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BRIEF REPORT

Mind Wandering, Motivation, and Task Performance Over Time: Evidence That Motivation Insulates People From the Negative Effects of Mind Wandering

Nicholaus P. Brosowsky
Duke University

Joseph DeGutis
Veterans Affairs Boston Healthcare System, Boston, Massachusetts

Mike Esterman
Veterans Affairs Boston Healthcare System, Boston, Massachusetts, and Boston University School of Medicine

Daniel Smilek
University of Waterloo

Paul Seli
Duke University

In the current study, we examined whether participant motivation was associated with fluctuations of attentional engagement and performance over time. We gauged participants' motivation and depth of mind wandering as they completed the metronome response task to determine whether fluctuations in inattention (indexed by task performance and depth of mind wandering) would be related to fluctuations in motivation. As in prior work, we found that, with increasing time on task, (a) self-reported depth of mind wandering increased, (b) task performance decreased, and (c) motivation waned. Extending this work, we found an interaction between motivation and mind wandering such that mind wandering was negatively associated with task performance when motivation was low, but unrelated to performance when motivation was high. These results suggest that motivation may help improve task performance by reducing the depth of mind wandering, while also providing insulation from the negative effects of mind wandering, when it does occur.

Keywords: mind wandering, inattention, motivation, time on task

A considerable amount of research has demonstrated that mind wandering and task-performance vary as a function of time on task. In particular, with increasing time on task, performance tends to decrease (Helton & Russell, 2011, 2012; Mackworth, 1948; Parasuraman et

Nicholaus P. Brosowsky, Department of Psychology and Neuroscience, Duke University; Joseph DeGutis, Veterans Affairs Boston Healthcare System, Boston, Massachusetts; Mike Esterman, Veterans Affairs Boston Healthcare System and Department of Psychiatry, Boston University School of Medicine; Daniel Smilek, Department of Psychology, University of Waterloo; Paul Seli, Department of Psychology and Neuroscience, Duke University.

Data, analysis code, article preparation code, and preprint are available at osf.io/t45pb.

Correspondence concerning this article should be addressed to Nicholaus P. Brosowsky, Department of Psychology and Neuroscience, Duke University, 417 Chapel Drive, Durham, NC 27708. E-mail: nicholaus.brosowsky@duke.edu

al., 2009) and mind wandering tends to increase (e.g., Cunningham, Scerbo, & Freeman, 2000; McVay & Kane, 2012; Thomson, Seli, Besner, & Smilek, 2014). Traditionally, decreases in performance over time on task have been attributed to the depletion of attentional resources (e.g., Caggiano & Parasuraman, 2004; Helton & Russell, 2013; Hirst & Kalmar, 1987; Warm, Dember, & Hancock, 1996). According to this view, people are limited in the attentional resources available for information processing at any given moment in time. Moreover, the cumulative cost of sustaining attention over time depletes these resources and results in corresponding decreases in performance.

An alternative to the resource depletion account, however, is that increases in time on task result in waning motivation to attend to/perform well on a given task and that such decreases in motivation results in increased mind wandering and decreased task performance (Thomson, Besner, & Smilek, 2015; for similar perspectives, see Esterman, Grosso, et al., 2016; Hancock, 2013; Kurzban, Duckworth, Kable, & Myers, 2013). Here, we examine the veracity of this latter motivation account by exploring the role that participant motivation plays in the fluctuation of attentional engagement and performance over time during a laboratory task.

The motivation account is an extension of the "opportunity cost" model of subjective effort and task performance (Kurzban et al., 2013); a potential framework for understanding the relationship between motivation, mind wandering, and task performance. According to this model, one's attentional resources can be simultaneously deployed to only a limited number of tasks or mental operations. In contrast to the resource depletion accounts (e.g., Caggiano & Parasuraman, 2004; Helton & Russell, 2013; Hirst & Kalmar, 1987; Warm et al., 1996), the opportunity cost model suggests that these resources do not decrease over time, but rather, that the prioritization of allocating resources to one task at the expense of other, potentially more rewarding alternatives (i.e., opportunity cost), increases over time. Such alternative activities could include physically performing other tasks (e.g., watching a movie or writing an e-mail to your friend), deliberately thinking about future tasks (e.g., intentionally mind wandering) or inadvertently finding oneself immersed in task-unrelated thoughts (e.g., unintentionally mind wandering). Accordingly, when the value of these alternative activities exceeds that of the current task, people experience an aversive feeling of mental effort, which results in boredom (Struk, Scholer, Danckert, & Seli, 2020) and, consequently, prompts them to reallocate their resources to these alternatives.

Viewing the extant literature on mind wandering through the lens of the opportunity cost model, Thomson et al. (2015) highlighted an important aspect of most research on mind wandering: Namely, that in such research, participants are often presented with monotonous and boring tasks for which good performance tends to confer little in the way of "benefits" beyond that of pleasing the experimenter and/or contributing to science. Therefore, one ought to expect participants to weigh the costs of attending to such boring and monotonous tasks as greater than the benefits of doing so, and as such, participants should experience relatively high rates of task inattention/mind wandering throughout the task.

There is, however, an additional level of nuance to consider. Because the boring and monotonous tasks that researchers provide are often novel to the participants, information pertaining to the expected utility of sustaining attention to the tasks is not immediately available. Rather, it is only through exposure to such tasks that participants come to gain some appreciation of the costs and benefits of attending to the tasks. Thus, at the outset of the tasks, participants should—given their lack of knowledge pertaining to the potential costs and benefits of attending to the tasks—engage in relatively low rates of inattention/mind wandering, and, over time, as they gain increasing amounts of information about the costs and benefits associated with the tasks, they should increasingly value disengagement over engagement; as such, one should observe decreased attentiveness or increased mind wandering with time-on-task (for a similar argument, see Esterman, Grosso, et al., 2016; Esterman & Rothlein, 2019).

Finally, the reduced value given to the oft-boring and monotonous tasks employed by researchers of mind wandering might be construed in terms of a reduction in motivation to focus on the task as it unfolds (Thomson et al., 2015). And indeed, there is some evidence to suggest that global levels of motivation are associated with both mind wandering and task performance. Unsworth and McMillan (2013), for instance, had participants read a passage and intermittently presented thought probes to gauge whether participants were "on task" or "mind wandering." Following the reading task, a memory test was given and participants reported their level of motivation to perform well on the reading task. Results indicated that people who reported lower overall levels of task-based motivation while reading tended to (a) more frequently engage in mind wandering while reading and (b) perform more poorly on the memory test. Moreover, the researchers found that the association between motivation and test performance was fully mediated by mind wandering: People reporting lower levels of motivation tended to engage in more mind wandering, and this increased propensity to mind-wander was in turn associated with poorer test performance.

Extending the work of Unsworth and McMillan (2013); Seli, Cheyne, Xu, Purdon, and Smilek (2015) sought to determine whether the reported relation between motivation and mind wandering might depend on whether the mind wandering in question occurred with or without intention. The author's reasoned that motivation should influence controlled processes (i.e., intentional mind wandering), but should have little (if any) influence on uncontrolled processes (i.e., unintententional mind wandering; e.g., Giambra, 1995). Seli et al. (2015) had participants complete a sustained-attention task (the metronome response task [MRT]; Seli, Cheyne, & Smilek, 2013) and periodically asked participants to indicate whether they were "on task," "intentionally mind wandering," or "unintentionally mind wandering." As hypothesized, Seli et al. (2015) found that, whereas levels of motivation were negatively associated with participants' rates of intentional mind wandering, they were not associated with rates of unintentional mind wandering during the same task (see also, Seli, Wammes, Risko, & Smilek, 2016).

Although the aforementioned studies provide important insights into the relation between motivation and mind wandering, it is important to note that these studies assessed global motivation levels at the end of the experiments. However, Thomson et al.'s (2015) application of the opportunity–cost model to the mind-wandering literature suggests a more nuanced, tighter coupling of mind wandering, motivation, and performance as they unfold over time. First, Thomson et al.'s motivation account predicts that motivation should fluctuate over time as participants learn the cost and benefits of attending to and performing the task. Second, it predicts that momentary fluctuations in motivation should be negatively associated with mind wandering and task performance; if motivation decreases, attentional resources should be diverted away from the task toward task-unrelated thoughts, resulting in an increase in self-reported mind wandering and poorer task performance.

In the present study, to determine whether such temporally dynamic coupling exists, we assessed task performance, depth of mind wandering (using thought probes with a continuous response scale; e.g., Seli et al., 2014), and participant motivation throughout a sustained-attention task (i.e., the MRT). To index participant motivation over time, we employed a novel probing procedure, which entailed intermittently pausing the task and asking participants to report their current level of task-based motivation. In line with Thomson et al.'s motivation account, we expected to find that fluctuations in inattention—indexed by task performance and depth of mind wandering—would be related to fluctuations in motivation, with a general pattern of decreased motivation over time, coupled with an increase in inattention (i.e., deeper mind wandering and poorer performance).

Moreover, based on work by Unsworth and McMillan (2013), we expected to find that at the within-subjects level, participant motivation would be associated with superior task performance, such that people who report higher levels of motivation should also engage in shallower mind wandering, which should in turn be associated with superior task performance.

Method

All experimental tasks were programmed in HTML, CSS, and JavaScript. The experiment code is available at osf.io/t45pb.

Participants

Participants were 166 individuals who completed a "human intelligence task" posted on the Amazon Mechanical Turk (www.mturk.com). Two participants were removed for not completing the experiment and 15 participants were removed for failing to produce a response to more than 10% of trials, indicating a failure to comply with instructions (see Seli et al., 2013). All participants provided informed consent and were treated in accordance with guidelines approved by the ethics committee at Duke University. Participants were paid $3.00 (U.S. dollars) for completing the task, which lasted approximately 20 min. Participants were told the experiment would take less than 30 min but were not informed about how many trials they would be presented with or how often they would be asked to report their thoughts and/or motivation.

The Metronome Response Task (MRT)

Each MRT trial began with 650 ms of silence followed by the presentation of a tone (lasting 75 ms) and a further 575 ms of silence (total trial duration = 1,300 ms). Participants were instructed to "press the spacebar synchronously with the onset of each tone so that your responses are made at the exact time at which each tone is presented." Participants first completed 18 practice trials to familiarize them with the task. Following the practice trials, participants reported their level of motivation to perform well on the task (see below), after which they completed 600 experimental trials.

Rhythmic-response times (RRTs; Seli et al., 2013) were calculated on each trial as the difference between the onset of each tone and the associated spacebar press. The mean RRT therefore provides a measure of the extent to which participants approximate the onset of the tone. However, variability in RRTs is the primary measure of interest yielded by the MRT (Seli et al., 2013). To compute the RRT variability score, we first categorized RRTs in five-trial moving windows over the task duration. As in Seli, Carriere, et al. (2014), to minimize problems of contamination, we excluded responses from the first five trials of the MRT, as well as the five responses following each thought probes. Within each five-trial window, we then computed the variances of the observed RRTs, after which we normalized these scores using a natural logarithm transform (as in Seli et al., 2013), and then averaged these transformed variance scores for an overall measure of RRT variance (hereafter referred to as "MRT variability"). As we were interested in examining MRT variability as a function of time on task, for each participant, we then calculated MRT variability for each of 4 blocks of 150 trials (which corresponded to the presentation of the motivation probes).

Participant Motivation

To assess participant motivation, we presented four motivation probes throughout the MRT; this allowed us to assess motivation as the task unfolded. Each motivation probe occurred following the completion of 90 MRT trials. Thus, participants received eight motivation probes, two occurring within each block of MRT trials. Participants were informed that they would be periodically asked to report their level of motivation, but uninformed about the frequency of the prompts and the number of intervening trials between prompts. Upon presentation of each motivation probe, participants saw the following instruction: "We would now like to know about your motivation level over the last few minutes of the task. Please be as honest and accurate as possible." The response options were 1 (*not at all motivated*), 2 (*not very motivated*), 3 (*somewhat motivated*), 4 (*very motivated*), or 5 (*completely motivated*).

Depth of Mind Wandering Thought Probes

Throughout the MRT, depth of mind wandering was sampled using intermittently presented thought probes. Four thought probes were randomly presented in each block of 150 trials (for a total of 16 probes). When a thought probe was presented, the task temporarily stopped and the participant was presented with the following question: "To what extent were you mind wandering just before seeing this screen?" Participants were instructed to report their depth of mind wandering by using a sliding scale, the anchors for which were 0 (*not at all mind wandering*) to 100 (*fully mind wandering*). Participants responded by dragging an HTML slider input along the scale. Participants received the following instructions regarding the thought probes:

> While you are completing this task, you may find yourself thinking about things other than the task. These thoughts are referred to as "task-unrelated thoughts." Having task-unrelated thoughts is perfectly

normal, especially when one has to do the same thing for a long period of time.

Over the course of this task, we would like to determine how frequently you are focused on the task and how frequently you are thinking about thoughts that are unrelated to the task. To do this, every once in a while, the task will temporarily stop and you will be presented with a thought-sampling screen that will ask you to indicate whether, just before seeing the thought-sampling screen, you were focused on the task or focused on task-unrelated thoughts.

Being focused on the task means that, just before the thought-sampling screen appeared, you were focused on some aspect of the task at hand. For example, if you were thinking about your performance on the task, or if you were thinking about when you should make a button press, these thoughts would count as being on-task.

On the other hand, experiencing task-unrelated thoughts means that you were thinking about something completely unrelated to the task. Some examples of task-unrelated thoughts include thoughts about what to eat for dinner, thoughts about an upcoming event, or thoughts about something that happened to you earlier in the day. Any thoughts that you have that are not related to the task you are completing count as task-unrelated.

When the thought-sampling screen is presented, we will ask you to indicate the extent to which you were engaged in "task-unrelated thoughts," more commonly referred to as mind wandering.

To do this, we will present you with a thought-sampling screen that looks like this: [example image of input display].

Data Analysis and Article Preparation

This article was prepared using R (R Core Team, 2019). A variety of notable R packages were used for data analysis (Bates, Mächler, Bolker, & Walker, 2015; Fox & Weisberg, 2019; Kuznetsova, Brockhoff, & Christensen, 2017; Singmann, Bolker, Westfall, Aust, & Ben-Shachar, 2019; Wickham, François, Henry, & Müller, 2019; Wickham & Henry, 2019), data visualization (Fox & Weisberg, 2018; Kassambara, 2019; Wickham, 2016; Wilke, 2019), and general article preparation (Aust & Barth, 2018). All data, analysis and article preparation code can be found at osf.io/t45pb.

Results

Participants

Prior to all analyses, data from two participants were removed because they failed to complete the experiment, and data from an additional 15 participants were removed because they failed to produce a response to more than 10% of trials, indicating a failure to comply with instructions (see Seli et al., 2013). Of the 166 participants, 104 completed an optional demographic survey. The full sample consisted of 36 female and 68 male, with an average age of 37.01 (SD = 12.14).

Mind Wandering, Motivation, and Performance

We were primarily interested in the relationship between mind wandering, motivation, and performance fluctuations across the task (see Figure 1 and Table 1). To that end, we compared linear mixed-effect models implemented in R (R Core Team, 2019), with MRT variability as the dependent measure (five-trial windows); subjects as random effects; and trial window, depth of mind wandering and motivation as fixed effects. We tested four models (all include trial window as a fixed factor) with variations of these fixed effects as inputs: (a) mind wandering only; (b) motivation only; (c) both mind wandering and motivation; and (d) mind wandering, motivation, and their interaction.

These analyses could produce several possible outcomes. For example, because overall motivation and mind wandering were correlated across subjects, and because both measures demonstrated similar changes over time, it could be that MRT variability explained by mind wandering and motivation were dependent on shared variance between predictors. In this case both would be significant predictors alone as in Models a and b, but neither would be significant in the same model (c and d). Alternatively, mind wandering and motivation could explain some degree of unique variance in MRT variability, such that both are significant predictors (Models c or d) or interact (Model d).

First, the full model containing both fixed effects as well as the interaction effect (Model d) was preferred over both simple models, Model a, $\chi^2(df = 2) = 39.88$, $p < .001$; Model b, $\chi^2(df = 2) = 94.05$, $p < .001$, and over the model with only main effects, Model c, $\chi^2(df = 2) = 16.4$, $p < .001$. Within model d, the fixed effect of mind wandering was significant, $F(1,15692.02) = 58.54$, $MSE = 127.74$, $p < .001$. As was the effect

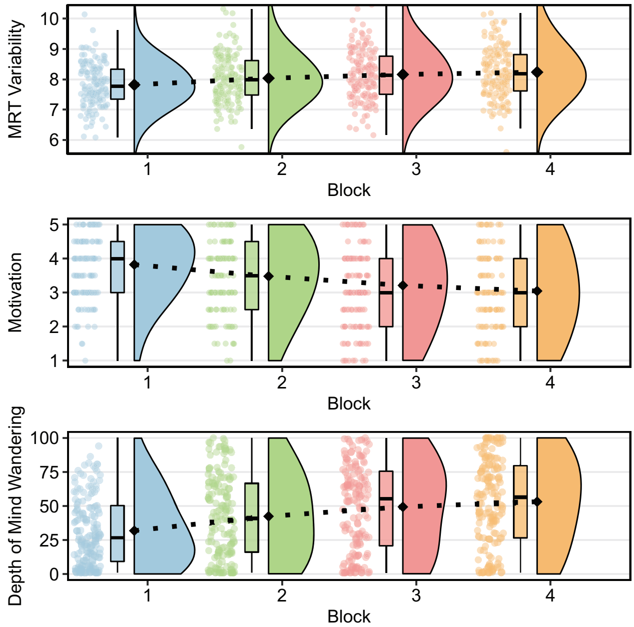

Figure 1. Distributions of participant data for metronome response task (MRT) variability, motivation, and mind wandering, plotted across trial blocks. See the online article or the color version of this figure.

of block, $F(38{,}20919.28) = 19.63$, $MSE = 42.83$, $p < .001$, though the effect of motivation was not, $F(1{,}11233.99) = 0$, $MSE = 0.01$, $p = 0.952$. The main effects, however, were qualified by a significant interaction between motivation and mind wandering, $F(38{,}20919.28) = 19.63$, $MSE = 42.83$, $p < .001$, demonstrating that the effect of motivation on MRT variability depended on the depth of mind wandering. Specifically, there was little to no influence of motivation on MRT variability when participants report no mind wandering and increases as depth of mind wandering increases (see Figure 2).

General Task Performance

Although not of primary interest, for the sake of completeness, we also examined the between-subjects Pearson product–moment correlation coefficients for overall MRT variability ($M = 8.06$, $SD = 0.75$), motivation ($M = 3.39$, $SD = 1.08$), and depth of mind wandering ($M = 44.15$, $SD = 27.11$) across the entire task. Given that prior work (Seli et al., 2013) predicted directional effects, we tested each hypothesis using a one-tailed test. Results indicated a significant positive correlation between overall MRT variability and overall depth of mind wan-

Table 1
Descriptive Statistics Across Blocks for Metronome Response Task (MRT) Variability, Depth of Mind Wandering, and Motivation

Block	MRT variability	Depth of mind wandering	Motivation
1	7.82 (0.7)	31.83 (25.76)	3.82 (1)
2	8.04 (0.83)	42.38 (30.24)	3.48 (1.15)
3	8.16 (0.86)	49.3 (32.23)	3.21 (1.26)
4	8.23 (0.88)	53.11 (31.98)	3.05 (1.31)

Note. Standard deviations are presented within parentheses.

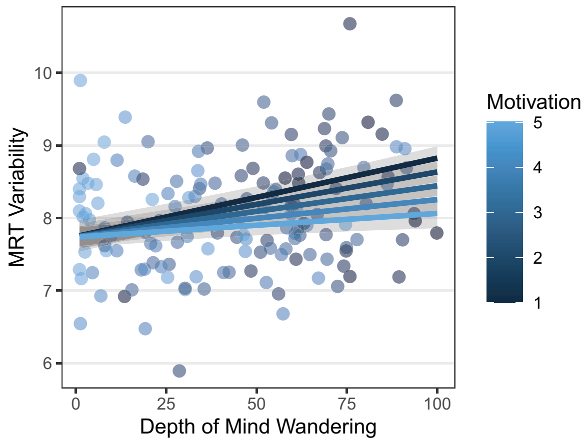

Figure 2. Linear mixed-effect model predictions plotted over participant data; metronome response task (MRT) variability is plotted as a function of depth of mind wandering and motivation. Data points represent average participant depth of mind wandering and motivation scores. See the online article or the color version of this figure.

dering (r = .20, 95% confidence interval [CI] [.04, .35], t(147) = 2.43, p = .008); a significant negative correlation between MRT variability and motivation (r = −.14, 95% CI [−.29, .03], t(147) = −1.66, p = 0.045); and a significant negative correlation between overall motivation and overall depth of mind wandering (r = −.61, 95% CI [−.70, −.50], t(147) = −9.29, p < .001).

Between-Subjects Time-on-Task Effects

Finally, we examined participants' MRT variability, depth of mind wandering, and motivation levels across the four blocks of 150 trials (see Figure 1 and Table 1). We conducted three separate repeated-measures analyses of variance (ANOVAs) examining these measures as function of block (four blocks of 150 trials). Across all three ANOVAs, Mauchly's tests of sphericity were significant (all ps < .001), and as such, we report the Greenhouse–Geisser-corrected values for these analyses. Results of the first ANOVA, which examined MRT variability as a function of block, indicated that there was a significant effect of block, F(2.60, 385.53) = 33.69, MSE = 0.17, p < .001, $\hat{\eta}_p^2$ = .185, 90% CI [0.13, 0.24], as well as a significant linear trend, F(1,444) = 95.81, MSE = 0.15, P < .001, $\hat{\eta}_p^2$ = .177, 90% CI [0.13, 0.23]). Thus, as reported in previous work (e.g., Thomson et al., 2014), here we found that performance worsens (as indicated by *increased* MRT variability) over time on task.

Results of the second ANOVA, which examined depth of mind wandering as a function of the four blocks, likewise indicated that there was a significant effect of block, F(2.55, 376.96) = 55. 68, MSE = 275.07, p < .001, $\hat{\eta}_p^2$ = .273, 90% CI [0.21, 0.33], and a significant linear trend, F(1,444) = 159.76, MSE = 233.54, p < .001, $\hat{\eta}_p^2$ = .265, 90% CI [0.21, 0.32]. Consistent with previous work employing dichotomous thought probes (e.g., Seli, Ralph, Konishi, Smilek, & Schacter, 2017; Thomson et al., 2014), this result indicates that the depth of people's engagement in their mind wandering increases as a function of time on task.

Results of the third ANOVA, which examined participant motivation as a function of the four blocks of the MRT, also yielded a significant effect of block, F > (2.13, 315. 89) = 52.65, MSE = 0.46, p < .001, $\hat{\eta}_p^2$ = .262, 90% CI [0.19, 0.32], and a significant linear trend, F(2.13, 315.89) = 52.65, MSE = 0.46, p < .001, $\hat{\eta}_p^2$ = .262, 90% CI [0.19, 0.32]. Interestingly, and as predicted by Thomson et al. (2015), this result indicates that people's motivation to perform well on the MRT decreased linearly as the task progressed.

Auditory Presentation in JavaScript Web Experiments (Reanalysis of Reimers & Stewart, 2016)

In the MRT participants attempt to synchronize their responses with an auditory stimulus presented every 1,300 ms. One might be concerned about the timing accuracy of presenting repeated auditory stimuli within a web browser. Our data only includes timestamps for when the browser triggers an auditory stimulus, which does introduce some variability (M = 1,302.71 ms), SD = 16.96 ms). This, however, does not give us any information about how variable the timing is between the intended and actual sound delivery; For that, we would need to record the sound delivery externally with specialized equipment.

To date, Reimers and Stewart (2016) is the only study that has looked at auditory presentation accuracy in web-based experiments using this method. Their primary purpose, however, was to determine the lag between visual and auditory stimulus onsets and do not report the variability in auditory onsets. We reanalyzed their open data to address this issue. Their tests ranged in code implementation methods, systems, and browsers. For our present purposes we limited our analyses to the JavaScript implementation methods on FireFox and Chrome browsers running on a desktop PC (Dell OptiPlex 9010 running Windows 7, i3-3220, 8Gb, Intel HD 2500). For their stimulus presentation tests, they presented a 1,000-ms sine wave every 1,500 ms. What we were primarily interested in is the variability in the interstimulus intervals between auditory onsets. We did this by calculating the lag between the intended interstimulus interval (1,500 ms) and the actual interstimulus interval as recorded by the external equipment (see Reimers & Stewart, 2016 for more details).

The coding methods described in Study 1 most closely resembles the coding methods implemented in our experimental design. Reanalyzing this dataset, we found a consistent lag between the intended and actual sound delivery in both Chrome (M = 80.01 ms, SD = 0.05 ms) and Firefox browsers (M = 201.49 ms, SD = 8.51 ms). However, despite the lag, there was little variability in the in the interstimulus intervals. That is, the actual sound delivery tended to lag by 80 to 200 ms but lagged in a reliable manner resulting in a fairly stable interstimulus interval, albeit a longer interval than intended (1,580 to 1,700 ms instead of the intended 1,500 ms).

We also reanalyzed the data from Reimers and Stewart's Study 4. Here they used a more modern method for delivering auditory stimuli whereby the browser "looks ahead" at every animation frame and schedules the auditory presentation using the highly accurate audio clock. The results of this analysis shows considerably reduced lag and variability in both Chrome (M = 0.01 ms, SD = 0.7 ms) and Firefox browsers (M = 71.03 ms, SD = 0.08 ms).

Therefore, we find both coding implementation methods are fairly consistent in their interstimulus intervals, though Chrome seems to outperform Firefox in terms of lag and variability. Limiting participants to using a Chrome browser would therefore improve timing accuracy. We would also recommend that future studies adopt the audio scheduling method to improve timing performance. There are user-friendly JavaScript libraries such as Tone.js (https://tonejs.github.io/; Mann, 2015) that make adopting these more accurate scheduling methods straightforward. Additionally, we have included a more recent code example of the MRT using this method in the OSF repository.

Discussion

In the present experiment, we examined the veracity the motivation account which posits that time-based variations in mind wandering and task performance might owe to a waning of participant motivation over time (Thomson et al., 2015; see also Kurzban et al., 2013). Of primary interest were the relationships among mind wandering, motivation, and performance fluctuations over time. Surprisingly, here we found an interaction between motivation and mind wandering. Whereas Unsworth and McMillan (2013) found that, at the individual-differences level, the influence of motivation on performance was indirect—that is, mediated by mind wandering—our result suggests a more complex relationship between motivation, mind wandering, and task performance. Specifically, we found that depth of mind wandering was not associated with changes in task performance when motivation was high, but that it was negatively associated with performance when motivation was low. Conversely, when depth of mind wandering was low, motivation had little influence on performance.

Considering performance across the task, our results are also consistent with Thomson et al.'s (2015) proposal: We found that, with increasing time on task, (a) self-reported depth of mind wandering increased, (b) task performance decreased, and (c) motivation waned. These findings provide some initial support for Thomson et al.'s (2015) proposal and suggest that when people have low levels of motivation to perform well on a task, they will relinquish control which will in turn result in deeper levels of mind wandering and poorer task performance. Additionally, we found that higher depths of mind wandering were associated with poorer performance overall on the MRT task and associated with lower motivation.

More generally, collapsing across blocks we found that depth of mind wandering was associated with poorer performance on the MRT task and lower motivation. Additionally, we found that higher rates of motivation were associated with better performance on the MRT task. This latter result is notable in that a recently attempted conceptual replication of Seli et al. (2013) failed to find an association between overall rates of motivation and overall performance on the MRT task (Anderson, Petranker, Lin, & Farb, 2020). Here, we do find a significant association. However, it is worth noting that this is only significant using a one-tailed test—and would be nonsignificant with a two-tailed test—so we encourage the reader to cautiously interpret this result, and conclude that more research on this issue is needed to draw a definitive conclusion.

Returning to the primary result, the interactive relationship between mind wandering and motivation is both interesting and novel. On the one hand, it suggests that when depth of mind wandering is high, motivation might insulate performance from the negative consequences of inattention. That is, the positive association between mind wandering and impaired performance was strongest when motivation was low and weakest when motivation was high. This would be heartening as it would suggest that by influencing motivation, researchers might be able to increase the likelihood that people will value task engagement over disengagement, while also providing insulation from the negative effects of mind wandering, when it does occur. On the other hand, when depth of mind wandering was already low, motivation appeared to have little influence on performance. This could be because (a) whereas motivation influences performance by increasing attentional focus, (b) when attention is already maximally focused on the task, motivation has little influence. Importantly however, we cannot assess the causal direction of the moderating effects. Future work is needed to determine whether mind wandering is moderating the effect of motivation or motivation moderating the effect of mind wandering.

Similarly, it remains unclear how motivation might be able to shield task performance from the negative effects of mind wandering. One possibility is that motivation facilitates participants' automatization of the primary task, freeing up resources for mind wandering, while reducing the negative impact on of mind wandering on performance (Brosowsky, Murray, Schooler, & Seli, 2020; Esterman, Noonan, Rosenberg, & DeGutis, 2013; Esterman & Rothlein, 2019; Mason et al., 2007; Teasdale et al., 1995; see also, Moors & De Houwer, 2006). Alternatively, motivation may influence cognitive flexibility (Braem & Egner, 2018; Diamond, 2013), task monitoring, or proactive control (Botvinick & Braver, 2015; Esterman, Poole, Liu, & DeGutis, 2016). If, for instance, we assume that switching between internal and external tasks is effortful and resource-demanding, and results in a performance cost (e.g., Monsell, 2003), then motivation may enable greater flexibility in switching, thereby reducing that cost (Botvinick & Braver, 2015).

Motivation may also facilitate on- versus off-task monitoring such that the influence of mind wandering is reduced because participants more quickly become conscious of off-task thoughts and are therefore able to reorient their attention back to the task when their performance begins to suffer. Thus, meta-awareness of attention and performance monitoring, may not be entirely captured by our measure of mind wandering. The frequency and/or depth of mind wandering could be similar across participants but those with high motivation—and better monitoring—might be more strategic about when they engage in mind wandering and when they do not (e.g., Seli et al., 2013, 2016). Therefore, another potentially fruitful avenue for future work is to examine how the negative effects of mind wandering could be mitigated through metaawareness, task and performance monitoring, and switching flexibility.

Through the lens of the opportunity cost model, our finding can be interpreted straightforwardly: being incentivized or motivated to perform the task, shifts the cost-benefit analysis (biasing it toward more task-related benefits than costs), and as such, increases the likelihood of sustained engagement. It is important to note, however, that we did not manipulate motivation. Instead, we measured participants' motivation to perform the task. Further work is needed to assess the effects of manipulating motivation on mind wandering and task performance. In any case, given that mind wandering is frequently associated with costly errors (see Mooneyham & Schooler, 2013, for a review), our results are particularly encouraging, and suggests a new avenue of research for potential methods of remediation aimed at improving task-attentiveness and performance.

In addition to speaking directly to the literature on mind wandering, the present findings also speak to the resource depletion account of the vigilance decrement. According to this view, successful completion of vigilance tasks requires limited attentional resources and as a vigil unfolds over time, the available resources are systematically depleted leading to performance declines over time on task (Helton & Warm, 2008; Smit, Eling, & Coenen, 2004). Along these lines, Helton and Warm (2008 p. 22) note that "observers reported feeling less energetic after the vigil than prior to its start. Decreasing energetic arousal indicates mental fatigue or resource depletion." From this perspective, our findings could be interpreted such that depleted resources simultaneously causes both lowered motivation and increases in mind wandering. Alternatively, individuals may become less interested in completing the task as it unfolds. The reduction in energetic arousal over time-on-task reported by Helton and Warm (2008) might therefore not reflect resource depletion, but rather increasing levels of boredom that might accompany low levels of motivation. In this case, poor task performance is not caused by a lack of resources, but instead by a reallocation of resources to mind wandering or off-task thoughts.

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