Connecting Two Opposing Constructs: Mind Wandering and Mindfulness

by

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Mind wandering is a universal phenomenon that accounts for almost half of our everyday experience (Killingsworth & Gilbert, 2010). Although there are demonstrated benefits to mind wandering, it comes at quite a cost, especially when we need to concentrate on current tasks (Mooneyham & Schooler, 2013). Hence, there is a great demand to identify strategies that reduce mind wandering and ameliorate its disruptive impact on task performance. Mindfulness, a construct that is inherently opposite to mind wandering, has recently emerged as a promising antidote (Schooler et al., 2014). However, there has been very limited research examining the direct effects of mindfulness on mind wandering. Furthermore, research paradigms on mind wandering might also provide a unique channel for us to further understand the underlying working mechanism of mindfulness as an emotion regulation strategy. To answer these questions, we conducted two studies in which both mind wandering and mindfulness were examined.

Study 1 explored the operationalization of mind wandering and the relationship between mind wandering and motivation to attend to thoughts and to perform well on the task at hand during a sustained attention task. Results support the use of both task-relatedness and stimulus-dependency for classifying episodes of mind wandering. Analysis revealed a significant mediational model in which the relationship between performance motivation and overall task performance is mediated by the proportion of on-task thoughts when controlling for positive affect. Study 2 examined the effects of a 10-minute mindfulness meditation among highly anxious individuals using the same research paradigm. When compared to a control condition, meditation shifted the focus of attention from internal information towards external stimuli and prevented task performance from declining during episodes of distractions. Meditation also demonstrated additional benefits in emotion regulation and provided some insight into its underlying mechanism. Implications of these findings and the relationship between mind wandering and mindfulness are discussed.

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Introduction

Mind wandering is a universal experience that occurs regularly in everyday life. In fact, some research estimates that one third to one half of our thoughts in a given day represent mind wandering. In studies using experience-sampling methods, participants received random thought probes multiple times a day and were asked to report their real-time conscious experiences. Approximately 24-47% of all reports were classified as mind wandering (Kane et al., 2007; Killingsworth & Gilbert, 2010; McVay, Kane, & Kwapil, 2009; Song & Wang, 2012). Furthermore, one study showed that at least 30% of mind wandering was sampled during almost every activity (Killingsworth & Gilbert, 2010). When studied in a laboratory setting, the frequency of mind wandering is estimated at 22-31% (Franklin et al., 2013; Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011).

There has been an increasing interest in the phenomenology of mind wandering. Not surprisingly, most mind wandering episodes focus on personal concerns (Kane et al., 2007; McVay et al., 2009; Smallwood, O'Connor, Sudberry, Haskell, & Ballantyne, 2004). This is consistent with Klinger's (1971) current concerns theory which stipulates that during less important tasks one's personal goals or concerns can be easily cued by the environment. Additionally, mind wandering seems to endorse a particular temporal orientation. Approximately 41% of mind wandering episodes are related to future events (Song & Wang, 2012), occurring 59 times a day on average (D'Argembeau, Renaud, & Van der Linden, 2011). Laboratory studies revealed similar results—around 43-48% of mind wandering is future oriented (Baird, Smallwood, & Schooler, 2011; Stawarczyk et al., 2013). Individuals were more likely to wander prospectively when they had less interest or experience with the current task (Smallwood, Nind, & O'Connor, 2009) or when they reflected on themselves (Smallwood et al., 2011). In terms of its content, future-oriented mind wandering is usually self-relevant, goal-directed, concrete, structured, and intentional (Baird et al., 2011;

Stawarczyk et al., 2013) and is primarily carried out for planning and decision-making (D'Argembeau et al., 2011).

Costs and benefits of mind wandering

Not surprisingly, such an incessant and intrusive phenomenon comes with a cost. Mind wandering has been found to disrupt performance on a wide range of activities (for a review see Mooneyham & Schooler, 2013). When participants were asked to read a text, mind wandering was associated with increased speed (Franklin, Smallwood, & Schooler, 2011) but worse performance on subsequent comprehension tests (Franklin, Mooneyham, Baird, & Schooler, 2014; Smallwood, McSpadden, & Schooler, 2008) and superficial processing of perceptual information (Smilek, Carriere, & Cheyne, 2010).

To examine the impact of mind wandering on sustained attention, most studies have used the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). The SART requires participants to respond to frequent non-target stimuli while withholding their response to rare target stimuli. Episodes of mind wandering were associated with lower response accuracy and higher response variance (Cheyne, Solman, Carriere, & Smilek, 2009; Stawarczyk et al., 2013; Stawarczyk, Majerus, Maj, et al., 2011). Such results were replicated when using a different task, the Metronome Response Task (MRT; Seli, Cheyne, & Smilek, 2013). In the MRT, participants are asked to respond synchronously to a constant series of tones. Greater response variance was associated with episodes of mind wandering (Seli, Carriere, Levene, & Smilek, 2013) and higher magnitude of mind wandering (Seli et al., 2014).

Mind wandering not only interferes with reading and attention tasks, but also can have a negative impact on mood. A large-scale experience-sampling study indicated that people are less happy during mind wandering, regardless of their current activity

(Killingsworth & Gilbert, 2010). When controlling for self-reported interest, mind wandering still predicted negative mood (Franklin et al., 2013). On the other hand, prior negative mood also predicted mind wandering (Poerio, Totterdell, & Miles, 2013). The frequency of mind wandering was higher among dysphoric participants (Smallwood, O'Connor, Sudbery, & Obonsawin, 2007). Mind wandering among depressed individuals was primarily past-oriented (Smallwood & O'Connor, 2011) and predicted negative thinking (Marchetti, Koster, & De Raedt, 2012). Furthermore, after negative mood induction, healthy participants reported more mind wandering and performed worse on the SART (Smallwood, Fitzgerald, Miles, & Phillips, 2009; Vinski & Watter, 2013).

Given the pervasiveness of mind wandering and its well-documented costs, how is it that we continue to function well? In fact, preliminary research does suggest two benefits to mind wandering—autobiographical planning and creative thinking (Schooler et al., 2014). As reviewed earlier, mind wandering is predominantly future-oriented. Under undemanding conditions, such a prospective bias allows us to build connections among our past, present, and future identities (Smallwood & Andrews-Hanna, 2013). It facilitates management of long-term goals, as mind wandering was associated with a tendency to resist an immediate reward in favour of a larger but later reward (Smallwood, Ruby, & Singer, 2013). Mind wandering also improves creativity. It was found that participants with higher levels of mind wandering were more creative when solving problems that were previously encountered (Baird et al., 2012).

Theoretical models for mind wandering

To account for the costs and benefits of mind wandering, two major theories have been proposed: (1) the attentional resource theory (Smallwood & Schooler, 2006), and (2) the executive control failure theory (McVay & Kane, 2010). The attentional resource theory assumed that mind wandering consumes executive resources and therefore predicted that: (1) mind wandering and controlled processing compete for the same limited executive resources; (2) mind wandering will impair task performance when the primary task requires controlled processing; and (3) mind wandering is so automatic that it often lacks deliberate or explicit intent (Smallwood & Schooler, 2006).

In contrast, the executive control failure theory assumed that mind wandering does not consume executive resources, but reflects failures of executive control (McVay & Kane, 2010). It predicted that: (1) executive control can prevent current concerns from entering our conscious experiences, i.e., mind wandering, and (2) individual variation in executive control determines the occurrence of mind wandering (McVay & Kane, 2010). Additionally, the executive control failure theory incorporated Watkins' (2008) control theory and stipulated that: (1) an abstract level of construal of personal goals will lead to more mind wandering, and (2) those with higher executive control are more likely to construal at a concrete level. Despite their differences, both theories agreed that mind wandering entails a superficial representation of the external environment and a shift of attention from the primary task to personal goals, which could impair task performance (McVay & Kane, 2012; Smallwood, 2013).

This construct of mind wandering has also been validated by neuroimaging studies (for a review see Gruberger, Ben-Simon, Levkovitz, Zangen, & Hendler, 2011). There seems to be a close link between the "default mode network" (DMN; Raichle et al., 2001) and mind wandering. The DMN refers to a network of brain regions in the medial prefrontal and parietal areas that is highly activated at rest but less activated during cognitively demanding tasks (Gusnard, Raichle, & Raichle, 2001). DMN activity has been proposed as a neural correlate of mind wandering (Gruberger et al., 2011). Studies demonstrated that the DMN was highly activated during mind wandering (Christoff, Gordon, Smallwood, Smith, &

Schooler, 2009; Mason et al., 2007b). Specifically, DMN activation was associated with both subjective reports and behavioural measures of mind wandering (Christoff et al., 2009). The magnitude of DMN activity was positively correlated with self-reported propensity to mind wander (Mason et al., 2007b). In addition, researchers identified a negative functional connectivity between the DMN and the primary sensory cortices, suggesting that mind wandering indeed represents a decoupling from the external sensory environment (Christoff, 2012). Similarly, in a study that examined event-related potentials (ERPs), mind wandering was associated with a reduction in cognitive analysis of the external environment (Smallwood, Beach, Schooler, & Handy, 2008).

Operationalization of mind wandering

After more than a decade of investigation, we now have a much better understanding of the phenomenology, associated costs and benefits, and the underlying neural basis of mind wandering. However, when we take a closer look at the very first step of this scientific exploration—the operationalization of mind wandering—there is surprisingly little consistency in what kinds of thoughts are considered to actually constitute "mind wandering". Is any thought not immediately relevant to the task at hand mind wandering? Is mind wandering something of which we are aware? Can mind wandering intermingle with task-related thoughts? Most studies have used a dichotomous classification system such that a thought is either "on-task" or "mind wandering" (Kane et al., 2007; McVay & Kane, 2009; McVay et al., 2009). Other studies extended this dichotomous classification system into three categories: "tuned out" (mind wandering with awareness), "zoned out" (mind wandering without awareness), and "on-task" (Christoff et al., 2009; Seli, Cheyne, et al., 2013; Smallwood, Beach, et al., 2008; Smallwood, McSpadden, et al., 2008). Alternatively, some studies measured the degree of mind wandering using a 5-point Likert scale, i.e., from completely on-task to completely mind wandering (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Mrazek, Smallwood, & Schooler, 2012; Seli et al., 2014).

Even determining what constitutes "off-task" thoughts is more complex that it might seem at first blush. Some researchers have operationalized mind wandering as simply "task-unrelated thought", i.e., unrelated to the current task (Christoff, 2012; Kane & McVay, 2012; Levinson, Smallwood, & Davidson, 2012; Smallwood, O'Connor, et al., 2004). However, other researchers have defined "on-task" thoughts as being stimulus dependent and mind wandering as "stimulus-independent thought", i.e., decoupled from the external environment (Mason et al., 2007a, 2007b; Teasdale et al., 1995; Teasdale, Proctor, Lloyd, & Baddeley, 1993). However, task-relatedness and stimulus-dependency are not interchangeable and should be treated as independent dimensions when classifying mind wandering (Klinger, 2009). For example, a task-unrelated thought may be stimulus-dependent (e.g. thinking about a noise one is hearing); whereas a stimulus-independent thought can be task-related (e.g. evaluating the current task one is performing).

In an effort to replace the problematic dichotomous approach, a two-dimensional classification system was recently proposed (Stawarczyk, Majerus, Maj, et al., 2011). Based on task-relatedness and stimulus-dependency, it divided all conscious experiences into four categories: (1) task-related and stimulus-dependent (i.e., on-task); (2) task-related and stimulus-independent (i.e., task-related interferences, TRIs); (3) task-unrelated and stimulus-dependent (i.e., external distractions, EDs); and (4) task-unrelated and stimulus-independent (i.e., mind wandering). Under this new system, researchers found that mind wandering was associated with the highest DMN activation (Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011) and impaired task performance to the same extent as EDs but not TRIs (Stawarczyk, Majerus, Maj, et al., 2011). However, to our knowledge, no published study so far has directly compared these two classification systems and it still remains a question if task relatedness and stimulus dependency are indeed two separate dimensions when defining mind wandering.

Mind wandering and motivation

Other than the operationalization of mind wandering, there is a more practical question that needs to be answered—what are the factors that are associated with mind wandering? If these factors indeed relate to mind wandering, they might provide important implications in terms of how to manage mind wandering when we need to concentrate. Over the last decade, motivation has emerged a factor that is closely linked to conscious experiences and task performance. It was observed that additive incentives led to an increased pupil diameter (indicating more mental effort) and predicted better performance on a reading span task (Heitz, Schrock, Payne, & Engle, 2008). In another study, self-reported levels of motivation to remain on-task predicted better performance during an intelligence test (Unsworth & McMillan, 2014). More importantly, it was observed that lower performance motivation predicted a greater propensity to engage in off-task thoughts, which then led to poorer performance on a reading comprehension test (Unsworth & McMillan, 2013).

However, research on the relationship between mind wandering and motivation is still preliminary. Almost all studies examined one type of motivation exclusively—motivation to perform well on the current task. It is equally possible that individuals might feel motivated to engage in some of their internal thoughts and avoid others. These two types of motivation, i.e., one's motivation to approach and to avoid their conscious experiences, could also affect their frequency of mind wandering and task performance. For example, if one is motivated to think about an upcoming stressful event or to avoid thinking about a recent unpleasant experience more so than to perform well on the task, that person might engage in more mind wandering and subsequently perform poorer on the current task. When an individual is motivated to both approach and to avoid the same thought, e.g. worrying about finances but at the same time trying to rein in anxiety, internal attention might flit around between thoughts about finances, worry about being anxious, and efforts to remain on-task (i.e., as a means of distraction from the worry). It could be that the latter might result in the greatest mind wandering and performance deficits. Hence, how we prioritize goals (i.e., the degree of motivation to perform well on the task and to approach/avoid certain goals) is likely to guide our internal focus of attention and affect our conscious experiences.

Mindfulness as an antidote to mind wandering

In the process of identifying an antidote for mind wandering, researchers intuitively focused their attention on its opposite construct (Schooler et al., 2014). The logic is simple—if there is a construct that describes the absence of mind wandering, any training that promotes this construct should also reduce mind wandering. This has led us to mindfulness, a psychological construct that originated from the Buddhist tradition.

Mindfulness, a concept that is central to Buddhist philosophy has attracted growing scientific interest in the last few decades (McIntosh, 1997). The original term for mindfulness is the Pali word *sati*, derived from the verb *sarati* meaning “to remember” (Bodhi, 2011). In classic literature, *sati* is used to describe a lucid awareness of what is objectively taking place in the phenomenological world (Chiesa, 2012). According to the Pali Cannon, the initial task of mindfulness is “to keep a bare registering of the facts observed as free as possible from distorting conceptual elaborations” (Bodhi, 2011, p. 32). Right mindfulness (*samma sati*), or skilful practice of mindfulness, is included as the seventh element of the Noble Eightfold Path that leads to the cessation of suffering.

In the modern context, the construct of mindfulness has been more concrete and specific. Jon Kabat-Zinn provided one of the earliest modern definitions of mindfulness as "paying attention in a particular way, on purpose, in the present moment, and non-judgmentally" (Kabat-Zinn, 1994, p. 4). Several efforts have been made to further operationalize mindfulness. It was described as a combination of: (1) self-regulation of attention, such as sustained attention, attention switching, and inhibition, and (2) a particular orientation towards one's experience, including curiosity, openness, and acceptance (Bishop et al., 2006). Alternatively, mindfulness was constructed as "re-perceiving", a significant shift in the following perspectives: (1) intention, including self-regulation, self-exploration, and self-liberation; (2) attention, including vigilance, switching, and inhibition; and (3) attitude, such as patience, compassion, and non-striving (Shapiro, Carlson, Astin, & Freedman, 2006). In general, there is a wide consensus that mindfulness can be characterized as present-oriented attention and awareness (Chiesa, 2012).

The meaning of mindfulness depends on the context in which it is used. Mindfulness can describe a specific state when the individual is attending to the present moment (Lau et al., 2006). Mindfulness can also refer to a dispositional trait that differs between and within individuals, whether single-faceted (Walach, Buchheld, Buttenmüller, Kleinknecht, & Schmidt, 2006) or multi-faceted (Baer, Smith, & Allen, 2004; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). Furthermore, mindfulness is often used interchangeably with practices that cultivate mindfulness, especially meditation (Awasthi, 2012).

Unlike mindfulness, the term meditation refers to a wide variety of activities, ranging from relaxation techniques to spiritual exercises. A meta-analysis identified five categories of meditation: mantra meditation, mindfulness meditation, Yoga, Tai Chi, and Qi Gong (Ospina et al., 2007). Within the traditional context, meditation involves three progressive stages: *dharana* (i.e., concentration), *dhyana* (i.e., contemplation), and *samadhi* (i.e., containment).

With a prolonged period of one-pointed attention (*dharana*), one enters a contemplative state of passive attention (*dhyana*), which then leads to a standstill state (*samadhi*) where the mind is contained and controlled (Rao, 2011).

In modern Western psychology, meditation has been conceptualized as a family of emotional and attentional regulatory strategies (Dunn, Hartigan, & Mikulas, 1999; Lutz, Slagter, Dunne, & Davidson, 2008). In general, there are two types of meditation: focused attention (FA) meditation and open monitoring (OM) meditation (Lutz et al., 2008). Whereas FA meditation involves focusing attention on a specific object for a prolonged period of time, OM meditation is characterized by monitoring the field of experience from moment to moment with acceptance (Lutz et al., 2008). Most mindfulness-based interventions, such as the Mindfulness Based Stress Reduction (MBSR; Kabat-Zinn, 1990), involve a combination of both FA and OM meditations and use meditation as a means to cultivate mindfulness.

Benefits of mindfulness training

Mindfulness meditation was first introduced in the 1970 as a behavioural intervention for patients with chronic pain, which later evolved into MBSR (Kabat-Zinn, 1982). Since then, mindfulness has steadily gained momentum in the medical and psychological literature. Following the establishment of MBSR, three other interventions have been developed using mindfulness concepts and practices, including Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2002), Dialectical Behavioural Therapy (DBT; Linehan, 1993), and Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, & Wilson, 1999). All four approaches utilize similar techniques to enhance awareness and acceptance, but differ on their philosophical roots, emphasizes, and targeted populations (Brown, Ryan, & Creswell, 2007). The efficacy of mindfulness-based interventions is well supported by a wealth of clinical research (Baer, 2006). A recent review of randomized clinical trials (Keng, Smoski, & Robins, 2011) concluded that mindfulness-based interventions generally reduced psychological symptoms and emotional reactivity and enhanced behavioural regulation and subjective well-being. Mindfulness-based interventions also led to improved medical symptoms, enhanced physical health, and better interpersonal relationships (Brown et al., 2007).

The beneficial effects of mindfulness training extend beyond clinical symptoms. It has been shown to enhance a wide variety of cognitive functions, including attention, working memory, and executive functioning (Chiesa, Calati, & Serretti, 2011). Experienced meditators performed significantly better in tasks involving sustained attention (Josefsson & Broberg, 2011; Pagnoni & Cekic, 2007) and selective attention (Hodgins & Adair, 2010). Extensive meditation experience was also associated with enhanced capability in conflict monitoring (Jha, Krompinger, & Baime, 2007) and attention switching (Hodgins & Adair, 2010). Similarly, after intensive mindfulness training, novices demonstrated improvements on sustained attention (MacLean et al., 2010), selective attention (Braboszcz et al., 2013; Moore, Gruber, Derose, & Malinowski, 2012), and conflict monitoring (Allen et al., 2012; Tang et al., 2007). Apart from attentional processes, short-term mindfulness training also led to improvements on working memory capacity (Chambers, Lo, & Allen, 2007; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010) and executive functioning (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010).

Within both Buddhist tradition and modern psychology, mindfulness is generally accepted as a result of intensive, longitudinal, and systematic training. Daily practice is usually required during mindfulness-based interventions, such as MBSR and MBCT. Long-term meditation experience was associated with enhanced cognitive functions and brain structural changes (Pagnoni & Cekic, 2007; Taylor et al., 2013). However, it does not necessarily mean that mindfulness training is only effective when practiced for months or even years. Instead, an increasing body of research has demonstrated that even one session of mindfulness meditation (as brief as 8-10 minutes), when delivered to novices, produced observable improvements on mood states (Johnson, Gur, David, & Currier, 2013), emotion regulation (Erisman & Roemer, 2010), insightful problem-solving (Ren et al., 2011), and time perception (Kramer, Weger, & Sharma, 2013).

The impact of mindfulness training has also been observed within human brain anatomy. Experienced meditators showed greater gray matter concentration in brain regions that are relevant for interoception and meditation (Holzel et al., 2008). Extensive meditation experience was associated with increased cortical thickness in brain regions that are responsible for attentional, emotional, and sensory processes, including the prefrontal cortex, right anterior insula, and anterior cingulate cortex (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010; Holzel et al., 2007; Lazar et al., 2005). Long-term meditation practice also led to altered activity level and functional connectivity within certain DMN areas, indicating a more present-oriented default mode (Brewer et al., 2011; Taylor et al., 2013). Similar structural changes were observed after novices completed short-term mindfulness training. Integrative Body-Mind Training, a meditation method based on traditional Chinese medicine, led to greater activation of the anterior cingulate cortex after 3 hours (Tang et al., 2009) and increased white matter integrity in the anterior cingulate cortex after 11 hours of practice (Tang et al., 2010). After 8 weeks of MBSR, novices showed increased gray matter concentration in the left hippocampus and temporal-parietal junction (Holzel, Carmody, et al., 2011) and greater activation of the ventrolateral prefrontal cortex (Farb et al., 2007), which are responsible for self-regulation and self-referential processing.

The underlying mechanism of mindfulness training

With promising results from clinical and neuropsychological research, more attention has been paid to the underlying processes of mindfulness training. In a recent meta-analysis (Holzel, Lazar, et al., 2011), four processes were identified: (1) attention regulation; (2) body awareness; (3) emotion regulation; and (4) change to perspective on the self. Most mindfulness training starts with practices that cultivate attention regulation and awareness of body sensations. With more practice, the individual is then able to focus their meditation on emotional stimuli. Research suggest that mindfulness is likely to regulate negative emotions via two mechanisms: (1) reappraisal, by reconstruing the negative events in a more adaptive manner (Garland, Gaylord, & Fredrickson, 2011), and (2) exposure and extinction, by accepting the negative emotions without reacting (Roemer, Orsillo, & Salters-Pedneault, 2008). Eventually, the individual realizes that negative emotions are transitory and can be handled skilfully and such an insight then leads to a different perspective on the self (Holzel, Lazar, et al., 2011).

Among the four proposed components, emotion regulation is generally accepted as the most critical underlying mechanism of mindfulness (Davidson, 2010). It was argued that mindfulness training is associated with a top-down emotion regulation among short-term practitioners but a bottom-up emotion regulation among long-term practitioners (Chiesa, Serretti, & Jakobsen, 2013). In a seminal paper, Mark Williams (2010) put forward a theoretical model by introducing two modes of mind. The first mode is sensory-perceptual, in which emotions are turned on and off by external contingencies (e.g. "I feel sad because I did poorly on this test"). The second mode is verbal-conceptual, in which emotions are symbolically represented and internally simulated (e.g. "I feel sad because I have never been successful at school"). Problems arise when we are stuck in the second mode when external contingencies are no longer present (e.g. continuing to feel sad in the absence of failures).

Therefore, it was argued that mindfulness training cultivates the ability to distinguish the internal model from the external one (Williams, 2010).

Connecting mind wandering to mindfulness training

Surprisingly, there has been very limited research on how mindfulness improves emotion regulation. When it comes to the underlying mechanisms of mindfulness, our knowledge is still in its infancy (Holzel, Lazar, et al., 2011). Here again, mind wandering and mindfulness, two constructs that are opposite in nature, offer a novel solution to each other's impasse. While mindfulness may provide an antidote to mind wandering, established research methodology on mind wandering could shed light upon the working mechanism of mindfulness.

If we conceptualize mind wandering as a thought that is both task-unrelated and stimulus-independent (Stawarczyk, Majerus, Maj, et al., 2011), then the ability to be mindfully focused on the present moment should be a opposite construct . In fact, Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), one of the most commonly used measures of mindfulness, does not directly assess mindfulness, but uses "mindlessness" to gauge trait mindfulness. In three previous studies (Cheyne, Carriere, & Smilek, 2006; Cheyne et al., 2009; Deng, Li, & Tang, 2012), lower trait mindfulness as measured by the MAAS was consistently associated with indirect markers of mind wandering during the SART.

To our knowledge, three experimental studies have directly examined the impact of mindfulness on mind wandering. A two-week mindfulness training program led to improved GRE performance, greater working memory capacity, and reduced retrospective self-reports of mind wandering during the GRE and a working memory test (Mrazek et al., 2013). In another study, following seven weeks of mindfulness training, university students reported being on-task more often and demonstrated higher response accuracy during the SART

(Morrison, Goolsarran, Rogers, & Jha, 2014). Similarly, after practicing mindfulness meditation for eight minutes, participants showed reduced behavioural markers of mind wandering during the SART, compared to those who received passive relaxation or a reading task (Mrazek et al., 2012). In general, mindfulness does appear to be effective in curbing mind wandering.

However, there are several limitations with the above-mentioned studies. Firstly, mind wandering was measured either retrospectively (Mrazek et al., 2013) or indirectly using behavioural indicators (Mrazek et al., 2012). In order to answer the question if mindfulness training reduces mind wandering, we need to directly sample participants' conscious experiences, for example by introducing thought probes at which people report on the thought they were experiencing when the probe appeared. Secondly, all three studies (Morrison et al., 2014; Mrazek et al., 2013; Mrazek et al., 2012) used overall task performance as behavioural measures of mind wandering, but none was able to examine how well people were performing when they experienced specific types of thoughts (i.e., on-task thoughts or mind wandering). It is possible that mindfulness training not only reduces the frequency of mind wandering thoughts but also ameliorates the disruptive impact of mind wandering on task performance.

Established methodology on mind wandering also allows us to identify the underlying working mechanism of mindfulness as an emotion regulation strategy. Using the thought probe technique, individuals' conscious experiences can be sampled and classified based on several phenomenological dimensions. Most studies on mind wandering only examined task-relatedness or stimulus-dependency as these two distinguish on-task thoughts from mind wandering. However, thought reports can also be classified according to their temporal orientation and affective valence (Baird et al., 2011; Franklin et al., 2013; Smallwood & O'Connor, 2011; Stawarczyk et al., 2013), which might provide a unique channel for us to examine the efficacy of mindfulness in emotion regulation. Within temporal orientation, a thought could be oriented towards the past, present, or future. As mindfulness is characterized as present-oriented attention and awareness (Chiesa, 2012), mindfulness training should therefore promote more present-oriented thoughts, thus reducing ruminations (past-oriented) and worries (future-oriented). Likewise, a thought report can be classified as negative, neutral, or positive in terms of its affective valence. Given the abundant evidence supporting the efficacy of mindfulness in regulating negative emotions (Chiesa et al., 2013), it is also likely that mindfulness training would promote more positive thoughts and reduce the disruptive impact of negative thoughts on task performance. Research methodology on mind wandering will allow us to explore these two possibilities.

In addition, the relationship between mind wandering and motivation might offer more insight into the underlying mechanism of mindfulness training. As reviewed earlier, mindfulness entails a present-focused attention (Chiesa et al., 2011) and a nonreactive orientation towards one's experience (Bishop et al., 2006; Shapiro et al., 2006). During a typical meditation, when the practitioner becomes aware of not being on-task, they will first acknowledge and accept their mind wandering and subsequently shift their attention back to meditation (Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012). If we describe this process in terms of motivation, mindfulness practice should lead to reduced motivation towards mind wandering but enhanced motivation to perform well on the current task. Hence, the goal of performing well on the current task is prioritized over the goals of thinking about mind wandering thoughts and avoiding thinking about mind wandering thoughts. In fact, this process might well explain the efficacy of mindfulness in treating anxiety disorders. Anxious populations are characterized by robust attenional biases towards threat, including a bias to attend to threat and a bias to avoid threat (Cisler & Koster, 2010). Recent clinical trials revealed that mindfulness training could reduce such biases among anxious populations

(Roemer et al., 2008; Roemer, Williston, Eustis, & Orsillo, 2013), which then led to improved clinical symptoms (Boettcher et al., 2014; Holzel et al., 2013).

Current studies

With the hope of bridging two separate lines of research and gaining more insight into the working mechanism of mindfulness, we conducted two laboratory studies using undergraduate samples. In both studies, we made use of established paradigms of mind wandering—the MRT, in which participants are asked to respond to a series of metronome tones and report their conscious experiences at random intervals. During the MRT, participants also reported their motivation to perform well on the task as well as their motivation to approach and to avoid their conscious experiences. For each thought that participants reported at thought probes, we had independent judges rate it on multiple dimensions, including task-relatedness, stimulus-dependency, temporal orientation, and affective valence. The MRT provided two indexes of mind wandering: (1) the frequency of different categories of reported thoughts, including mind wandering, and (2) performance on the task; that is, degree of synchrony between the tone and the response. This methodology would allow us to examine (1) the phenomenology of conscious experiences sampled during the MRT; (2) the disruptive impact of mind wandering on task performance; and (3) the relationship among motivation, mind wandering, and task performance.

Study 1 aimed to clarify the operationalization of mind wandering by comparing two popular classification systems on their ability to distinguish different categories based on their associated behavioural response. The first one is a dichotomous system, i.e., a thought report is classified as either on-task or mind wandering, whereas the second one is a two-dimensional system, i.e., a thought report is classified based on task-relatedness and stimulus-dependency. We explored if the two-dimensional system can further distinguish different types of off-task thoughts, i.e., task-related interferences, external distractions, and mind wandering. Study 1 also investigated the relationship between motivation and mind wandering. Each participant reported their negative and positive current concerns as well as their motivation to approach and to avoid their current concerns. We explored if higher motivation to think about or to avoid current concerns leads to greater mind wandering and poorer task performance and if higher performance motivation predicts less mind wandering, which then results in better task performance.

Based on results from study 1, we adopted a similar research paradigm and a two-dimensional system for classifying mind wandering in study 2. To understand the effectiveness of mindfulness training, we recruited a group of highly anxious individuals, as they are more likely to experience negative cognitions as well as interference from mind wandering episodes. Instead of measuring motivation towards their current concerns, we asked participants to indicate to what extent they feel motivated to approach and to avoid their reported thoughts in each thought probe. Study 2 involved two types of intervention—participants either performed mindfulness meditation or listened to an audiobook for 10 minutes. We explored if mindfulness meditation reduces mind wandering while ameliorating the disruptive impact of mind wandering on task performance. Furthermore, study 2 aimed to explore the underlying mechanism of mindfulness training in emotion regulation. We investigated if meditation promotes present-oriented and positive thinking while protecting task performance from the interference of negative thoughts. We also extended results from study 1 and sought to better understand the relationship among mind wandering, mindfulness, and motivation.

Study 1: The Classification of Mind Wandering and Its Relation to Motivation

This study first aimed to clarify the operationalization of mind wandering by directly comparing two popular classification systems: a dichotomous system (on-task versus mind wandering) and a two-dimensional system (based on task-relatedness and stimulus-dependency) on their ability to distinguish different categories of thoughts based on associated behavioural response. Participants completed two blocks of MRT and reported the content of their conscious experiences at random thought probes. We then asked participants to classify their thought reports as either on-task or mind wandering using the dichotomous system, and had independent judges rate the same thoughts on task-relatedness and stimulus-dependency following the two-dimensional system. We examined if different categories of thought reports are associated with different patterns of behavioural response.

More importantly, this study explored the relationship between mind wandering and motivation. Prior to each block of MRT, participants identified one current concern (either positive or negative) using a self-report questionnaire that we developed for this study. After completing each block of MRT, participants indicated their levels of motivation felt during the task, including: (1) motivation to approach their current concern; (2) motivation to avoid their current concern; and (3) motivation to perform well on the current task. The MRT provided two indexes of mind wandering—subjective reports (i.e., the proportion of different categories of thought reports) and behavioural measures (i.e., overall task performance). We then examined if each type of motivation is associated with mind wandering and more specifically, if the relationship between motivation and overall performance is mediated by the frequency of on-task thoughts.

We predicted: (1) under both classification systems, on-task thoughts are associated with better task performance; (2) under the two-dimensional classification system, thoughts that are both task-unrelated and stimulus-independent (i.e., mind wandering) are associated with the poorest task performance; (3) participants are more motivated to avoid their negative current concern and more motivated to approach their positive current concern; (4) higher motivation to approach positive current concern and higher motivation to avoid negative current concern both predict greater mind wandering and poorer task performance, whereas higher motivation to approach and to avoid negative current concern predict the greatest mind wandering and the poorest task performance; and (5) higher performance motivation predicts more on-task thoughts, which then lead to better task performance.

Methods

Participants

Undergraduate students ($N = 96$) were recruited from the University of Waterloo in exchange for course credits. Four of them failed to complete the whole procedure and among those who completed, one had too much missing data and was therefore removed. Hence, we have 91 participants (62 females) with complete data for data analyses. The age ranged from 17 to 25 years, with a mean age of 19.97 years ($SD = 1.67$). None of these participants were excluded due to excessive omissions (i.e., more than 10% of the trials) or extreme scores on trait anxiety and attention control capacity (i.e., more than two standard deviations from the mean). Outliers on mood measures were corrected by replacing them with the next highest or lowest values. The protocol received ethical clearance from the Office of Research Ethics at the University of Waterloo.

Self-report measures

Participants completed the State-Trait Inventory for Cognitive and Somatic Anxiety-Trait (STICSA; Ree, French, MacLeod, & Locke, 2008) the Attention Control Scale (ACS; Derryberry & Reed, 2002), and the International Positive and Negative Affect Schedule Short Form (I-PANAS-SF; Thompson, 2007), measuring individual differences in trait anxiety, attention control capacity, and mood states. We included the STICSA and the ACS to exclude participants who are overly anxious or who have extreme capacities in attention control, as they are likely to contaminate our subjective reports and behavioural measures of mind wandering. The I-PANAS-SF was employed to investigate changes to mood states throughout the study. Participants completed the ACS in the beginning of this study and the I-PANAS-SF at three time points: at baseline, after the desirable block, and after the undesirable block. The STICSA was part of a mass testing procedure that participants completed online prior to their participation.

The STICSA (Ree et al., 2008) contains 21 items of anxiety symptoms measuring general trait anxiety. Participants rated to what extent they agreed with each statement on a 4-point Likert scale (from 1 “not at all” to 4 “very much so”). This measure has demonstrated good validity and reliability by confirmatory factor analyses using both clinical and college samples (Gros, Antony, Simms, & McCabe, 2007; Gros, Simms, & Antony, 2010). The ACS includes 20 items assessing people’s abilities to focus attention, to shift attention between tasks, and to flexibly control thoughts. Participants rated how frequently they experienced attention control failure when they are stressed and/or anxious on a 4-point Likert scale (from 1 “almost never” to 4 “always”). This measure has demonstrated good psychometric properties in both adults and children (Ólafsson et al., 2011; Verstraeten, Vasey, Claes, & Bijttebier, 2010). Lastly, the I-PANAS-SF is a short form of the PANAS (Watson, Clark, & Tellegen, 1988), which contains 10 items assessing mood states and comprises two subscales, one measuring positive affect and the other measuring negative affect (5 items each). Participants rated the extent to which their feeling is consistent with each item on a 5-point Likert scale (from 1 “very slightly or not at all” to 5 “extremely”). The I-PANAS-SF has demonstrated excellent validity and internal consistency in diverse samples across cultures (Crawford & Henry, 2004; Dyck, Jolly, & Kramer, 1994; Karim, Weisz, & Rehman, 2011).

Involuntary thought questionnaire (current concerns)

As proposed in the current concerns theory (Klinger, 1971), involuntary thoughts are manifestations of current concerns, originated from one’s personal goals. We therefore defined current concerns as involuntary thoughts that have been most frequent in participants’ everyday life. While the desirable involuntary thought represents their positive current concern, the undesirable involuntary thought reflects their negative current concern. Prior to each block of the MRT, participants were first introduced to the concept of desirable (or undesirable) involuntary thought and then completed the involuntary thought questionnaire based on their everyday experience. Within this questionnaire, participants described their most recent and frequent desirable (or undesirable) involuntary thought in the last few days before their participation in this study. They then rated it on the following dimensions: (1) form (verbal proposition, imagery, or impulse); (2) perspective of imagery (actor or observer perspective); (3) duration; (4) frequency (occurrences per day); (5) temporal orientation (past, present, or future); (6) perceived anxiety (1 = not at all, 7 = extreme); (7) perceived pleasantness (-3 = very unpleasant, 3 = very pleasant); (8) perceived acceptability (-3 = very unacceptable, 3 = very acceptable); (9) perceived intrusiveness (-3 = very intrusive, 3 = very unintrusive); and (10) perceived dismissability (-3 = very difficult to be dismissed, 3 = very easy to be dismissed). We then performed analyses to investigate differences between positive and negative current concerns on these phenomenological dimensions.

The Metronome Response Task (MRT)

The MRT (Seli, Cheyne, et al., 2013) is a sustained attention task in which participants have to respond synchronously to a periodic metronome tone presented through the speakers. In each MRT trial, participants were first presented with 650ms of silence, followed by a metronome tone lasting 75ms, and then another 575ms of silence. Hence, the total duration for a single trial was 1,300ms. Participants were instructed to press the spacebar in synchrony with the metronome so that their key-press was made at the exact time when each metronome tone was presented. Each participant completed two blocks of MRT on a computer using the E-Prime software (Psychology Software Tools, 2007). In each block, there were 20 practice trials followed by 500 experimental trials.

Thought probes

Throughout the MRT, one thought probe was randomly presented within every set of fifty trials. Hence, each participant received 10 thought probes per block. Upon the presentation of a thought probe, the metronome tone stopped and participants read the following question: “what was the thought you were having just prior to this moment”. They were instructed to enter their responses into a textbox on the screen using the keyboard. Participants then received another question: “were you on-task or off-task” and had to choose either “on-task” or “off-task” by pressing a corresponding key. They were told that “on-task” means focusing on the task and “off-task” means not focusing on the task. After answering both questions, participants pressed the spacebar to resume the MRT.

After initial data collection, we recruited four independent judges and asked them to rate each thought report on task-relatedness and stimulus-dependency using published criteria (Stawarczyk, Majerus, Maj, et al., 2011). All judges were trained and went through a cross-coding validation procedure to ensure inter-rater reliability. Based on the two-dimensional classification system (Stawarczyk, Majerus, Maquet, et al., 2011), each thought report was then assigned to one of the following four categories: (1) on-task thoughts; (2) task-related interferences (TRIs); (3) external distractions (EDs); and (4) mind wandering. In addition, all thought reports were rated on their relationship to current concerns, i.e., if the reported thought was related to positive or negative current concern identified by the same participant. Analysis demonstrated satisfactory inter-rater reliability (kappa), ranging from 0.73 to 0.90. Inter-rater averages were calculated and significant discrepancies were resolved through discussion. However, if no details were provided at the thought probe (e.g. reporting “nothing” or “having nothing in mind”), we did not code this thought probe and excluded it from relevant analyses.

In summary, each thought reports was classified using either a self-classified dichotomous system (i.e., determined by participants) or an experimenter-classified two-dimensional system (i.e., determined by independent judges).

MRT measures

There are several measures obtained from the MRT. Rhythmic Response Time (RRT) was first calculated as the difference between the time of the key-press and the onset of the metronome tone. Mean RRT therefore indicates whether the participant's general responses precede or succeed the metronome tone. A more important measure is response variance. Higher RRT variance indicates less synchronous response, reflecting poorer task performance. To obtain mean RRT variance for each participant, we first calculated the variance of RRT for every five trials except the very first five trials and the five trials following each thought probe (see Seli, Carriere, et al., 2013) and then computed the average. We also calculated RRT variance for the five trials immediately preceding each category of thought reports—when following the dichotomous classification system: (1) on-task RRT variance and (2) off-task RRT variance; and when following the two-dimensional classification system: (1) on-task RRT variance, (2) TRIs RRT variance, (3) EDs RRT variance, and (4) mind wandering RRT variance. However, as variance data from the MRT was highly skewed in the positive direction, we followed established procedures (Seli, Carriere, et al., 2013; Seli, Cheyne, et al., 2013) and adjusted all variance measures using a natural logarithm transform. When two thought probes were positioned to each other within five trials, we excluded the second one from analyses to avoid potential contamination.

Hence, for each participant, we calculated their mean RRT, mean RRT variance, and RRT variance associated with each category of thought reports. In addition, we included omission rate, which indicates the proportion of trials that participants omitted.

Motivation measures

After completing each block of MRT, participants reported their levels of motivation using a visual analogue scale. They were asked to place a vertical mark on a horizontal line of 9.1cm to indicate the extent to which they felt motivated. If they just completed the desirable block, they would report: (1) “how motivated to think about the desirable involuntary thought during the task”, i.e., approach motivation towards positive current concern; (2) “how motivated to avoid thinking about the desirable involuntary thought during the task”, i.e., avoidance motivation towards positive current concern, and (3) “how motivated to perform well on the task”, i.e., performance motivation. Likewise, if they just completed the undesirable block, they would report: (1) approach motivation towards negative current concern; (2) avoidance motivation towards negative current concern; and (3) performance motivation. Their responses were measured and entered in centimeters.

Procedures

After providing informed consents, participants were asked to complete a set of self-report measures. They were then invited to complete two blocks of identical activities. In each block, they first answered the involuntary thought questionnaire, finished 500 MRT trials with 10 thought probes, and then completed measures of motivation and mood states. The only difference between these two blocks was that in the desirable block, participants answered the involuntary thought questionnaire and motivation measures according to their desirable involuntary thought (representing their positive current concern), whereas in the undesirable block, the involuntary thought questionnaire and motivation measures were based on their undesirable involuntary thought (representing their negative current concern). The order of which they completed the desirable and undesirable blocks was counterbalanced. In total, the whole session lasted about an hour.

Results

Involuntary thought questionnaire and motivation towards current concerns

All participants were asked to identify one desirable involuntary thought and one undesirable involuntary thought that were most frequent in their everyday life. While the desirable involuntary thought represents their positive current concern, the undesirable involuntary thought reflects their negative current concern. The characteristics of reported current concerns are presented in Table 1. Consistent with our expectation, negative current concern was more anxiety provoking and unpleasant (both $p_s < .001$). In addition, negative current concern was perceived as less acceptable, $p < .001$, more intrusive, $p < .01$, and more difficult to be dismissed, $p < .001$, with a longer duration, $p < .05$. However, there was no significant difference between positive and negative current concerns regarding their form, frequency, or temporal orientation (all $p_s > .11$).

Importantly, analysis revealed a significant difference between positive and negative current concerns in their associated approach and avoidance motivation (both $p_s < .001$). Participants indeed reported higher motivation to approach their positive current concern and higher motivation to avoid their negative current concern during the MRT, which confirmed our prediction.

However, participants did not experience one type of current concerns more often than the other during the MRT ($p > .36$). In fact, we observed a surprisingly low base rate of thought reports that were related to current concerns (3.79-4.62%). In this study, an important goal was to examine if motivation to approach and to avoid current concerns is associated with mind wandering. Although we did measure motivation towards positive and negative current concerns, most participants did not experience their current concerns during the MRT. Therefore, we cannot proceed with analyses on the relationship between approach/avoidance motivation and mind wandering. Nonetheless, performance motivation was measured independently from current concerns. Despite that we were unable to examine our hypothesis pertaining to approach motivation and avoidance motivation, we could still assess our prediction on performance motivation. In following analyses, we investigated if performance motivation is associated with mind wandering and more importantly, if the relationship between performance motivation and overall task performance is mediated by the frequency of on-task thoughts.

Table 1. Characteristics of current concerns

Dimensions	Positive current concern	Negative current concern	*z*	*t*	Cohen's *d*
Form			-0.42	--	--
Verbal	34.1%	43.9%			
Impulse	12.1%	16.5%			
Imagery (actor)	36.2%	20.9%			
Imagery (observer)	17.6%	18.7%			
Duration			-2.43*	--	--
<1 min	53.8%	37.4%			
1-30 min	44.0%	51.6%			
>30 min	2.2%	11.0%			
Temporal orientation			-1.62	--	--
Past	15.4%	24.2%			
Present	35.2%	38.4%			
Future	49.4%	37.4%			
Frequency (per day)	4.89 (5.29)	4.93 (9.04)	--	0.40	0.00
Anxiety (1 to 7)	2.27 (1.70)	5.15 (1.33)	--	14.18***	1.49
Acceptability (-3 to +3)	1.80 (1.60)	-0.32 (1.79)	--	-8.40***	0.88
Pleasantness (-3 to +3)	2.07 (1.46)	-1.22 (1.92)	--	-11.80***	1.24
Intrusiveness (-3 to +3)	-0.56 (1.53)	0.24 (1.75)	--	3.35**	0.35
Dismissibility (-3 to +3)	-0.16 (1.61)	-1.00 (1.49)	--	-3.93***	0.41
Recurrence rate %	3.79 (6.30)	4.62 (6.84)	--	0.92	0.10
Approach motivation	3.79 (2.80)	2.56 (2.27)	--	3.93***	0.41
Avoidance motivation	2.76 (2.33)	4.59 (2.85)	--	-5.08***	0.53

Note: For frequency, $N = 82$; for other dimensions, $N = 91$. Standard deviations from the mean are presented in brackets. Sign tests, Wilcoxon signed ranks test, and paired-sample t-tests were performed to examine differences between positive and negative current concerns. * $p < .05$, ** $p < .01$, *** $p < .001$.

Self-report measures, performance motivation, and MRT measures

Each participant completed three self-report measures on trait anxiety, attention control, and mood states. Means and standard deviations for these measures are presented in Table 2. No outliers on trait anxiety or attention control were identified (> 2 SD_s). In order to examine the changes in mood states throughout the study, a one-way repeated measures ANOVA was performed on positive and negative affect respectively. We observed a significant main effect of time on positive affect, F (2, 180) = 9.20, $\eta^2_p = .093$, $p < .001$, and negative affect, F (1.685, 151.605) = 5.20, $\eta^2_p = .055$, $p < .01$, using Greenhouse-Geisser correction. Further analysis revealed an elevated positive affect at baseline (both $p_s < .01$) and a reduced negative affect after the desirable block (both $p_s < .01$).

Performance motivation, MRT measures, and proportions of specific thought reports are displayed in Table 3. We observed no significant difference between desirable and undesirable blocks in performance motivation or any MRT measures (all $p_s > .53$). Whether using the dichotomous classification system or the two-dimensional classification system, we observed no significant between-block difference in proportions of thought reports (all ps > .10). Given participants performed similarly in both blocks, we decided to combine desirable and undesirable blocks when conducting further analyses.

Table 2. Means and standard deviations of self-report measures.

Measures	Mean	*SD*
ACS	50.36	7.60
STICSA	36.91	11.55
PA T1	13.19	3.40
NA T1	6.30	1.57
PA T2	11.91	4.01
NA T2	5.86	1.42
PA T3	11.73	4.27
NA T3	6.38	2.11

Note: Standard deviations from the mean are presented in brackets. ACS: attention control scale; STICSA: state-trait inventory of cognitive and somatic anxiety-trait version; PA: positive affect; NA: negative affect; T1: at baseline; T2: after the desirable block; T3: after the undesirable block.

Table 3. Means and standard deviations for performance motivation, MRT measures, and proportions of thought reports.

Measures	Desirable block	Undesirable block	*t*	Cohen's *d*
Performance motivation	5.74 (2.31)	5.61 (2.36)	0.55	0.06
MRT				
Mean RRT	-41.51 (52.10)	-42.66 (54.10)	0.48	0.03
Mean RRT variance	8.11 (0.63)	8.08 (0.65)	0.63	0.07
Omission rate %	1.1 (1.3)	1.1 (1.3)	0.31	0.05
Dichotomous system				
On-task %	37.9 (23.5)	34.6 (20.7)	1.48	0.16
Off-task %	62.1 (23.5)	65.4 (20.7)	1.48	0.16
Two-dimensional system				
On-task %	25.1 (20.2)	23.8 (19.5)	0.59	0.06
TRIs %	12.2 (14.1)	12.0 (12.8)	0.17	0.02
EDs %	23.4 (16.4)	21.8 (15.8)	0.85	0.09
MW %	37.8 (21.6)	41.8 (22.9)	-1.67	0.18

Note: $N = 91$. Standard deviations from the mean are presented in brackets. RRT: rhythmic response time; TRIs: task related interferences; EDs: external distractions; MW: mind wandering. Paired-sample t-tests were performed to examine differences between desirable and undesirable blocks. *** $p < .001$.

Comparing two classification systems

We first examined the phenomenology of conscious experiences sampled during the MRT and explored if the classification of mind wandering is consistent across two systems. A total number of 1,820 thoughts were sampled and rated by both participants and independent judges. However, 20 of them were excluded due to empty or insufficient information. To facilitate our comparison, we broke down the distribution of dichotomously classified thought reports based on the two-dimensional system in Table 4. Correlational analyses were conducted and phi coefficients were calculated to explore if the distribution of thoughts are similar across different classification systems. We observed a significant positive association between the on-task/off-task dichotomy and task-relatedness, $\phi = .749$, p $< .001$, and between the on-task/off-task dichotomy and stimulus-dependency, $\phi = .317$, p

< .001. Results suggest that when we asked participants to determine if a thought was on-task or off-task, they intuitively considered both task-relatedness and stimulus-dependency.

Table 4. Distribution of thought reports based on two classification systems.

			Two-dimensional system				Total
			On-task	TRIs	EDs	MW	
Dichotomous system	On-task	Count	390	160	53	41	644
		Proportion of on-task	60.6%	24.8%	8.2%	6.4%	100%
	Off-task	Count	55	60	358	683	1156
		Proportion of off-task	4.8%	5.2%	31.0%	59.0%	100%
	Total	Count	445	220	411	724	1800
		Proportion of total	24.7%	12.2%	22.9%	40.2%	100%

Note: TRIs: task-related interferences; EDs: external distractions; MW: mind wandering.

More critically, we examined different categories of thought reports based on their associated behavioural response. We sought to answer the following three questions within this comparison: (1) if on-task thoughts are associated with better performance in the dichotomous system; (2) if on-task thoughts are associated with better performance in the two-dimensional system; and (3) if task-unrelated and stimulus-independent thoughts (i.e., mind wandering) are associated with the poorest performance in the two-dimensional system, whereas lower response variance indicates better task performance during the MRT, higher response variance reflects poorer MRT performance.

For the dichotomous classification system, means and standard deviations of RRT variance associated with on-task and off-task reports are presented in Table 5. A paired-sample t-test was performed to examine if RRT variance was lower when participants were on-task. Results indeed indicate that participants performed better during on-task reports, t (89) = -2.18, d = 0.23, p < .05.

For the two-dimensional classification system, means and standard deviations of each RRT variance are also presented in Table 5. According to this system, on-task thought is defined as both task-related and stimulus-dependent, whereas TRIs, EDs, and mind wandering all represent different levels of off-task activity. We therefore combined TRIs, EDs, and mind wandering into a new category "distractions" and performed the same paired-sample t-test comparing on-task RRT variance with distractions RRT variance. On-task reports were indeed associated with better task performance, t (87) = -2.19, d = 0.23, $p < .05$.

To answer the third question, we first performed a 2 (task-relatedness) × 2 (stimulus-dependency) repeated measures ANOVA on RRT variance. We observed no main effect of task-relatedness, F (1, 62) = 0.35, $p = .58$, or stimulus-dependency, F (1, 62) = 0.64, $p = .43$, but a significant interaction between these two, F (1, 62) = 7.29, $\eta^2_p = .105$, $p < .01$. Further analysis indicated that response variance was lowest during on-task reports. For a thought report that was task-related, response variance was significantly lower when it was also stimulus-dependent ($p < .05$). In comparison, for a thought report that was task-unrelated, response variance was considerably higher when it was also stimulus-dependent (p = .17). However, we observed no significant difference among TRIs, EDs, and mind wandering in their associated response variance. Therefore, results do not support our prediction that mind wandering is associated with the poorest performance. However, the two-dimensional system allowed us to identify TRIs and EDs and to distinguish TRIs and EDs from on-task reports, which was not possible under the dichotomous system.

Table 5. Means and standard deviations for RRT variance associated with each category of thought reports.

RRT variance	N	Mean	*SD*
Dichotomous system			
On-task	90	7.97	0.75
Off-task	90	8.13	0.67
Two-dimensional system			
On-task	88	7.95	0.75
TRIs	71	8.26	1.15
EDs	85	8.17	0.84
MW	89	8.12	0.78
TRIs, EDs, and MW combined	91	8.12	0.67

Note: TRIs: task-related interferences; EDs: external distractions; MW: mind wandering.

Mind wandering and performance motivation: A mediational model

We first conducted correlational analyses to explore if performance motivation is associated with mind wandering. Due to the low occurrence rate of current concerns during the MRT, we decided not to process with analyses involving approach and avoidance motivation towards current concerns. We only included these two motivation measures here for exploratory purpose. We also included positive and negative affect in our analyses as mood has been previously demonstrated as closely linked to mind wandering (Smallwood, Fitzgerald, et al., 2009; Vinski & Watter, 2013). Results are presented in Table 6.

In both blocks, higher performance motivation was associated with more on-task reports and less mind wandering (all $p_s < .05$), whereas higher pre-task positive affect predicted more on-task reports (both $p_s < .05$). In addition, higher performance motivation and higher pre-task positive affect were associated with lower mean response variance, indicating better overall performance (all $p_s < .05$, except performance motivation in the desirable block, $p = .055$). However, there was no significant association between MRT performance and approach motivation, avoidance motivation, or negative affect. In summary, performance motivation and positive affect both predicted the proportion of on-task reports and overall task performance.

Table 6. Correlations among motivation, mood, proportions of thought reports, and MRT measures.

	Measures	Proportion of thought reports				MRT measures		
		On-task	TRIs	EDs	MW	Mean RRT	Mean RRT variance	Omission rate
Desirable block	Approach motivation	-.11	.02	-.07	.17	-.07	.13	-.15
	Avoidance motivation	.05	.26*	.15	-.28**	-.01	-.17	-.09
	Performance motivation	.46**	.00	-.21*	-.32**	.22*	-.20[1]	-.30**
	PA	.38**	-.08	-.18	-.14	.01	-.44**	-.15
	NA	-.20	-.09	.09	.18	-.10	.05	.04
Undesirable block	Approach motivation	-.02	.03	-.24*	.18	-.08	.10	-.13
	Avoidance motivation	-.14	.04	-.08	.13	.13	.03	.03
	Performance motivation	.46**	-.08	-.10	-.26*	.19	-.26*	-.08
	PA	.22*	-.08	.04	-.15	-.02	-.36**	-.20
	NA	-.11	.17	.04	-.03	-.08	-.06	.18

Note: N = 91. TRIs: task related interferences; EDs: external distractions; MW: mind wandering; PA: positive affect; NA: negative affect. Positive affect and negative affect were measured prior to the start of each block. [1] p = .055, * $p < .05$, ** $p < .01$.

As demonstrated earlier, on-task reports were associated with lower response variance. Therefore, a higher proportion of on-task reports should predict lower mean response variance. We next examined if on-task proportion mediated the relationship between performance motivation and mean response variance. In our mediational model, mean response variance is the dependent variable, performance motivation is entered as the predictor, and on-task proportion is the mediator. As positive affect also predicted on-task proportion and mean response variance, we entered positive affect as a second predictor in our mediational model so it could be controlled for. Following the procedure suggested by Woody (2011), we performed meditational analysis based on structural-equation-modeling (SEM) techniques using AMOS program (Arbuckle, 2006). The structural diagram for our meditational model is presented in Figure 1.

We first tested our mediational model when both blocks were combined. There are two potential mediation paths: (1) the relationship between performance motivation and mean response variance is mediated by on-task proportion, while controlling for positive affect; and

(2) the relationship between positive affect and mean response variance is mediated by on-task proportion, while controlling for performance motivation.

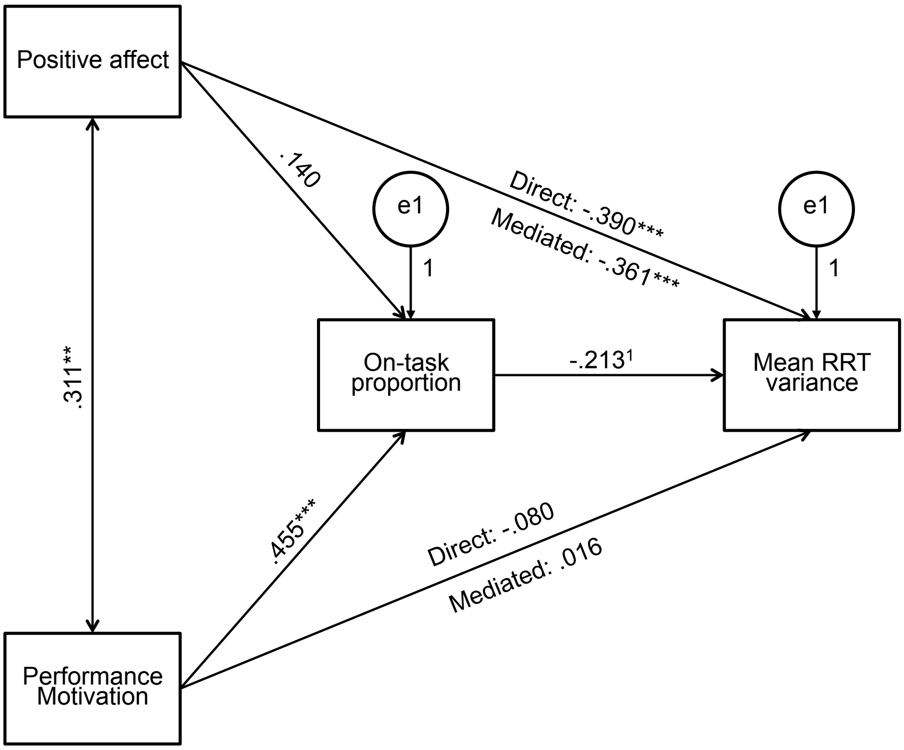
For the first mediation, analysis results suggest that performance motivation did not directly predict mean response variance, β = -.080, B = -0.024, SE = 0.030, p = .42. However, higher performance motivation was associated with a higher on-task proportion, β = .455, B = 0.039, SE = 0.008, p < .001, which marginally predicted lower mean response variance, β = -.213, B = -0.744, SE = 0.382, p = .052. When on-task proportion was included, the effect of performance motivation on mean response variance remained insignificant, β = .016, B = 0.005, SE = 0.033, p = .88, with a borderline Sobel z = -1.809, SE = 0.016, p = .07. Most importantly, a bias-corrected bootstrap analysis using 1,000 samples revealed a significant standardized indirect effect, p < .05, with a 95% confidence interval [-0.233, -0.006]. Hence, on-task proportion mediated the relationship between performance motivation and mean response variance when controlling for positive affect.

For the second mediation, analysis results indicate that higher positive affect directly predicted lower mean response variance, β = -.390, B = -0.067, SE = 0.017, p < .001. However, positive affect was not significantly associated with on-task proportion, β = .140, B = 0.007, SE = 0.005, p = .14. Therefore, on-task proportion did not mediate the relationship between positive affect and mean response variance when controlling for performance motivation. Figure 1 displays the mediation path diagrams with standardized correlation coefficients.

To further investigate the validity of this mediational model, we conducted the same analysis within each block of MRT. For the desirable block, results suggest a significant standardized indirect effect for both mediation path 1, p < .05, with a 95% confidence interval [-0.180, -0.009], and mediation path 2, p < .05, with a 95% confidence interval [-0.152, -0.005]. For the undesirable block, results only indicate a marginally significant standardized indirect effect for mediation path 1, $p = .055$, with a 95% confidence interval [-0.221, 0.002], but not for mediation path 2, $p = .40$, with a 95% confidence interval [-0.086, 0.027]. The mediation path diagrams with standardized correlation coefficients for each block are presented separately in Figure 2 and Figure 3.

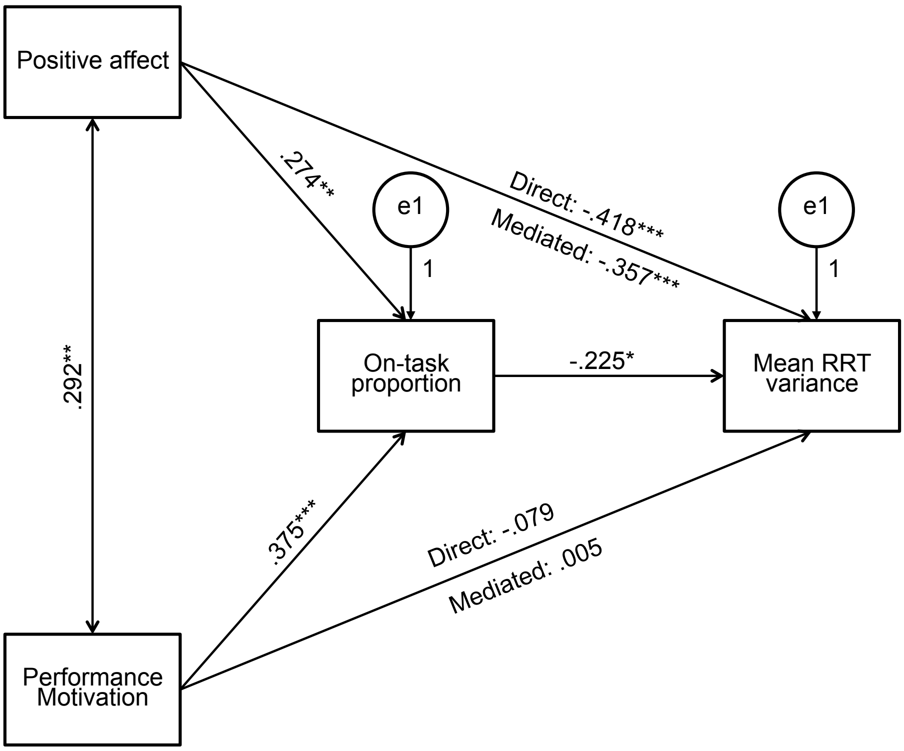
In summary, both performance motivation and positive affect were associated with mind wandering and overall task performance. More critically, the relationship between performance motivation and overall task performance was mediated by the proportion of on-task reports, while controlling for positive affect. Hence, participants with higher performance motivation reported being on-task more often and subsequently performed better throughout the task, regardless of their positive affect.

Figure 1. Mediation path diagrams when combining desirable and undesirable blocks, with standardized correlation coefficients.



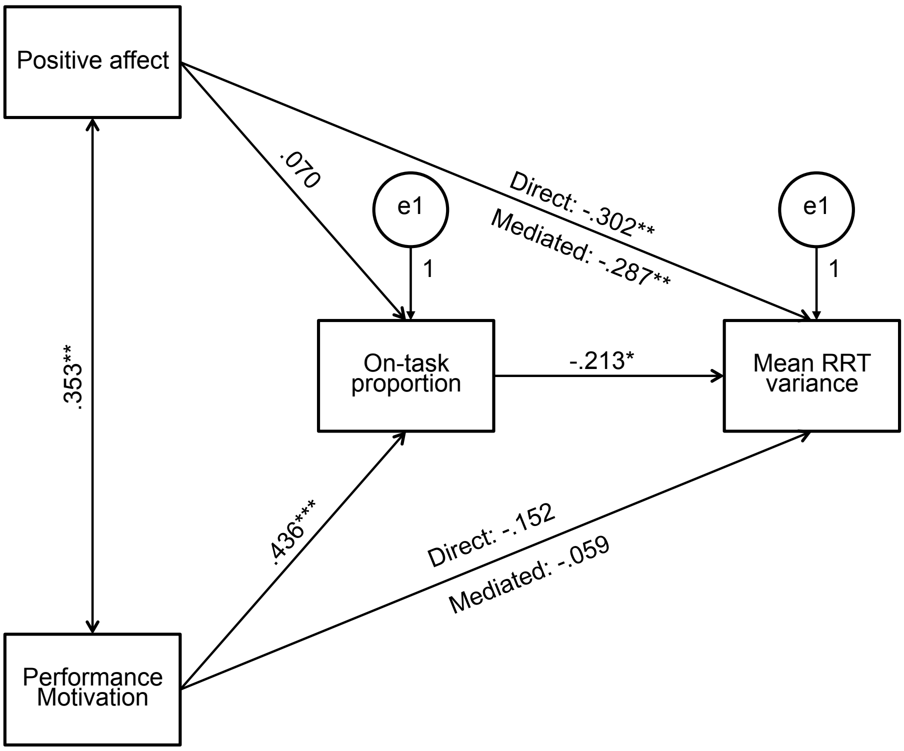
Note: [1] $p = .052$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 2. Mediation path diagrams for the desirable block, with standardized correlation coefficients.



Note: * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 3. Mediation path diagrams for the undesirable block, with standardized correlation coefficients.



Note: * $p < .05$, ** $p < .01$, *** $p < .001$.

Discussion

The first goal of this study was to operationalize mind wandering. We directly compared a dichotomous classification system and a two-dimensional classification system in terms of their ability to distinguish different categories of thoughts. In fact, there was a significant overlap between these two systems in terms of how thought reports were classified. Participants intuitively considered both task-relatedness and stimulus-dependency when determining if a thought was an episode of mind wandering.

Consistent with results from past studies (Seli, Carriere, et al., 2013; Seli, Cheyne, et al., 2013), we found that on-task reports were associated with better task performance under both systems. More importantly, the two-dimensional system allowed us to identify task-related interferences and external distractions and distinguish them from on-task reports, which was not possible under the dichotomous system. In fact, task-related interferences and external distractions are associated with poorer task performance when compared to on-task reports. Task-related thoughts only produced better task performance when they were also stimulus-dependent. Therefore, the two-dimensional classification system allowed us to make finer distinctions among different categories of conscious experiences. However, results do not support our prediction that task-unrelated and stimulus-independent thoughts (i.e., "classic" mind wandering) are associated the poorest task performance. We observed a huge variation within the category of mind wandering under the two-dimensional system and this might have contributed to our insignificant results.

This study also aimed to examine positive and negative current concerns and the relationship between participants' motivation to approach and to avoid their current concerns and mind wandering during the MRT. Compared to positive current concern, negative current concern was described as more anxiety provoking, unpleasant, unacceptable, intrusive, long-lasting, and difficult to be dismissed. Participants reported higher motivation to approach their positive current concern and higher motivation to avoid their negative current concern. However, very few thought reports sampled during the MRT were related to participants' current concerns, which prevented us from conducting further analyses on their motivation towards their current concerns. Hence, we cannot examine the relationship between mind wandering and approach/avoidance motivation. Such a low base rate of thought reports that were related to current concerns might be a result of our design. For example, participants might report situational thoughts rather than their current concerns on the involuntary thought questionnaire and independent judges might not have sufficient information to determine if a thought report is related to that participant's current concerns. To obtain more thought reports that are related to current concerns, future studies can introduce an induction procedure in which participants are asked to reflect on their current concerns or compose a short essay describing their current concerns.

Although we cannot perform analyses on participants' motivation towards their current concerns, we were able to examine performance motivation in relation to mind wandering and task performance. This still provided vital information regarding the relationship between mind wandering and motivation. It was observed that higher performance motivation and more positive affect both predicted more on-task reports and lower mean response variance, indicating better overall performance. More critically, further analysis demonstrated that when controlling for positive affect, the proportion of on-task reports significantly mediated the relationship between performance motivation and overall task performance. Participants with higher performance motivation reported more on-task thoughts and performed better on the task, regardless of their mood states. Therefore, any strategy that promotes higher performance motivation should theoretically ameliorate mind wandering. For example, mindfulness training might reduce mind wandering by increasing performance motivation as it entails a focus of attention in the here and now. Furthermore, we only measured performance motivation once in each block and it might reflect participants' subsequent evaluation of their performance rather than their actual motivation. Hence, future research needs to explore if this significant relationship between mind wandering and motivation still exists at the level of individual thought probes.

Study 2: The Effects of Mindfulness Meditation on Mind Wandering

This study first aimed to examine the effects of mindfulness training on mind wandering during an attention task. Highly anxious participants were randomly assigned to one of two conditions—either practicing mindfulness meditation or listening to an audiobook for 10 minutes. We adopted the same research paradigm used in study 1 to measure mind wandering here. Each participant completed two sessions of MRT—one before intervention and one after intervention. We then recruited independent judges and had them rate each thought report on both task-relatedness and stimulus-dependency, following the two-dimensional classification system used in study 1. We then examined the effects of mindfulness training on both subjective reports and behavioural measures of mind wandering when compared to the control condition.

This study also explored the underlying mechanism of mindfulness training as an emotion regulation strategy and more specifically, if mindfulness meditation promotes present-oriented and positive thinking. Following the experience sampling method used in study 1, we had independent judges rate each thought on temporal orientation (i.e., past, present, or future) and affective valence (i.e., negative, neutral, or positive). We examined if mindfulness training increased the proportion of present-oriented thoughts as well as the proportion of positive thoughts among highly anxious participants. In addition, we examined if mindfulness training ameliorated the disruptive impact of negative thoughts on task performance.

Another goal of this study was to extend results from study 1 and further understand the relationship among mind wandering, mindfulness training, and motivation. We used the same motivation measures as in study 1, including: (1) motivation to approach reported thoughts; (2) motivation to avoid reported thoughts; and (3) motivation to perform well on the current task. Instead of measuring approach and avoidance motivation towards current concerns and once per task, we asked participants to indicate their levels of motivation towards each reported thought. We then examined if motivation is associated with mind wandering and if mindfulness training has any beneficial impact on motivation.

We predicted: (1) compared to control condition, mindfulness meditation will improve overall performance on the MRT; (2) mindfulness meditation will attenuate the disruptive impact of distractions on task performance; (3) mindfulness meditation will reduce the frequency of mind wandering during the MRT; (4) mindfulness meditation will promote present-oriented and positive thoughts and attenuate the disruptive impact of negative thoughts on task performance; (5) while higher performance motivation is associated with better task performance, higher motivation to approach and to avoid reported thoughts are associated with poorer task performance; and (6) mindfulness meditation will increase performance motivation and reduce motivation to approach and to avoid reported thoughts, especially for distractions and negative thoughts.

Methods

Participants

Undergraduate students (N = 95) were recruited from the University of Waterloo in exchange for course credits. All participants completed the STICSA (Ree et al., 2008) as part of a mass testing procedure in the beginning of the academic term. Only those with a total score higher than or equal to 43 were invited to participate in this study. A cut-off score of 43 on STICSA has been shown to indicate a clinical level of anxiety (Van Dam, Gros, Earleywine, & Antony, 2013). Out of the original 95 participants, we removed four participants who fell asleep during intervention or had not slept for 24 hours, two in the meditation group who were experienced in meditation, two outliers on mean response times (more than two standard deviations from the mean), one with a current diagnosis of major depression, and four who did not comply with task instructions. Hence, there are 82 participants (55 females) with complete data for analyses. Participants were randomly assigned to either the meditation group (N = 42) or the control group (N = 40). The age ranged from 18-24 years, with a mean age of 19.99 years (SD = 1.84). All participants in the meditation group were novices to meditation. Analyses showed no significant difference between two groups in trait anxiety, trait mindfulness, or baseline mood (all $p_s > .07$). No participant was excluded due to excessive omissions (i.e., more than 10% of the trials). Outliers on baseline measures were corrected by replacing their values with the next highest or lowest values. The protocol received ethical clearance from the Office of Research Ethics at the University of Waterloo.

Self-report measures

Participants completed the STICSA (Ree et al., 2008), the Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003), and the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988), measuring individual differences in trait anxiety, trait mindfulness, and baseline mood. The STICSA was included in this study to pre-select highly anxious participants. We used the MAAS to examine if there was any baseline difference in trait mindfulness between the meditation group and the control group as it might contaminate the training effects. The PANAS was employed to explore changes to mood states throughout this study. Participants completed the MAAS in the beginning of this study and the PANAS at two time points: at baseline and at the end of the study. The STICSA was completed online prior to their participation.

The MAAS contains 15 items measuring the ability to sustain conscious awareness of attention in everyday life. Participants rated how often they experienced lapses of attention or conscious experiences on a 6-point Likert scale (from 1 "almost always" to 6 "almost never"). Items are distributed across cognitive, emotional, physical, interpersonal, and general domains. This measures has demonstrated a strong unidimensional factor structure and excellent psychometric properties (MacKillop & Anderson, 2007). The PANAS consists of 20 items measuring mood states, i.e., how the individual is feeling at the moment. This schedule generates two subscales: one measuring positive affect and the other measuring negative affect (10 items each). Participants rated the extent to which their feeling was consistent with each item on a 5-point Likert scale (from 1 "very slightly or not at all" to 5 "extremely"). The PANAS has demonstrated good validity and internal consistency in both clinical and non-clinical samples (Crawford & Henry, 2004; Dyck et al., 1994). Details about the STICSA were reviewed in study 1.

Intervention

Participants in the meditation group practiced a "Mindfulness of body and breath" exercise (Williams & Penman, 2011), in which they were instructed to focus their attention on the breath in their body and to remain open-minded to their experience. This exercise was designed for individuals with no prior experience of meditation and has been used extensively in both MBCT (Segal et al., 2002) and laboratory studies (Erisman & Roemer, 2010; Kramer et al., 2013). Participants were advised to keep their eyes closed during this exercise. The experimenter sat with the participant to ensure task compliance.

Participants in the control group listened to an audiobook version of JRR Tolkein's "The Hobbit" (Inglis, 2012). We selected a narrated story as the control condition because it requires a comparable amount of auditory attention. The audiobook of "The Hobbit" has been used as a control condition in previous studies on mindfulness (Johnson et al., 2013; Kramer et al., 2013; Zeidan et al., 2010). The beginning of the first chapter "An unexpected party" was played through the speakers. Participants were instructed to sit quietly and listen to the story. The experimenter made it explicit that the content of the story would not be tested. Again, the experimenter stayed with the participant to monitor their attentiveness.

The Metronome Response Task (MRT)

Each participant completed two sessions of the MRT as used in study 1. The only difference is its length. Due to time constraints, we included 250 experimental trials in each session of MRT within the current study. There were 18 additional practice trials in the first session MRT.

Thought probes

Participants received thought probes that were similar to those used in study 1. The first question was the same: "what was the thought you were having just prior to this moment". After entering their responses into a textbox on the screen, they received three more questions regarding their motivation: (1) "how motivated were you to think about this thought", i.e., approach motivation; (2) "how motivated were you to avoid thinking about this thought", i.e., avoidance motivation; and (3) "how motivated were you to perform well on this task", i.e., performance motivation. Participants were asked to rate their levels of motivation on a 9-point Likert scale from 1 (no motivation at all) to 9 (very strong motivation). After answering all four questions, participants had to press the spacebar to resume the MRT. Each participant had five thought probes per session.

After initial data collection, we followed the same two-dimensional classification system as in study 1. Three independent judges rated each thought probe on both task-relatedness and stimulus-dependency. Similarly, each thought report was assigned to one of four categories: (1) on-task thoughts; (2) task-related interferences (TRIs); (3) external distractions (EDs); and (4) mind wandering. In addition, all thought reports were rated on temporal orientation (past, present, or future) and affective valence (negative, neutral, or positive) using published criteria (Baird et al., 2011; Franklin et al., 2013; Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Smallwood, Nind, et al., 2009). For thoughts sampled during the second session MRT, they were further rated on training-relatedness (if related to intervention or not), which allowed us to examine participants' task compliance. Analysis revealed satisfactory inter-rater reliability (kappa), ranging from 0.73 to 0.92. Inter-rater averages were calculated and significant discrepancies were resolved through discussion.

MRT measures

We used the same MRT measures as in study 1. We calculated RRT variance for the five trials immediately preceding each category of thought reports: (1) on-task RRT variance; (2) TRIs RRT variance; (3) EDs RRT variance; and (4) mind wandering RRT variance. Therefore, for each participant, we calculated their mean RRT, mean RRT variance, RRT variance associated with each category of thought reports, and omission rate.

Procedure

After providing informed consents, participants completed a set of self-report measures and were then randomly assigned to either the meditation group or the control group. Following this, participants received the first session MRT, which included 250 trials and five thought probes. On completion, they were invited to an adjacent, quieter room and listened to a 10-minute audio recording with instructions to follow along as best as they could. Participants in the meditation group practiced mindfulness meditation, whereas participants in the control group listened to an audiobook. After intervention, participants performed the second session MRT and reported their mood states before they left the laboratory. In total, the whole procedure lasted about 50 minutes. The experimenter remained with the participant only during intervention to ensure task compliance.

Results

Self-report measures and changes in mood state

Participants completed the STICSA, MAAS, and PANAS (T1) at baseline and PANAS (T2) at the end of the study. Means and standard deviations of all self-report measures are presented in Table 7. Independent-sample t-tests were performed to examine differences between the meditation group and the control group. Most importantly, we observed no significant difference between two groups in any baseline measure (all $p_s > .07$). After intervention, two groups reported a similar proportion of thoughts that were related to the intervention they received ($p = .87$), indicating comparable task compliance. To examine the changes in mood states throughout the study, we performed a mixed ANOVA, in which time (T1 vs. T2) was entered as the within-subject factor and condition (meditation vs. control) was entered as the between-subject factor. For positive affect, we observed a significant main effect of time, $F\ (1, 80) = 16.87$, $\eta^2_p = .174$, $p < .001$, but no significant main effect of condition, $F\ (1, 80) = 0.09$, $p = .28$, or interaction, $F\ (1, 80) = 1.20$, $p = .76$. For negative affect, we found a significant main effect of time, $F\ (1, 80) = 7.71$, $\eta^2_p = .088$, $p < .01$, but no significant main effect of condition, $F\ (1, 80) = 2.85$, $p = .10$, or interaction, $F\ (1, 80) = 0.86$, $p = .36$. To our surprise, the results seem to suggest that both groups experienced lower positive and negative affect after intervention.

Table 7. Means and standard deviations of self-report measures.

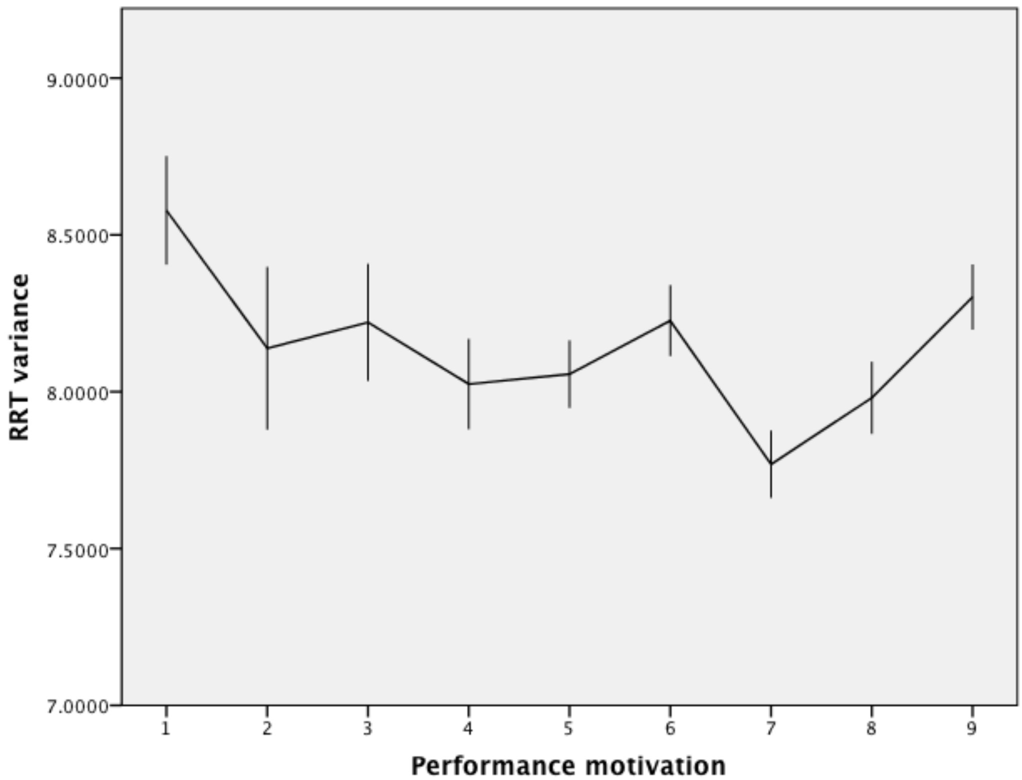
Measures	Meditation group (N = 42)	Control group (N= 40)	*t*	Cohen's *d*
STICSA	50.40 (7.72)	50.40 (7.73)	0.00	0.00
MAAS	51.12 (8.97)	47.76 (7.61)	1.83	0.40
PA T1	23.86 (6.62)	22.55 (5.75)	0.95	0.21
NA T1	15.55 (6.41)	17.30 (6.63)	-1.22	0.27
PA T2	20.62 (9.12)	18.80 (8.06)	0.96	0.21
NA T2	13.64 (5.41)	16.35 (7.14)	-1.93	0.43
Training-related thought reports %	17.62 (21.71)	18.50 (24.97)	-0.17	0.04

Note: Standard deviations from the mean are presented in brackets. STICSA: state-trait inventory of cognitive and somatic anxiety-trait version; MAAS: mindful attention awareness scale; PA: positive affect; NA: negative affect; T1: at baseline; T2: at the end of the study. Independent-sample t-tests were performed to examine between-group differences.

Motivation and MRT performance

We next examined if motivation measures (i.e., approach motivation, avoidance motivation, and performance motivation) predicted task performance at the level of individual thought probes. We first examined the relationship between performance motivation and task performance. Following the approach of Unsworth and colleagues (2014), we used a linear mixed model in which performance motivation and condition were entered as fixed factors and subject was entered as a random factor. When both sessions were combined, we observed a significant linear effect of performance motivation, F (8, 760.99) = 2.69, $p < .01$, but no significant effect of condition, F (1, 95.70) = 0.62, $p = .43$, or interaction, F (8, 760.99) = 1.62, $p = .12$. As shown in Figure 4, this suggests that participants performed better when their performance motivation was higher. However, the linear effect of performance motivation on response variance was only significant during the first session, F (8, 349.69) = 3.39, $p < .001$, not during the second session, F (8, 358.87) = 0.63, $p = .76$. Alternatively, we performed the same linear mixed model based on approach and avoidance motivation. Results indicated no significant effect of approach or avoidance motivation, condition, or interaction (all $p_s > .10$). Only performance motivation predicted task performance at individual thought probes.

Figure 4. RRT variance as a function of performance motivation, when both sessions were combined.



Note: Error bars represent one standard error of the mean.

Did meditation improve overall task performance?

In this study, we used mean RRT, mean RRT variance, and omission rate to represent overall performance during the MRT. Means and standard deviations of MRT measures are displayed in Table 8. To examine the impact of intervention on overall task performance, we performed a mixed ANOVA in which time (session 1 vs. session 2) was entered as the within-subject factor and condition (meditation vs. control) was entered as the between-subject factor. For mean RRT, analysis revealed a significant main effect of time, F (1, 80) = 27.07, η^2_p = .253, p < .001, but no main effect of condition, F (1, 80) = 0.05, p = .82, or interaction, F (1, 80) = 0.55, p = .46. Likewise, analysis on mean RRT variance indicated a significant main effect of time, F (1, 80) = 11.15, η^2_p = .122, p < .01, but no main effect of condition, F (1, 80) = 0.15, p = .70, or interaction, F (1, 80) = 0.39, p = .53. For omission rate, we observed no significant effect of time, F (1, 80) = 0.07, p = .79, condition, F (1, 80) = 0.44, p = .51, or interaction, F (1, 80) = 0.42, p = .52. In summary, meditation did not improve overall task performance as predicted. Instead, both groups demonstrated poorer task performance after intervention.

Table 8. Means and standard deviations of MRT measures.

Measures	Meditation group			Control group		
	Session 1	Session 2	*F*	Session 1	Session 2	*F*
Mean RRT	29.15 (53.20)	15.45 (58.71)	8.06**	22.57 (49.66)	13.19 (56.22)	3.59[1]
Mean RRT variance	8.01 (0.67)	8.19 (0.66)	18.12***	8.06 (0.60)	8.20 (0.62)	9.71**
Omission rate %	0.90 (0.93)	0.94 (1.25)	0.08	1.12 (1.18)	1.03 (1.12)	0.41

Note: For meditation group, N = 42; for control group, N = 40. Standard deviations from the mean are presented in brackets. Multivariate ANOVAs were performed to examine differences between session 1 and session 2. [1] p = .062, ** p < .01, *** p < .001.

Did mind wandering attenuate the disruptive impact of distractions or negative thoughts on task performance?

As few participants reported all four categories of thought reports in both sessions (N = 21), we combined TRIs, EDs, and mind wandering into the same category "distractions" as in study 1. We then examined if meditation helped participant perform better when they were distracted. Means and standard deviations of distractions RRT variance are displayed in Table 9. Again, the same mixed ANOVA analysis (time as within-subject factor and condition as between-subject factor) was performed here. We observed no significant main effect of condition, F (1, 79) = 0.79, p = .38, but a significant main effect of time, F (1, 79) = 5.17, η^2_p = .061, p < .05, and a significant time × condition interaction, F (1, 79) = 7.50, η^2_p = .087, p < .01. Additional analysis showed a significant increase in distractions RRT variance for the control group, F (1, 79) = 12.11, p < .001, but not for the meditation group, F (1, 79) = 0.11, p = .74.

We next performed the same mixed ANOVA analysis on RRT variance associated with negative thoughts. As only 28 participants reported negative thoughts in both sessions, our analysis is limited by this small sample size. Means and standard deviations of negative thoughts RRT variance are also presented in Table 9. We observed no significant main effect of time, $F(1, 26) = 1.41$, $p = .25$, or condition, $F(1, 26) = 0.10$, $p = .75$, but a significant time × condition interaction, $F(1, 26) = 4.30$, $\eta^2_p = .142$, $p < .05$. Further analysis showed a significant increase in negative thoughts RRT variance for the control group, $F(1, 26) = 6.77$, $p < .05$, but not for the meditation group, $F(1, 26) = 0.32$, $p = .57$.

Therefore, during episodes of distractions and negative thoughts, the control group performed significantly poorer after intervention, whereas the meditation group performed equally well if not better in the second session.

Table 9. Means and standard deviations of RRT variance associated with distractions and negative thoughts.

	Meditation group				Control group			
RRT variance	*N*	Session 1	Session 2	*F*	*N*	Session 1	Session 2	*F*
Distractions	42	8.03 (0.86)	7.99 (0.99)	0.11	39	7.94 (0.79)	8.38 (0.83)	12.11***
Negative thoughts	11	8.33 (0.87)	8.13 (1.15)	0.32	17	7.95 (0.94)	8.71 (0.93)	6.77*

Note: Distractions combined task-related interferences, external distractions, and mind wandering. Standard deviations from the mean are presented in brackets. Multivariate ANOVAs were performed to examine differences between session 1 and session 2. * $p < .05$, *** $p < .001$.

Did meditation reduce mind wandering?

To answer this question, the proportions of on-task reports, TRIs, EDs, and mind wandering in each session were calculated. Means and standard deviations of their proportions are displayed in Table 10. As above, a mixed ANOVA analysis (time as within-subject factor and condition as between-subject factor) was performed on each proportion. For the proportion of on-task reports, the mixed ANOVA revealed a significant main effect of time, $F(1, 80) = 12.48$, $\eta^2_p = .135$, $p < .001$, but no main effect of condition, $F(1, 80) =$

0.05, $p = .82$, or interaction, F (1, 80) = 1.12, $p = .29$. For the proportion of TRIs, the mixed ANOVA indicated no main effect of time, F (1, 80) = 0.04, $p = .84$, condition, F (1, 80) = 0.93, $p = .34$, or interaction, F (1, 80) = 0.04, $p = .84$.

Interestingly, for the proportion of EDs, we observed no main effect of time, F (1, 80) = 0.17, $p = .68$, or condition, F (1, 80) = 0.54, $p = .46$, but a significant time × condition interaction, F (1, 80) = 6.09, $\eta^2_p = .071$, $p < .05$. Similarly, analysis on the proportion of mind wandering revealed no main effect of condition, F (1, 80) = 0.07, $p = .79$, but a significant main effect of time, F (1, 80) = 6.97, $\eta^2_p = .080$, $p < .01$, and a significant time × condition interaction, F (1, 80) = 9.28, $\eta^2_p = .104$, $p < .01$. Further analysis indicated that while the control group experienced fewer EDs in the second session, F (1, 80) = 4.05, $p < .05$, the meditation group reported considerably more EDs after intervention, F (1, 80) = 2.17, $p = .15$. Likewise, the proportion of mind wandering increased significantly after intervention for the control group, F (1, 80) = 15.78, $p < .001$, but not for the meditation group, F (1, 80) = 0.08, $p = .77$.

In short, the control group experienced fewer EDs and more mind wandering after intervention, while the meditation group reported considerably more EDs and a stable proportion of mind wandering.

Table 10. Means and standard deviations of proportions of thought reports based on task-relatedness and stimulus-dependency.

Proportions	Meditation group			Control group		
	Session 1	Session 2	*F*	Session 1	Session 2	*F*
On-task %	17.14 (20.99)	10.95 (17.22)	3.13	19.00 (23.07)	7.50 (14.81)	10.30**
TRIs %	7.62 (13.22)	6.67 (13.00)	0.08	9.50 (16.32)	9.50 (19.21)	0.00
EDs %	30.95 (29.03)	38.10 (25.30)	2.17	36.00 (27.25)	26.00 (25.30)	4.05*
MW %	44.29 (29.81)	42.86 (25.21)	0.08	35.00 (31.30)	55.00 (29.96)	15.78***

Note: For meditation group, $N = 42$; for control group, $N = 40$. TRIs: task-related interferences; EDs: external distractions; MW: mind wandering. Standard deviations from the mean are presented in brackets. Multivariate ANOVAs were performed to examine differences between session 1 and session 2. * $p < .05$, ** $p < .01$, *** $p < .001$.

Did meditation promote present-oriented and positive thinking?

To answer this question, we calculated the proportion of each category of thought reports based on temporal orientation and affective valence. Means and standard deviations of their proportions are displayed in Table 11. We first performed the same mixed ANOVA analysis (time as within-subject factor and condition as between-subject factor) based on temporal orientation. For the proportion of present-oriented thoughts, analysis revealed a significant main effect of time, $F\ (1, 80) = 5.23$, $\eta^2_p = .061$, $p < .05$, no main effect of condition, $F\ (1, 80) = 0.62$, $p = .43$, and a marginally significant interaction, $F\ (1, 80) = 3.03$, $\eta^2_p = .036$, $p = .086$. Further analysis indicated a significant reduction in the proportion of present-oriented thoughts for the control group, $F\ (1, 80) = 7.92$, $p < .01$, but not for the meditation group, $F\ (1, 80) = 0.15$, $p = .70$. For the proportion of past-oriented thoughts, we observed a significant main effect of time, $F\ (1, 80) = 7.14$, $\eta^2_p = .082$, $p < .01$, a significant main effect of condition, $F\ (1, 80) = 7.33$, $\eta^2_p = .084$, $p < .01$, but no significant interaction, $F\ (1, 80) = 0.90$, $p = .35$. For the proportion of future-oriented thoughts, analysis revealed no significant effect of time, $F\ (1, 80) = 0.04$, $p = .85$, condition, $F\ (1, 80) = 1.64$, $p = .20$, or interaction, $F\ (1, 80) = 1.69$, $p = .20$.

The same analysis was performed based on affective valence. For the proportion of positive thoughts, a mixed ANOVA indicated no significant main effect of condition, F (1, 80) = 0.76, p = .39, but a significant main effect of time, F (1, 80) = 5.31, η^2_p = .062, p < .05, and a significant time × condition interaction, F (1, 80) = 4.08, η^2_p = .049, p < .05. Further analysis revealed a significant increase in the proportion of positive thoughts for the meditation group, F (1, 80) = 9.58, p < .01, but not for the control group, F (1, 80) = 0.04, p = .84. For the proportion of negative thoughts, we observed no significant effect of time, F (1, 80) = 1.84, p = .18, condition, F (1, 80) = 0.69, p = .41, or interaction, F (1, 80) = 0.57, p = .45. Likewise, for the proportion of neutral thoughts, we observed no significant effect of time, F (1, 80) = 0.68, p = .41, condition, F (1, 80) = 0.12, p = .73, or interaction, F (1, 80) = 0.40, p = .53.

In general, meditation did not seem to promote more present-oriented thoughts. However, the meditation group did report more positive thoughts after intervention, while such an effect was absent in the control group.

Table 11. Means and standard deviations of proportions of thought reports based on temporal orientation and affective valence.

Proportions	Meditation group			Control group		
	Session 1	Session 2	*F*	Session 1	Session 2	*F*
Temporal orientation						
Past %	9.52 (14.13)	13.33 (16.92)	1.52	17.00 (22.44)	25.00 (21.12)	6.39*
Present %	59.52 (29.79)	57.62 (25.45)	0.15	61.50 (29.14)	47.50 (28.17)	7.92**
Future %	30.95 (23.87)	27.62 (24.97)	0.63	21.00 (23.51)	25.50 (28.64)	1.09
Affective valence						
Negative %	17.62 (21.73)	12.38 (13.94)	2.28	18.50 (19.42)	17.00 (18.97)	0.18
Neutral %	78.10 (23.29)	74.29 (23.07)	1.09	75.00 (22.07)	74.50 (20.75)	0.02
Positive %	4.29 (8.31)	11.90 (16.56)	9.58**	6.00 (11.28)	6.50 (12.31)	0.04

Note: For meditation group, $N = 42$; for control group, $N = 40$. Standard deviations from the mean are presented in brackets. Multivariate ANOVAs were performed to examine differences between session 1 and session 2. * $p < .05$, ** $p < .01$.

Did meditation have any beneficial impact on motivation?

We included three motivation measures in this study: approach motivation, avoidance motivation, and performance motivation. Their means and standard deviations are displayed in Table 12. As above, we performed a mixed ANOVA analysis (time as the within-subject factor and condition as the between-subject factor) on each measure. For approach motivation, analysis revealed no significant effect of time, F (1, 80) = 0.01, p = .92, condition, F (1, 80) = 1.82, p = .18, or interaction, F (1, 80) = 0.02, p = .88. For avoidance motivation, analysis showed a significant main effect of time, F (1, 80) = 6.61, $\eta^2_p = .076$, $p < .05$, but no significant main effect of condition, F (1, 80) = 0.24, p = .63, or interaction, F (1, 80) = 2.40, p = .13. For performance motivation, we observed a significant main effect of time, F (1, 80) = 29.45, $\eta^2_p = .269$, $p < .001$, no main effect of condition, F (1, 80) = 0, p = .98, but a borderline time × condition interaction, F (1, 80) = 3.19, $\eta^2_p = .038$, p = .078. Further analysis revealed a significant decrease in performance motivation for the meditation group, F (1, 80) = 6.80, $p < .05$, as well as the control group, F (1, 80) = 25.39, $p < .001$. As shown in Figure 5, performance motivation decreased over time for both groups. However, performance motivation for the meditation group was lower in the first session but higher in the second session.

We next examined if meditation had any specific impact on motivation during episodes of distractions. Means and standard deviations of motivation measures for distractions are included in Table 12. We observed no significant time × condition interaction on any motivation measure (all $p_s > .11$). Similarly, we performed the same analysis on motivation during episodes of negative thoughts. Means and standard deviations of motivation measures for negative thoughts are displayed in Table 12. Our analysis is constrained by a small sample size ($N = 28$). Again, the mixed ANOVA analysis revealed no significant time × condition interaction on any motivation measure (all $p_s > .36$).

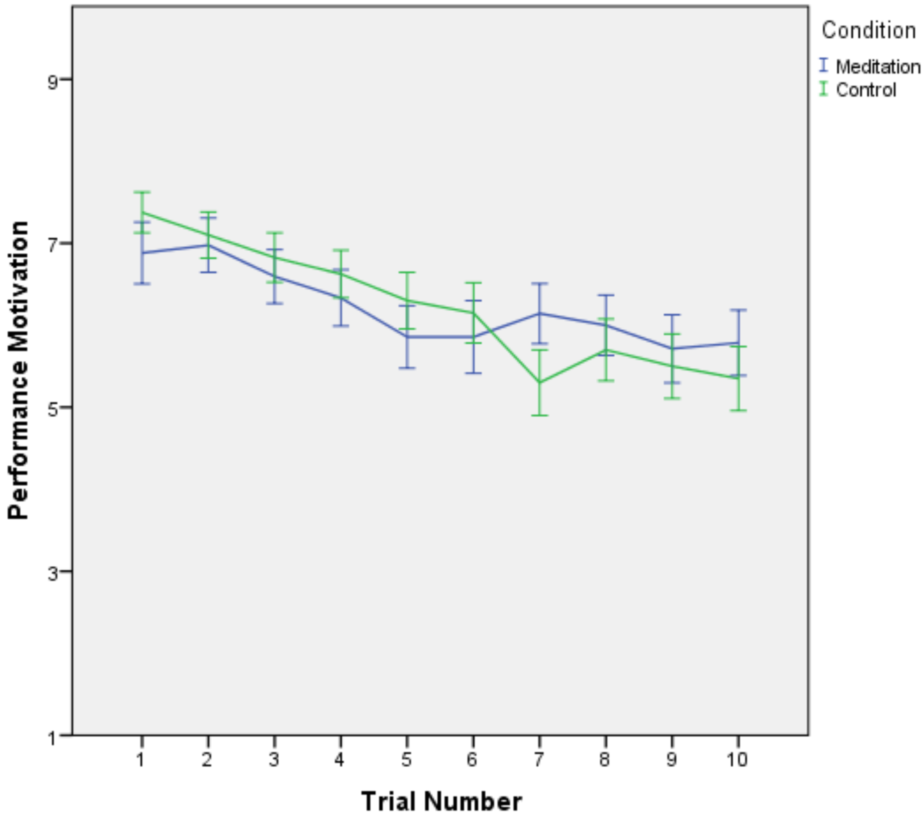
Hence, meditation did not seem to affect approach or avoidance motivation, whether or not during distractions or negative thoughts. General performance motivation decreased over time for both groups. However, meditation might have reversed this trend considerably.

Table 12. Means and standard deviations of motivation measures.

Motivation	Meditation group				Control group			
	N	Session 1	Session 2	*F*	N	Session 1	Session 2	*F*
All thoughts								
Approach	42	4.82 (1.74)	4.77 (2.43)	0.03	40	4.20 (2.02)	4.21 (2.39)	0.03
Avoidance	42	3.11 (1.37)	2.93 (1.79)	0.53	40	3.56 (1.91)	2.81 (1.67)	8.29**
Performance	42	6.53 (1.96)	5.90 (2.25)	6.80*	40	6.85 (1.67)	5.60 (2.13)	25.39***
Negative thoughts								
Approach	11	5.23 (2.67)	4.00 (3.22)	1.98	18	4.43 (2.86)	4.28 (2.67)	0.05
Avoidance	11	3.68 (2.54)	2.59 (2.45)	1.40	18	4.11 (2.94)	4.08 (3.18)	0.00
Performance	11	6.82 (2.26)	4.86 (2.28)	8.38**	18	6.54 (1.86)	4.69 (2.51)	12.25**
Distractions								
Approach	42	4.52 (2.02)	4.59 (2.48)	0.04	39	3.82 (2.09)	3.99 (2.41)	0.28
Avoidance	42	3.23 (1.56)	3.03 (1.90)	0.45	39	3.77 (2.21)	2.98 (1.76)	6.12*
Performance	42	6.51 (2.13)	5.85 (2.28)	7.19**	39	6.74 (1.67)	5.51 (2.18)	23.30***

Note: Distractions combined task-related interferences, external distractions, and mind wandering. Standard deviations from the mean are presented in brackets. Multivariate ANOVAs were performed to examine differences between session 1 and session 2. * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 5. Performance motivation as a function of trial number during the MRT.



Note: Error bars represent one standard error of the mean. Trials 1-5 were recorded in the first session. Trials 6-10 were recorded in the second session. Intervention took place between trial 5 and trial 6.

Discussion

The main purpose of this study was to examine the effects of a brief mindfulness meditation on subjective reports and behavioural measures of mind wandering during the MRT. Contrary to our expectation, meditation did not seem to improve overall task performance as all participants performed poorer after intervention. However, during episodes of distractions, meditation did prevent performance from further decline. Hence, meditation did attenuate the disruptive impact of mind wandering on task performance. While the control group reported fewer external distractions and more mind wandering after intervention, the meditation group experienced considerably more external distractions and a relatively fixed proportion of mind wandering. Results suggest that meditation shifted the focus of attention from internal information towards external stimuli, which might explain how mindfulness training reduces mind wandering.

Another goal of this study was to investigate the mechanism underlying the efficacy of mindfulness training in emotion regulation. We proposed that mindfulness training would promote present-oriented and positive thinking. In contrary to our expectation, mediation did not seem to enhance present-oriented thinking for those who practiced mindfulness. However, meditation did appear to promote positive thinking. After intervention, the proportion of positive thoughts increased almost threefold for the meditation group, but stayed relatively the same for the control group. More importantly, meditation attenuated the disruptive impact of negative thoughts on task performance. During episodes of negative thoughts, the control group continued to perform worse, while meditation prevented performance from deteriorating over time.

Lastly, we explored the relationship among mind wandering, mindfulness, and motivation. Participants performed better at a given thought probe when they reported higher performance motivation. Hence, we replicated the signification association between performance motivation and task performance from study 1 using a linear mixed model. However, we observed no relationship between mind wandering and participants' motivation to approach and to avoid reported thoughts. Inconsistent with our prediction, meditation did not seem to improve performance motivation, as both groups reported a significant reduction in their performance motivation after intervention. Mindfulness did not affect participants' motivation to approach or to avoid thought reports either, whether during episodes of distractions or negative thoughts. Hence, we failed to observe any beneficial impact of mindfulness training on motivation. Although we recruited a group of highly anxious participants in this study, few participants reported negative thoughts in both sessions. Such a low base rate of negative thoughts might have constrained the power of our analyses and contributed to our insignificant results on approach and avoidance motivation.

General Discussion

To bridge two separate lines of research on mind wandering and mindfulness, two experimental studies were conducted using similar research paradigm. In both studies, participants first completed several baseline measures and then completed a sustained attention task—the MRT (Seli, Cheyne, et al., 2013). During the MRT, we asked participants to respond synchronously to a series of metronome tones while reporting the content of their conscious experiences at random thought probes. Each thought report was then rated by independent judges on multiple dimensions and classified into different categories of thought reports. Participants also indicated their levels of motivation during the MRT, including motivation to approach their conscious experiences, motivation to avoid their conscious experiences, and motivation to perform well on the current task. We included these motivation measures as they directly influence participants' internal focus attention and may affect their task performance. To examine mind wandering, we made use of two indexes generated from this paradigm: subjective reports (i.e., proportions of different categories of thought reports) and behavioural measures (i.e., performance on the MRT).

In the first study, we compared two classification systems for mind wandering in terms of their ability to distinguish different categories of thought reports and examined the relationship between mind wandering and motivation. Results are in favour of the two-dimensional system for operationalizing mind wandering (i.e., using both task-relatedness and stimulus-dependency). Participants reported higher motivation to approach their positive current concerns and higher motivation to avoid their current concerns. Due to a low base rate of thought reports that were related to current concerns, we could not proceed with analyses examining the relationship between mind wandering and motivation to approach and to avoid current concerns. However, it was observed that higher performance motivation and more positive affect both predicted less mind wandering and better task performance. Further analysis revealed a robust mediational model—the proportion of on-task thoughts mediated the relationship between performance motivation and overall task performance when controlling for positive affect. Hence, regardless of their mood states, participants with higher performance motivation reported being on-task more often, which then led to better overall performance.

In the second study, we examined the effects of a 10-minute mindfulness meditation on mind wandering using the same research paradigm. Based on findings from study 1, we adopted the two-dimensional classification system for operationalizing mind wandering (i.e., based on task-relatedness and stimulus-dependency) and further explored the relationship among mind wandering, mindfulness, and motivation. In contrary to our prediction, participants in both meditation and control conditions demonstrated deteriorated task performance over time. However, meditation did prevent performance from further decline when participants were distracted. Meditation also prevented participants from having more mind wandering and promoted a shift of attentional focus from internal information to external stimuli. Additionally, participants who practiced meditation experienced almost three times more positive thoughts and showed no performance deterioration during negative thoughts, which might provide some insight into the working mechanism of mindfulness in emotion regulation. Among three measures of motivation, only performance motivation was significantly associated with task performance at the level of individual thought probes. We failed to observe any beneficial impact of mindfulness training on motivation, whether during episodes of distractions or negative thoughts.

Results from both studies support a two-dimensional system for classifying mind wandering. Not all distractions are mind wandering. Instead, previous studies have demonstrated that while some distractions are related to the appraisal of the current task (Smallwood, Davies, et al., 2004), some are oriented towards irrelevant stimuli, whether external or internal (Unsworth, Redick, Lakey, & Young, 2010). Within the dichotomous classification system, a thought report is considered either on-task or off-task (Christoff, 2012; Levinson et al., 2012; McVay & Kane, 2009). However, such a system does not allow us to distinguish task-related interferences and external distractions from thoughts that are both task-unrelated and stimulus-independent. In comparison, a two-dimensional classification system based on task-relatedness and stimulus-dependency (Stawarczyk, Majerus, Maj, et al., 2011) should permit a more precise categorization of conscious experiences. In study 1, the two-dimensional system not only significantly overlapped with the dichotomous system, but also allowed us to distinguish task-related interferences and external distractions from on-task thoughts. In fact, participants performed significantly poorer when they reported task-related interferences and external distractions. Furthermore, we observed a robust interaction effect of task-relatedness and stimulus-dependency on response variance, indicating that task-related thoughts only predicted better task performance when they were also stimulus-dependent. However, we do recognize that there are other factors that should be considered when distinguishing different subcategories of mind wandering, such as the depth of mind wandering and whether mind wandering is spontaneous or deliberate.

Therefore, our studies highlighted the importance of using both task-relatedness and stimulus-dependency for classing mind wandering. Not surprisingly, our findings are consistent with results from previous studies using the same classification system. A similar interaction effect of task-relatedness and stimulus-dependency on response variance was observed when using the SART (Stawarczyk, Majerus, Maj, et al., 2011). A neuroimaging study revealed that task-related interferences and external distractions were associated with higher levels of DMN activity than on-task thoughts (Stawarczyk, Majerus, Maquet, et al., 2011). Hence, one would assume that classic mind wandering (i.e., thoughts that are both task-unrelated and stimulus-independent) should be associated with the poorest task performance. However, results from our studies failed to confirm such a prediction. Instead, we found no significant difference among task-related interferences, external distractions, and mind wandering. More research is needed to examine if classic mind wandering indeed imposes the greatest disruption on task performance. In our studies, we had independent judges rate each thought report using written criteria. Despite our best efforts, participants occasionally gave incomplete information at thought probes and when this happened, thoughts were mostly likely classified as mind wandering. Ratings might be more accurate if we asked participants to rate their own thought reports on task-relatedness and stimulus-dependency. Future studies might also want to draw participants from the general population rather than using just undergraduate students. Given all our participants are enrolled in a fairly competitive university and their abilities to multi-task are likely to be higher than average. Therefore, episodes of mind wandering might not impair their task performance to an extent that we expected.

In both studies, we examined the relationship between mind wandering and motivation, especially participants' motivation to approach and to avoid their conscious experiences. In specific, we asked participants to indicate their levels of motivation towards their current concerns in study 1 and towards each thought report in study 2. We predicted that while higher motivation to approach or to avoid thoughts is associated with poorer task performance, higher motivation to approach and to avoid the same thoughts is associated with the poorest task performance. However, we failed to confirm such a prediction in our studies. In study 1, participants reported higher motivation to approach their positive current concerns and higher motivation to avoid their negative current concerns. However, as few participants reported thoughts that were related to their current concerns during the MRT, we were unable to carry out analyses regarding the relationship between mind wandering and approach/avoidance motivation. To overcome this limitation, we modified our research design in study 2 and measured participants' motivation to approach and to avoid each thought report sampled during the MRT. Surprisingly, neither approach motivation nor avoidance motivation demonstrated a significant main effect on the behavioural measure of mind wandering. Therefore, we did not find any significant relationship between mind wandering and participants' motivation to approach and to avoid their thoughts.

There are several factors that might have contributed to this non-significant result: (1) most thought reports were rated as neutral (74-78%), so participants were not likely to endorse high motivation to approach or to avoid these thoughts; (2) as participants demonstrated deteriorated performance over time, this might have contaminated our results; and (3) as participants received intervention between two sessions of MRT, which might have affected mind wandering and task performance, thus complicating our investigation on mind wandering and motivation. Despite this insignificant result, we still believe it is important for future researchers to examine mind wandering in relation to approach and avoidance motivation. How we prioritize goals, i.e., being motivated to approach some goals and avoid others, guides our internal focus of attention and should therefore affect our conscious experiences. To facilitate this investigation, future studies could consider using experimental manipulation or actual mood induction to elicit higher approach or avoidance motivation.

Other than approach and avoidance motivation, we also measured performance motivation in our studies, which emerged as a significant predictor of mind wandering and task performance. While study 1 examined the relationship between mean performance motivation and overall MRT performance, study 2 explored the relationship between performance motivation and task performance at each thought probe. Higher performance motivation not only predicted better overall performance, but also related to better performance at individual thought probes. More importantly, the proportion of on-task reports significantly mediated the relationship between performance motivation and overall task performance when controlling for positive affect. As reviewed earlier, there has been very limited research into performance motivation and mind wandering. Higher performance motivation did predict better performance on cognitive tasks (Heitz et al., 2008; Unsworth & McMillan, 2014), but only one published study directly investigated the relationship between mind wandering and performance motivation and suggested that their relationship was likely mediated by participants' propensity to engage in off-task thoughts (Unsworth & McMillan, 2013). Our study not only replicated their findings using a more appropriate task (i.e., using the MRT rather than a reading comprehension test) but also demonstrated that the mediational model was still valid when controlling for mood states, which is another important predictor of mind wandering.

The close relationship between performance motivation and mind wandering bears several implications for current research on mind wandering: (1) given the robust association between motivation and mind wandering, motivation should be routinely measured and controlled for in studies examining mind wandering, which is currently absent; (2) enhancing performance motivation might be an effective strategy for reducing mind wandering, which warrants empirical investigation; and (3) to better examine this mediational model, researchers may consider conducting experimental studies in which motivation is manipulated. In fact, we were able to replicate our results and obtained more evidence supporting this mediational mode in a similar but separate study (Seli, Cheyne, Xu, Purdon, & Smilek, In preparation).

Not surprisingly, the 10-minute mindfulness meditation proved to be effective in ameliorating the disruptive impact of off-task thoughts on task performance. While the control group continued to show deteriorated performance during episodes of distractions, those who practiced meditation performed equally well if not better when they were distracted. Unlike previous studies (Mrazek et al., 2013; Mrazek et al., 2012), meditation did not directly improve task performance here but only prevented it from further deterioration. We believe there are two possible explanations for this smaller effect size observed in study 2: (1) our study design was more stringent, as we included both pre-test and post-test, and (2) our mindfulness meditation was relatively short and mild. In a similar study that only involved a post-test, participants who practiced mindfulness breathing for eight minutes performed significantly better on the SART than two other control groups (Mrazek et al., 2012). In fact, if we only included post-test in our analysis, the meditation group did seem to outperform the control group when they were distracted, F (1, 79) = 3.79, p = .055. We would have reached the same conclusion that mindfulness training reduced behavioural indicator of mind wandering if we did not measure participants' performance at pre-test. Therefore, our study provides a more accurate picture of the impact of mindfulness training on mind wandering. In addition, the efficacy of mindfulness training in our study is likely constrained by its length and intensity. When delivered on a regular basis, seven weeks of mindfulness practice led to greater accuracy and lower response variance during the SART from pre-test to post-test (Morrison et al., 2014). Future research should examine if more intense mindfulness training is associated with greater beneficial effects on mind wandering.

Mindfulness training also promoted a particular focus of attention that might be helpful in curbing mind wandering. Although meditation did not reduce the frequency of mind wandering, it did prevent participants from having more episodes of mind wandering over the course of a repetitive, mechanic task. Consistent with findings from previous studies (Morrison et al., 2014; Mrazek et al., 2013), those who practiced meditation reported significantly fewer mind wandering episodes than the control group at post-test, F (1, 80) = 3.96, p = .050, while no significant between-group difference existed at pre-test. Hence, meditation must have shifted their focus of attention to something other than mind wandering thoughts. Indeed, the meditation group reported significantly more external distractions than the control group at post-test, $F(1, 80) = 4.68, p < .05$, but no such difference was observed at pre-test. Hence, meditation promoted a focus of attention away from mind wandering and towards external distractions. Both EDs and mind wandering are task-unrelated, reflecting different levels of distractions. The only difference is that EDs are stimulus-dependent while mind wandering is not. Therefore, meditation seemed to cultivate a focus of attention towards external stimuli other than internal information.

Such a shift in the focus of attention provides an important insight into the working mechanism of mindfulness. This not only explains why mindfulness is effective in curbing mind wandering, but also accounts for its clinical efficacy in managing repetitive thoughts, especially rumination. Repetitive thoughts are characterized as a process of "thinking attentively, repetitively, or frequently about one's self and one's world" (Segerstrom, Stanton, Alden, & Shortridge, 2003, p. 909). In fact, being internally oriented is a defining feature of repetitive thoughts (Watkins, 2008). Rumination, a typical class of repetitive thoughts, is conceptualized as thinking about one's personal goals "in the absence of immediate environmental demands" (Martin & Tesser, 1996, p. 7). Extensive research has demonstrated a close link between rumination and psychopathology (Watkins, 2009). A recent meta-analysis concluded that rumination significantly predicted anxiety, depression, eating, and substance-related disorders, with a large effect size (Aldao, Nolen-Hoeksema, & Schweizer, 2010). If a 10-minute meditation could promote a focus of attention away from internal, abstract information and towards stimuli in the "here and now", more intensive mindfulness training might be capable of reducing repetitive thoughts such as rumination. Indeed, it has been shown that mindfulness-based interventions are effective in treating repetitive thoughts, including rumination (Campbell, Labelle, Bacon, Faris, & Carlson, 2012; Robinson et al., 2010) and worry (Robins, Keng, Ekblad, & Brantley, 2012). Most studies conducted so far focused on attention control as the underlying mechanism of mindfulness training (Lutz et al., 2008), results from our studies suggest that where attention goes is probably as important as how attention is directed.

Mindfulness training also appeared as an effective strategy for emotion regulation. In study 2, the proportion of positive thoughts increased almost threefold for those who practiced meditation, but remained unchanged for the control group. In addition to subjective reports, we also observed beneficial effects of meditation on behavioural measures of negative thoughts. While the control group continued to demonstrate deteriorated performance during episodes of negative thoughts, those who practiced meditation performed equally when they reported negative thinking. Although the relatively small sample size (N = 28) might have limited the generalizability of our results, mindfulness training does seem to effectively enhance emotion regulation through two processes: (1) mindfulness promotes a tendency to engage in positive cognitions, and (2) mindfulness increases one's ability to let go of negative thoughts, thus ameliorating the disruptive impact of negative thoughts on task performance. In fact, there is empirical evidence supporting these two processes. It was found that after an 8-week mindfulness-based intervention, treatment-seeking students demonstrated reduced frequency of negative automatic thinking and increased ability to let go of negative automatic thoughts (Frewen, Evans, Maraj, Dozois, & Partridge, 2007). More systematic research is required to examine these two processes and to better understand the cognitive theories of mindfulness in emotion regulation.

In contrary to our expectation, mindfulness training did not seem to benefit overall task performance. Instead, performance deteriorated over time for both groups and there was no interaction between time and condition. A closer look at the fluctuation of response variance revealed a marked deterioration immediately after intervention, followed by a gradual recovery (see Figure 5). This suggests that task performance deteriorated the most immediately after intervention, regardless of the nature of intervention. In fact, such a robust effect of time on MRT performance has been documented elsewhere. When participants were given two blocks of MRT, their response variance was significantly higher in the second block (Seli, Cheyne, et al., 2013). It is possible that a 10-minute meditation might be too short to override this effect of time. Previous research findings seem to support this explanation: mindfulness training improved sustained attention only in studies that employed an intensive retreat (Chambers et al., 2007) or a longitudinal mindfulness program (Jha et al., 2007), but not in studies that involved short-term training, including a five-day retreat (Tang et al., 2007), two sessions of mindfulness induction (Polak, 2009), and a 25-minute meditation (Johnson et al., 2013). To better understand the observed performance deterioration after meditation, future research will need to (1) employ a sustained attention task that is less affected by intermission, and (2) utilize more intensive and longitudinal mindfulness training.

Mindfulness training did not demonstrate any beneficial impact on motivation either. Participants from both groups reported a marked reduction in performance motivation after intervention. Although meditation might have prevented performance motivation from further decline, such an effect only approached marginal significance. Likewise, we observed no significant effect of meditation on participants' motivation to approach and to avoid their reported thoughts. We recruited highly anxious participants in study 2, assuming they were more likely to report thoughts that they felt motivated to approach or to avoid. However, meditation did not have any beneficial impact on approach and avoidance motivation even when participants experienced distractions or negative thoughts. We believe our measurement might have contributed to this insignificant result: (1) participants might be biased to approach or to avoid their thought reports, but such attentional biases are often implicit and automatic (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van

IJzendoorn, 2007), and (2) despite using an anxious analogue sample, only a small proportion of though reports were rated as negative, which put a significant constraint on our data analysis. Future research might consider using attention tasks such as the dot-probe (MacLeod, Mathews, & Tata, 1986) to measure implicit attentional biases and recruit clinical populations or utilize mood induction procedures to obtain a higher base rate of negative cognitions.

There are other methodological weaknesses with the present studies. In study 1, we used involuntary thought questionnaire as an indirect measure of participants' current concerns. However, the most recent and frequent involuntary thought does not necessarily reflect a current concern. Participants might have reported a situational thought or a thought that is related to a past concern. Besides, when a thought report was rated on its relation to current concerns, independent judges might not have sufficient information to make an accurate decision. Therefore, future research should use a more direct measure of current concerns if possible. The second limitation of study 1 is the retrospective measure of performance motivation. As we only measured performance motivation once at the end of each block, the response participant provided might not represent how motivated they were during the task, but how well they thought they had performed. Hence, they might report higher performance motivation if they thought they performed well, which would contaminate our mediational model. Future studies should measure performance motivation throughout the task as what we did in study 2. One last limitation of study 1 is the experimenter-classified approach. We asked participants to report the content of their conscious experiences and then had independent judges rate each reported thought on task-relatedness and stimulus-dependency. Although all judges were properly trained, we still had many difficulties during our rating process. At times, participants either gave very limited information or reported multiple thoughts within one probe. In those cases, our ratings were not necessarily accurate and they might be influenced by subjective interpretation. Future researchers might consider using a self-classified approach by asking participants to rate their thought reports.

There are also several caveats with study 2. The first limitation is the timing of mood measures. Participants only received PANAS twice—one at the very beginning of the study and the other before they left the laboratory. We did not measure their mood states immediately before or after intervention and therefore had no means to examine the direct impact of meditation on mood states. As a result, we only observed a significant reduction in positive and negative affect over time, with no interaction between time and condition. Another caveat is the short duration of the MRT. Due to time constraints, we only included 250 trials and five thought probes in each session of MRT. Participants rarely reported all types of thought reports within five thought probes, which significantly constrained our ability to analyze behavioural measures. Furthermore, the MRT might be too short to provide an accurate measure of participants' sustained attention. Previous studies usually included 600-900 MRT trials (Seli et al., 2014; Seli, Cheyne, et al., 2013) or at least 500 trials per block as in study 1, which are more than twice the number of trials used in study 2. With a lower demand for sustained attention, it might be harder to distinguish participants who improved on sustained attention from those who did not. Future studies should include more experimental trials and more thought probes. The third limitation is the lack of a passive control condition in this study. We asked the control group to listen to an audiobook, assuming it employed a comparable amount of auditory attention. Although the very task has been used in several studies (Erisman & Roemer, 2010; Johnson et al., 2013; Zeidan et al., 2010), listening to an engaging audiobook such as The Hobbit might further distract participants. We are confident that it was not the case in the present study as participants in both conditions reported a similar proportion of training-related thoughts. However, future researchers may want to include a control condition in which participants simply rest for 10-minutes without listening to any tape.

In both studies, we exclusively focused on the disruptive impact of mind wandering on task performance and explored factors and strategies that can help individuals manage mind wandering. The fundamental assumption, although not explicitly stated, has been that mind wandering is a negative experience that should be minimized. However, such an assumption is clearly one-sided, as research has demonstrated many benefits of mind wandering. In fact, mind wandering facilitates autobiographic memory (Baird et al., 2011), making successful long-term plans (Smallwood et al., 2013), and creative thinking (Baird et al., 2012). During tasks that require continuous attention (such as the MRT), mind wandering is unproductive as it can be a source of error. However, during tasks that are not demanding or tasks that are already automated, mind wandering can be beneficial as it is associated with a range of cognitive capabilities (Schooler et al., 2014). While past-oriented mind wandering is associated with distress and unhappiness (Smallwood & O'Connor, 2011), future-oriented mind wandering orients individuals towards future events (Song & Wang, 2012). Therefore, the costs and benefits of mind wandering are both context and content dependent (Smallwood & Andrews-Hanna, 2013). Given the promising results from both of our studies, it is necessary to continue the research on potential remedies for mind wandering, such as motivation and mindfulness. However, it is equally important for future researchers to note that mind wandering can be beneficial at times and should not be curtailed at all cost.

In conclusion, the present studies provide implications for research on both mind wandering and mindfulness. In study 1, results support a two-dimensional classification system in which mind wandering is operationalized as both task-unrelated and stimulus-independent. Motivation, a construct that has been mostly absent in mind wandering literature, emerged as a promising factor in relation to subjective reports and behavioural measures of mind wandering. Higher performance motivation predicted more on-task reports, which then led to better overall performance. More research is still needed to examine the relationship between mind wandering and one's motivation to approach and to avoid their conscious experiences. In study 2, a brief mindfulness meditation not only ameliorated the disruptive impact of off-task thoughts on task performance, but also shifted the attentional focus from internal information to external stimuli. A better understanding of these two processes will have important implications for treating repetitive thoughts such as rumination and worry. Furthermore, research paradigm on mind wandering provided important insight into the underlying mechanism of mindfulness as an emotion regulation strategy. A 10-minute mindfulness meditation not only promoted positive thinking but also protected task performance from negative thoughts. There are many benefits of bridging these two separate lines of research on mind wandering and mindfulness—mindfulness could be an antidote to mind wandering, and at the same time mind wandering might help us understand the working mechanism of mindfulness.

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