ms)	Painful	Fz	−0.28 (0.422)	−1.52 (0.536)
		FCz	0.38 (0.471)	0.77 (0.546)
		Cz	1.91 (0.485)	0.75 (0.508)
	Neutral	Fz	−1.35 (0.524)	−1.73 (0.679)
		FCz	−0.76 (0.529)	−0.90 (0.690)
		Cz	0.83 (0.526)	0.20 (0.615)
Late, P3 (550–700 ms)	Painful	Cz	6.84 (0.895)	5.84 (0.912)
		CPz	7.06 (0.863)	6.25 (0.815)
		Pz	6.39 (0.912)	5.60 (0.904)
	Neutral	Cz	6.11 (1.017)	5.65 (0.879)
		CPz	6.30 (0.975)	6.14 (0.913)
		Pz	5.54 (1.004)	5.29 (0.907)

Mean amplitudes (and standard errors of the means) are reported for the early and late components of empathetic response at electrode sites Fz, FCz, and Cz, and Cz, Cpz, and Pz, respectively, as a function of on-task and mind-wandering states

17.53, $p < .001, \eta_p^2 = .493$], but not for neutral [$F(1, 18) = 1.06, p = .317, \eta_p^2 = .056$], stimuli. In short, the initial positive-going response to painful images was significantly attenuated in the period immediately preceding mind-wandering versus on-task attentional reports.

We performed the same analysis on the P3 component of the late response across a 550- to 700-ms poststimulus time window. As in the ascending phase of this late response to painful images, an enhanced positive deflection, resembling a late-latency P3, emerged in this time window that was specific to painful images in the on-task condition. However, neither the main effects of attention state [$F(1, 18) = 3.23, p = .089$] and image type [$F(1, 18) = 2.58, p = .126$] nor the interaction was significant [$F(1, 18) = 3.17, p = .092$]. This indicates that, although we observed a trend toward reduced attention to painful images in this time window during mind wandering, the effect did not reach significance.

Discussion

The results from Experiment 1 thus indicated that only the later response to others' pain, as identified by Fan and Han (2008), is labile to attenuation during periods of mind wandering. That the early response did not show any attentional

modulations suggests that more automatic processing of empathy for pain occurs, regardless of whether attention was on or off task. Importantly, the attentional effects in the ascending phase of the later response was measured via modulations in the ERPs elicited by the painful but not the neutral visual images, indicating that it was not simply due to general sensory attenuation present during mind-wandering states (e.g., Kam et al., 2011). Although we observed only a trend in the effect of mind wandering on the P3 component of the later response to the painful images, the overall data pattern supports the hypothesis that mind wandering can, in fact, modulate at least some aspects of affectively salient stimulus processing. Furthermore, that the accuracy rates of the painful judgments did not differ significantly between the two attentional states suggests that this neural response reflects the processing of images recognized as painful versus neutral, instead of simply the recognition of an ambiguous situation.

This finding, however, also raised an important question: To what extent does mind wandering actually affect our subjective perception of other people's pain? In particular, neither the ERP nor behavioral data from Experiment 1 provided much insight into the depth or range of the subjective affective experience of the observed pain in others, and specifically, how mind wandering may have altered it. As such, the goal of our second experiment was to examine whether the effect of mind wandering extends to self-reported measures of perceived pain in others. Specifically, in Experiment 2, participants were asked to rate the painfulness of hand images on a 5-point Likert scale while we again asked for task-related attentional reports at trial block completion. If mind wandering can in fact modulate our sensitivity to pain in others, it predicted that pain ratings should selectively decrease for painful images immediately preceding "mind-wandering" versus "on-task" attention reports.

Experiment 2

Method

Participants A group of 37 participants (25 females, 12 males; $M = 22.3$ years old, $SD = 3.31$) completed the experiment in exchange for \$5. These participants were newly recruited and did not participate in our first experiment. All were all right handed, had normal or corrected-to-normal vision, and gave written informed consent. All procedures and protocols of this study were approved by the UBC Behavioral Review Ethics Board.

Stimuli and paradigm The visual stimuli were similar to those used in Experiment 1, with the following exceptions: The total of 400 images (200 of hands in painful positions, 200 of hands in comparable but neutral conditions) were actual photographs rather than cartoon-ized images, and each image measured

13.1×9.6 cm (see Fig. 1b). We created this larger image set for two reasons. First, we wanted to provide the participants with a variety of images to rate, rather than having them continuously rate the same 40 images used in Experiment 1. Second, given that Fan and Han (2008) reported a larger affect-related effect using more naturalistic versus cartoon-ized images, and that this effect influenced the ratings of perceived pain, we decided to use images that would capitalize on these effects.

Each trial began with an image presented for 400 ms, followed by a rating screen for 2,400 ms that prompted participants to rate how painful the image looked, on a scale from 1 (*not painful*) to 5 (*very painful*). The intertrial interval was randomly varied from 150 to 250 ms. As in Experiment 1, participants were asked to report their attention state at the end of each trial block as either being "on task" or "mind wandering," and given definitions of these states prior to testing. Each testing session lasted approximately 30 min, and each of the 400 images was presented only once during the session. The session itself was broken down into 20 blocks, with each block varying in duration from 45 to 75 s (i.e., 15 and 25 trials).

Results

To ensure that we had reliable ratings estimates in each condition for each participant, we limited the data analysis to only those participants who provided three or more reports apiece of "mind wandering" and "on task," which in the minimum case would correspond to approximately 20 ratings in the given attentional condition. This criterion excluded 14 participants, reducing the actual data analyses to a final sample of 23 participants. (14 females, nine males; $M = 22.4$ years old, $SD = 3.41$). Averaged across these participants, 65% of the trial blocks ended with an "on-task" report, and 35% ended with a "mind-wandering" report ($SD = 3.05$). On the basis of the assumptions that our neutral stimuli were indeed perceived as nonpainful and that they would predominantly be rated as "not painful," we predicted a floor effect of the neutral stimuli a priori, from our results in Experiment 1. As such, although we report both omnibus ANOVAs showing interactions and follow-up analyses, our interpretation will primarily focus on the painful images only.

As in Experiment 1, we averaged the ratings separately for the painful and neutral stimuli 12 s preceding attentional reports, which are shown at the bottom of Table 2. We observed a reduction in ratings during mind-wandering states for the painful but not for the neutral images. Whereas the main effect of stimulus type was significant [$F(1, 22) = F(1, 22) = 82.66$, $p < .001$], the main effect of attention state [$F(1, 22) = 3.15$, $p = .090$] did not reach significance. Furthermore, the interaction was only near significant [$F(1, 22) = 3.57$, $p = .072$]. Nevertheless, planned *t*tests indicated that behavioral

Table 2 Behavioral ratings of painful and neutral images in Experiment 2

Time Window	Stimuli	Attention State	
		On Task	Mind Wandering
9 s	Painful	3.32 (0.151)	3.01 (0.174)
	Neutral	1.58 (0.121)	1.57 (0.141)
12 s	Painful	3.29 (0.144)	3.05 (0.167)
	Neutral	1.60 (0.122)	1.59 (0.144)

Mean behavioral ratings (and standard errors of the means) of each image type are reported as a function of attentional state. The ratings were averaged across 9 s and 12 s immediately preceding an attention report. Behavioral ratings ranged from 1 (*not painful*) to 5 (*extremely painful*)

ratings decreased significantly during mind wandering for painful images [$t(22) = 2.17, p = .041, d = .46$] but not for neutral images [$t(22) = 0.14, p = .889, d = .03$].

Although our initial behavioral results suggest that mind wandering reduces sensitivity to others' pain, we found only a trend toward an interaction between attention and stimulus type, despite a significant attention effect for painful images shown in the 12 s preceding attentional reports. We then wanted to examine how the effect of mind wandering on ratings might change as data were averaged across a decreasing distance in time from the attentional self-report at trial block completion. Although we initially used a 12-s analysis time window in order to maintain consistency with Experiment 1, we were no longer constrained by the need to compute ERP waveforms, which required large numbers of events for averaging. As such, in order to maximize the validity of the attention reports for the images analyzed, we restricted the analysis of ratings to images presented in the 9 s preceding attention reports, shown at the top of Table 2. This reduction in time (i.e., 3 s) corresponded to one less trial/rating to be included in the averaged data. We therefore repeated our initial analyses using ratings averaged 9 s preceding the attentional reports and found significant main effects of attention state [$F(1, 22) = 4.13, p = .054$] and stimulus type [$F(1, 22) = 83.87, p < .001$], as well as a significant interaction [$F(1, 22) = 6.03, p = .022$]. Follow-up *t*tests confirmed a reduction in ratings during mind wandering for painful images [$t(22) = 2.53, p = .019, d = .54$] but not for neutral images [$t(22) = 0.18, p = .862, d = .04$].

Control analysis As an additional control issue, we wanted to consider task fatigue over time as a possible confound in our data. In particular, with task fatigue undoubtedly growing over time, might participants have been more inclined toward mind-wandering states later during testing than earlier, thereby confounding mind-wandering with habituation or general fatigue states (and, by extension, biasing the on-task data toward the outset of the testing session, prior to the onset of task fatigue)? To examine this possibility, we broke down the

percentages of “on-task” reports by quartiles across the testing session, which were 84%, 75%, 53%, and 46%, respectively. This indicated that mind-wandering reports did indeed increase over time, a finding consistent with increased task fatigue over the testing session. Nevertheless, given the relatively equal distributions of subjective reports in the third and fourth quartiles of data collection, we did a subanalysis of the pain ratings in the second half of this experiment and found a significant decrease for painful images during mind wandering (on-task rating = 3.15, mind-wandering rating = 2.68; $p < .001$), but not for neutral images (on task = 1.41, mind wandering = 1.37; $p > .05$). This control analysis replicated our main finding, but suggested that although fatigue effects may indeed have been present in our data, they could not alone account for the effects of mind wandering that we reported.

Discussion

These results were thus consistent with the hypothesis that mind wandering significantly attenuates sensitivity to the perceived pain of others. We observed that the average ratings for neutral images were slightly above 1 (i.e., *not painful*; $M = 1.65, SD = 0.65$), confirming our assumption and validating the neutral stimuli. This suggests that some neutral photos were given a rating higher than 1, which is understandable, because the position of the hand in some of these photos may have looked slightly uncomfortable to some participants, even though they may have been significantly less painful than the “painful” images. Importantly, the fact that we found variability in this rating, and specifically that not all neutral images were rated consistently as 1 (*not painful*) during the mind-wandering state, indicates that participants were actually performing the task; that is, if they were just mindlessly rating the images, they would have just given the same response to all of the neutral images, as well as identical, higher pain ratings to all of the painful images. Given these findings, it thus suggests that mind wandering does in fact decrease our sensitivity to the observed pain or discomfort of others. We will discuss the broader implications of our findings below.

General discussion

In the present study, we examined whether mind wandering modulates the processing of affectively salient stimuli. Toward addressing this issue, in Experiment 1 we found that the late ERP response to painful images was selectively attenuated immediately preceding subjective reports of mind wandering, relative to when attention was focused “on task.” In Experiment 2, we found that the subjective ratings for how painful images appeared were also reduced in the moments immediately preceding reports of mind wandering. Taken

together, our findings support the proposal that the processing of affectively salient stimuli associated with sensitivity to other people's pain is subject to direct modulation by transient fluctuations in task-related attention states. In light of these data and the conclusions, several important questions and issues follow.

First, if we become less sensitive to the physical discomfort of others when we mind wander, why is that? One explanation is based on the executive function model of mind wandering (Smallwood & Schooler, 2006), whereby mind wandering decouples executive resources from the external environment and directs them internally in order to facilitate inner trains of thought. If resources are allocated elsewhere, then the photos may not be fully processed. An incomplete representation of the situation in the photo may thereby reduce its perceived intensity, an interpretation that is consistent with the P3-level effect of mind wandering that we reported for the neutral images. Nevertheless, this model would predict a similar attenuation in processing of both painful and neutral images. That only the response to painful stimuli was reduced during mind-wandering states suggests that other mechanisms may have been involved.

Another possibility is that the result might be related to the impact of disembodied mental states on neurocognitive functioning. For example, in a study of autobiographical memory, Eich, Nelson, Leghari, and Handy (2009) found that when we recall past personal events from a third-person visual perspective, the number of physical sensations ascribed to the memory decreases (e.g., noting butterflies in one's stomach or sweat on one's palms), relative to when recalling the same memory from a first-person visual perspective. Moreover, this effect was associated with a significant decrease in activity in the insula, a cortical region closely associated with visceral, physiological monitoring of one's bodily state. Given such evidence, mind wandering may impact physical monitoring of the body in a manner akin to a disembodied, third-person perspective during memory recall. Not only is this possibility consistent with our findings from Experiment 1 showing a specific attenuation in the later response to pain, but it aligns with the notion that mind wandering is akin to a form of mental time travel, in which we mentally disengage from the physical here-and-now in order to reminisce about the past or fantasize about the future (e.g., Schooler et al., 2011; Smallwood et al., 2011). In other words, the evidence converges on mind wandering as a cognitively disembodied state.

Second, our findings also demonstrate a critical expansion in the scope of neurocognitive processes that are susceptible to modulation by mind wandering. Specifically, using impoverished, affectively neutral stimuli, prior studies have shown that mind wandering reduces the sensory and cognitive processing of both visual and auditory stimuli (Kam et al., 2011; O'Connell et al., 2009; Smallwood, Beach, et al., 2008). In our data, however, we found that the responses to observing pain in others were also attenuated when participants mind wandered,

as measured via both ERPs and subjective ratings of pain. This suggests that the impact of mind wandering is not restricted to the sensory/perceptual and cognitive processing of affectively neutral stimuli, but extends to the processing of stimuli with some measure of affective saliency as well. Consistent with this result, mind wandering has previously been associated with increased negative moods (e.g., Killingsworth & Gilbert, 2010; Smallwood, Fitzgerald, Miles, & Phillips, 2009). As such, our data indicate that the effects of mind wandering extend beyond mood per se. Rather, there appears to be a tight link between task-related attention and the intensity of our affect-related responses to external stimuli.

A third, related issue concerns the absence of decoupling from the neutral images during mind-wandering episodes. That is, whereas past studies have shown an attenuation of the P3 to affectively neutral stimuli in mind-wandering states (Barron et al., 2011; Smallwood, Beach, et al., 2008), we did not observe the same P3 attenuation to our neutral images. What might explain this difference? For one thing, the nature of the stimuli used in past studies (i.e., numbers and geometric shapes) was notably different from that in the present study (i.e., naturalistic photos), even though all of these stimuli may all be considered neutral. Furthermore, the lack of P3 modulation in neutral images in this study was in fact consistent with our previous findings of an absence of P3 attenuation to the target when probes were presented in the upper and lower visual fields (Kam et al., 2011). Both findings suggest that mind-wandering-related P3 modulations appear to decrease as the stimulus set or task becomes more complicated or engaging, at least for more affectively neutral stimuli. Critically, that we observed a trend for a reduction in the P3 to painful images in the present study validates the subjective reports of attentional states.

The fourth issue pertains to the somatosensory response to perceived pain. In particular, previous studies have shown that observing others in pain modulates the laser-evoked (Valeriani, Betti, Le Pera, de Armas, Miliucii, Restuccia, Aglioti, 2008) and somatosensory-evoked (Bufalari, Aprile, Avenanti, di Russo, & Aglioti, 2007) potentials over the somatosensory cortex. Similar findings have been reported in studies using magnetoencephalography (Betti, Zappasodi, Rossini, Aglioti, & Tecchio, 2009) as well as transcranial magnetic stimulation (Avenanti, Bueti, Galati, & Aglioti, 2005). Although these results converge on the notion that the mere observation of others' pain impacts on sensory-related somatic neural processing, the paradigms and methodology used elicited a neural response that was notably different from ours. An important difference is that many of these studies induced acute pain in their participants and measured their response to the induced pain. In our study, however, no such stimulation was induced in our participants, and therefore any sensory response elicited in our experiments would be strictly restricted to the visual domain. As such, although we would not expect to observe any

somatosensory response in our data, it would be interesting for future research to examine whether the effects of mind wandering would extend to attenuated somatosensory responses to direct stimulation.

As a final point, the ERP-based responses to pain have been dissociated into two components, as previously noted—an initial, automatic simulation of the pain, followed by a more evaluative analysis of the pain and its context (Decety & Lamm, 2006; Fan & Han, 2008; Gu & Han, 2007). Within this model, we found an effect of mind wandering only on the later, evaluative response to observed pain. This result is consistent with those of Fan and Han, who found that the later empathy response was subject to modulation by top-down attentional influences, but the earlier sensory-related response was not. In Fan and Han's study, attention was manipulated by invoking a dual-task situation, such that some proportion of attentional resources were deliberately directed away from processing the affective images. In the present study, we were studying a distinct form of attention, and in particular, natural, transient fluctuations in whether one is paying attention to the task at hand (e.g., Dosenbach et al., 2008). The collective evidence thus indicates that only the later stages of empathetic responses to pain are susceptible to varying forms of attentional modulation.

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References

- Armony, J. L., & Dolan, R. J. (2002). Modulation of spatial attention by fear-conditioned stimuli: An event-related fMRI study. *Neuropsychologia*, *40*, 817–826.
- Avenanti, A., Buetti, D., Galati, G., & Aglioti, S. M. (2005). Transcranial magnetic stimulation highlights the sensorimotor side of empathy for pain. *Nature Neuroscience*, *8*, 955–960.
- Barron, E., Riby, L., Greer, J., & Smallwood, J. (2011). Absorbed in thought: The effect of mind wandering of the processing of relevant and irrelevant events. *Psychological Science*, *22*, 596–601.
- Betti, V., Zappasodi, F., Rossini, P. M., Aglioti, S. M., & Tecchio, F. (2009). Synchronous with your feelings: Sensorimotor (gamma) band and empathy for pain. *Journal of Neuroscience*, *29*, 12384–12392.
- Botvinick, M., Jha, A. P., Bylsma, L. M., Fabian, S. A., Solomon, P. E., & Prkachin, K. M. (2005). Viewing facial expressions of pain engages cortical areas involved in the direct experience of pain. *NeuroImage*, *25*, 312–319.
- Braboszcz, C., & Delorme, A. (2011). Lost in thoughts: Neural markers of low alertness during mind wandering. *NeuroImage*, *54*, 3040–3047.
- Bufalari, I., Aprile, T., Avenanti, A., di Russo, F., & Aglioti, S. M. (2007). Empathy for pain and touch in the human somatosensory cortex. *Cerebral Cortex*, *17*, 2553–2561.
- Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions. *Proceedings of the National Academy of Sciences*, *106*, 8719–8724.
- Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*, 215–229.
- Decety, J., & Lamm, C. (2006). Human empathy through the lens of social neuroscience. *The Scientific World Journal*, *6*, 1146–1163.
- Delplanque, S., Lavoie, M. E., Hot, P., Silvert, L., & Sequeira, H. (2004). Modulation of cognitive processing by emotional valence studied through event-related potentials in humans. *Neuroscience Letters*, *356*, 1–4.
- de Vignemont, F., & Singer, T. (2006). The empathetic brain—When and why. *Trends in Cognitive Sciences*, *10*, 435–441.
- Dosenbach, N. U. F., Fair, D. A., Cohen, A. L., Schlaggar, B. L., & Petersen, S. E. (2008). A dual-networks architecture of top-down control. *Trends in Cognitive Sciences*, *12*, 99–105. doi:10.1016/j.tics.2008.01.001
- Eich, E., Nelson, A. L., Leghari, M. A., & Handy, T. C. (2009). Neural systems mediating field and observer memories. *Neuropsychologia*, *47*, 2239–2251.
- Fan, Y., & Han, S. (2008). Temporal dynamic of neural mechanisms involved in empathy for pain: An event-related brain potential study. *Neuropsychologia*, *46*, 160–173.
- Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology*, *46*, 521–530. doi:10.1111/j.1469-8986.2009.00796.x
- Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., Van Essen, D. C., & Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences*, *102*, 9673–9678.
- Frank, D. W., & Sabatinelli, D. (2012). Stimulus-driven reorienting in the ventral frontoparietal attention network: The role of emotional content. *Frontiers in Human Neuroscience*, *6*, 116. doi:10.3389/fnhum.2012.00116
- Franklin, M. S., Smallwood, J., & Schooler, J. W. (2011). Catching the mind in flight: Using behavioral indices to detect mindless reading in real time. *Psychonomic Bulletin & Review*, *18*, 992–997. doi:10.3758/s13423-011-0109-6
- Goubert, L., Craig, K. D., Vervoort, T., Morley, S., Sullivan, M. J. L., de C Williams, A. C., & Crombez, G. (2005). Facing others in pain: The effects of empathy. *Pain*, *118*, 285–288. doi:10.1016/j.pain.2005.10.025
- Gruberger, M., Ben-Simon, E., Levkovitz, Y., Zangen, A., & Hendler, T. (2011). Towards a neuroscience of mind wandering. *Frontiers in Human Neuroscience*, *5*, 56.
- Gu, X., & Han, S. (2007). Attention and reality constraints on the neural processes of empathy for pain. *NeuroImage*, *36*, 256–267.
- Gusnard, D. A., & Raichle, M. E. (2001). Searching for a baseline: Functional imaging and the resting human brain. *Nature Reviews*, *2*, 685–694.
- Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage*, *24*, 771–779.
- 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. doi: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. doi: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. doi:10.1162/jocn_a_00375
- Kensinger, E. A., & Schacter, D. L. (2006). Amygdala activity is associated with the successful encoding of item, but not source, information for positive and negative stimuli. *Journal of Neuroscience*, *26*, 2564–2570. doi:10.1523/JNEUROSCI.5241-05.2006

- Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science*, *330*, 932. doi:10.1126/science.1192439
- 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. doi:10.3389/fnhum.2012.00139
- Li, W., & Han, S. H. (2010). Perspective taking modulates event-related potentials to perceived pain. *Neuroscience Letters*, *469*, 328–332.
- 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.
- McKiernan, K. A., D'Angelo, B. R., Kaufman, J. N., & Binder, J. R. (2006). Interrupting the "stream of consciousness": An fMRI investigation. *NeuroImage*, *29*, 1185–1191.
- Morris, J. S., Friston, K. J., Büchel, C., Frith, C. D., Young, A. W., Calder, A. J., & Dolan, R. J. (1998). A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain*, *121*, 47–57.
- 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 predicts errors up to 20 s before they occur. *Journal of Neuroscience*, *29*, 8604–8611. doi:10.1523/JNEUROSCI.5967-08.2009
- Phelps, E. A., Ling, S., & Carrasco, M. (2006). Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science*, *17*, 292–299.
- Rimé, B., Herbette, G., & Corsini, S. (2004). The social sharing of emotion: Illusory and real benefits of talking about emotional experiences. In I. Nyklicek, L. R. Temoshok, & J. J. M. Vingerhoets (Eds.), *Emotional expression and health*. London: Harwood Academic Press.
- 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.
- Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. F., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science*, *303*, 1157–1162. doi:10.1126/science.1093535
- Smallwood, J., Baracaia, S. F., Lowe, M., & Obonsawin, M. (2003). Task unrelated thought whilst encoding information. *Conscious and Cognition*, *12*, 452–484.
- Smallwood, J., Beach, E., Schooler, J. W., & Handy, T. C. (2008a). 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. doi:10.1016/j.brainres.2011.03.072
- Smallwood, J., Fitzgerald, A., Miles, L. K., & Phillips, L. H. (2009). Shifting moods, wandering minds: Negative moods lead the mind to wander. *Emotion*, *9*, 271–276.
- Smallwood, J., McSpadden, M., & Schooler, J. W. (2008b). When attention matters: The curious incident of the wandering mind. *Memory & Cognition*, *36*, 1144–1150. doi:10.3758/MC.36.6.1144
- Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*, 946–958. doi: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. *Conscious and Cognition*, *20*, 1120–1126.
- Starwarczyk, D., Majerus, S., Maquet, P., & D'Argembeau, A. (2011). Neural correlates of ongoing conscious experience: Both task-unrelatedness and stimulus-independence are related to default network activity. *PLoS One*, *6*, e16997. doi:10.1371/journal.pone.0016997
- Valeriani, M., Betti, V., Le Pera, D., de Armas, L., Miliucii, R., Restuccia, D., & Aglioti, S. M. (2008). Seeing the pain of others while being in pain: A laser-evoked potentials study. *NeuroImage*, *40*, 1419–1428.