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Studying in the region of proximal learning reduces mind wandering

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Abstract Insofar as mind wandering has been linked to poor learning, finding ways to reduce the propensity to mind wander should have implications for improving learning. We investigated the possibility that studying materials at an appropriate level of difficulty with respect to the individual's capabilities—that is, studying in the region of proximal learning (RPL)—might reduce mind wandering. In Experiments 1 and 2, participants were probed for their attentional state while they studied blocks of English–Spanish word pairs that were (a) easy, (b) in the RPL, or (c) difficult. We found that studying materials in the RPL was associated with reduced mind wandering. Test performance on items studied while mind wandering was also poorer. In Experiment 3, we investigated the relation between differences in participants' mastery and mind wandering. We found that high performers mind wandered more when studying the easier word pairs, whereas low performers mind wandered more when studying the difficult items. These results indicate that the RPL is specific to the individual's level of mastery and that mind wandering occurs when people are outside that region.

Keywords Mind wandering · Region of proximal learning · Learning and memory · Metacognition · Attention

The tendency for our thoughts to drift away has been given many names, such as daydreaming (Singer, 1975), task-unrelated thought (Smallwood, Baracaia, Lowe, & Obonsawin, 2003), and more recently, mind wandering (Smallwood & Schooler, 2006). From mindless reading to imagining a night out, mind wandering is characterized by the decoupling of thought from the current task onto internal mental events (Smallwood, 2013; Smallwood & Schooler, 2006). Imaging studies linking mind wandering to the default mode network activity (e.g., Mason et al., 2007) support the idea that mind wandering is linked to disengagement from the external environment (Schooler et al., 2011). Unfortunately, we are not always aware when our thoughts drift off, since the propensity to do so is spontaneous and often occurs without awareness (Christoff, 2012; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). Worse yet, our minds engage in off-task thinking up to 50 % of the time (Killingsworth & Gilbert, 2010), and it is thought to be very difficult to prevent it from happening.

There is abundant evidence that when the mind goes offline, performance suffers. From increased error rates on simple vigilance tasks (e.g., McVay & Kane, 2009; Smallwood et al., 2004) to poorer response inhibition and working memory (e.g., Kam & Handy, 2014), poorer performance on daily-life activities (McVay, Kane, & Kwapil, 2009), and lower life satisfaction (Mar, Mason, & Litvack, 2012), mind wandering has been associated with deficits on a variety of measures. Not only does task performance decline, but people also process fewer details and are less aware of events around them when our minds drift off. Neurocognitive studies have linked mind wandering with attenuated sensory (Braboszcz & Delorme, 2011; Kam et al., 2011; O'Connell et al., 2009), cognitive (Smallwood, Beach, Schooler, & Handy, 2008), and affective (Kam, Xu, & Handy, 2014) processing of stimuli. Moreover, previous research showed that people exhibit irregular eye movements and blink patterns during periods of mindless reading (Franklin, Smallwood, & Schooler, 2011; Reichle, Reineberg, &

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Schooler 2010; Smilek, Carriere, & Cheyne, 2010; Uzzaman & Joordens, 2011). The costs of mind wandering are widespread and extend beyond conventional experiments to important real-life activities such as learning.

Indeed, those who have reported more mind wandering have also performed worse on measures of reading comprehension and memory for lecture material. Mind wandering has been linked to impaired reading comprehension (Feng, D'Mello, & Graesser, 2013; Franklin et al., 2011; Reichle et al., 2010; Smallwood, 2011; Smallwood et al., 2004), worse knowledge retention (Farley, Risko, & Kingstone, 2013; Thomson, Smilek, & Besner, 2014), poorer memory for online lectures (Szpunar, Khan, & Schacter, 2013), lower exam and SAT scores (Lindquist & McLean, 2011; Unsworth, McMillan, Brewer, & Spillers, 2012), and diminished recall (Feng et al., 2013; Metcalfe & Xu, 2016; Smallwood, McSpadden, & Schooler, 2007). When we disengage from tasks requiring high levels of processing—for instance, reading or word encoding—our ability to process and perform the task worsens (Feng et al., 2013; Foulsham, Farley, & Kingstone, 2013; Smallwood et al., 2003). Furthermore, performance decrements were specific to the periods of offline thinking: participants who reported mind wandering when reading specific passages also recalled less when asked about those passages (Smallwood, McSpadden, & Schooler, 2008). Simply put, mind wandering appears to pose a serious threat to learning, making it crucial to understand what might drive one's mind to go offline, and how this might be prevented.

Considerable research has suggested that factors such as boredom and fatigue (Smallwood & Schooler, 2006), as well as negative affect (Killingsworth & Gilbert, 2010), are correlated with an increased propensity to mind wander in daily life. Data from Risko, Anderson, Sarwal, Engelhardt, and Kingstone (2012) showed that students mind wandered more and recalled less during the second half of an online lecture, as opposed to the first half. As people spend more time on a task, fatigue and boredom increase, making it more likely for their minds to drift off (McVay & Kane, 2009; Metcalfe & Xu, 2016; Smallwood et al., 2003; Smallwood, Riby, Heim, & Davies, 2006). Work on individual differences also suggests that motivation and interest alter one's tendency to mind wander (Antrobus, Singer, & Greenberg, 1966; Grodsky & Giambra, 1990–1991; Jackson & Balota, 2012; Krawietz, Tamplin, Radvansky, 2012; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Unsworth et al., 2012; Unsworth & McMillan, 2013). For example, Unsworth and McMillan proposed a model in which interest predicted motivation, and motivation in turn predicted mind wandering. Thus, fatigue and boredom appear to increase the proclivity to mind wander, whereas increased interest may keep a person on task.

To date, though, few empirical experiments have investigated methods to reduce mind wandering. The motivational and interest finding (e.g., Unsworth & McMillan, 2013)—that people who report being more interested tend not to mind wander—suggest that if it were possible to experimentally manipulate interest, this might affect one's proclivity to mind wander. The region of proximal learning (RPL) model, which will be discussed in a moment, proposes that if the difficulty of the task is calibrated to the knowledge state of the learners, their interest can be elicited. We therefore used the individually calibrated level of task difficulty, as determined by the model, to investigate whether studying in one's own RPL might reduce mind wandering.

According to the RPL framework, people learn best and are most engaged when performing tasks whose difficulty is titrated to their own ability and expertise level (Metcalfe, 2009, 2011; Metcalfe & Kornell, 2005). People become bored from the lack of challenge in very easy tasks, and at the other extreme, exceedingly difficult tasks can be frustrating and tedious. Thus, people should spend more time and effort on tasks in their own RPL. The idea of tasks being "just right" is similar to previous theories of human instruction and learning (e.g., Atkinson, 1972; Berlyne, 1978; Piaget, 1952; Vygotsky, 1987), which have proposed that people focus on materials that are most amenable to being mastered. An individual's RPL consists of items just beyond the learner's mastery—that is, the easiest as-yet-unmastered materials. On the other hand, both already-mastered and more difficult items are outside the RPL.

The RPL framework is compatible with the work of Berlyne (1978), who investigated the relation between curiosity and stimulus complexity. He found that arousal, measured by pupil dilation and skin conductance, was elicited when people looked at slightly asymmetric patterns (Berlyne, 1978). People were more curious and spent a longer time staring at those slightly challenging images than at either very simple, predictable, symmetric images (i.e., too easy) or complex and unpredictable images (i.e., too difficult). Materials in one's own RPL are analogous to Berlyne's slightly asymmetric patterns, since they would be slightly beyond an individual's current grasp and should, therefore, elicit curiosity when studied.

Experimental data on study choice and time allocation have shown that people tend to select and focus on studying items inside their own RPL (e.g., Metcalfe, 2002; Son & Metcalfe, 2000). For instance, participants often select the easiest as-yet-unlearned items to study (Kornell & Flanagan, 2014; Kornell & Metcalfe, 2006; Metcalfe, 2002, 2009; Metcalfe & Kornell, 2003, 2005; Thiede & Dunlosky, 1999). Kornell and Metcalfe (2006) found that participants learned more when they were forced to study RPL materials, as opposed to non-RPL materials. Despite having the same amount of study time, participants recalled fewer non-RPL items when assigned to study them. These findings in support of an RPL highlight the importance of focusing on individually appropriate tasks and materials.

As learning progresses, the particular items occupying an individual's RPL change. Metcalfe (2002) showed that college students initially focused on items of medium difficulty, turning to more difficult items only when study time was increased. In another study, Price and Murray (2012) had naïve Chinese speakers select Chinese characters of varying difficulties for study. Initially, the participants chose to study the easiest Chinese characters, but over time they began selecting characters of medium difficulty, suggesting that they had learned the easier alternatives (Price & Murray, 2012). This transition toward more difficult materials arguably occurs after an individual has mastered the easier materials. Thus, the RPL is constantly adjusted to fit the individual's current level of learning, and differs among individuals.

Insofar as individuals differ in their knowledge and expertise, each person's optimum study choice of material difficulty, which is based on that person's RPL, is expected to differ. An expert has the correct schemas and knowledge to master more difficult tasks and materials than does a novice. Tasks and materials inside the expert's RPL are, hence, more difficult than those within the RPL of a novice. Metcalfe (2002) showed that items occupying the RPL of fluent Spanish speakers were more difficult than the items in the RPL of novice Spanish speakers. Similarly, concepts and information occupying the RPLs of top-performing students would be expected to be more difficult than those in the RPLs of students who have yet to grasp the basics—a topic that we investigated in Experiment 3.

We explored the relation between the RPL and mind wandering in Experiments 1 and 2 by giving participants a pretest, in an attempt to determine which word pairs were in their RPLs, and then having them report their attentional states while studying a series of pairs that were (a) very easy, (b) in the RPL, or (c) too difficult. We predicted that participants would mind wander less when studying in their RPLs, as opposed to when studying very easy or very difficult materials. We also expected participants to mind wander more over time as they became fatigued.

Experiment 1

The participants in Experiment 1 took a pretest and provided judgments of learning (JOLs) on a series of English–Spanish word pairs. This pretest was intended to allow us to classify pairs into those that were too easy, too difficult, or in the RPL. Participants then studied the word pairs—blocked by whether the pairs were easy, in the RPL, or difficult—and were probed, while doing so, to see whether they were mind wandering. They then completed a final test. We predicted that participants would learn a higher proportion of RPL word pairs than of either the too-difficult or the too-easy pairs. We also predicted that participants would report less mind wandering when studying materials in the RPL than when studying materials that were either too easy or too difficult. Finally, we predicted that items "studied" while people were mind wandering would be learned worse than those studied when they were on task.

Method

Participants

In all, 25 Columbia University undergraduates participated for partial course credit, but one participant was excluded for not understanding the task and two were excluded for not completing the experiment, resulting in 22 usable participants (13 females and nine males; $M = 20.14$ years old, $SD = 1.93$). One participant reported being a native Spanish speaker and was included because the RPL was computed to the participant's expertise. Excluding this participant did not change the patterns in the data, however. We approximated the number of participants needed for this experiment from the numbers in previous RPL experiments (e.g., Kornell & Metcalfe, 2006). All participants gave written consent and were treated in accordance with the ethical principles of the Psychonomic Society and of Columbia University's Internal Review Board.

Materials

The materials used were 155 English–Spanish word pairs, 144 of which were taken from previous research (Metcalfe, 2002; Metcalfe & Kornell, 2003, 2005). The additional 11 Spanish–English pairs that were added were perfect conjugates, so participants without any Spanish background would be able to guess the translations and/or provide high JOLs. The word pairs varied in difficulty from perfect conjugates (e.g., TAXI and TAXI), to medium items (e.g., MUSIC HALL and VODEVIL), to very difficult pairs (e.g., STAIN and CHAFARRINADA).

Design

We used a within-participants design in which we treated difficulty—easy, RPL (medium), or difficult, which was determined by a pretest for each participant individually—as if it were an independent variable. The duration of each study block was also manipulated. There were four duration levels of probe timing (15, 30, 60, and 90 s), crossed with each of the three difficulty levels. We varied duration so that participants would not be able to anticipate the onset of the attentional probe during study, and collapsed across duration for the analysis. The dependent variables of interest were the frequency of reported mind wandering, measured in the study phase, and learning, measured by proportions correct in the final test. A total of 12 blocks were presented, four per difficulty level. Blocks were permuted such that each of the three difficulties—easy, RPL (medium), and difficult—showed up in a randomized fashion every three blocks, but associated with different durations. Each word pair was presented an average of 7.70 times over the course of the entire study period (SD_{easy} = 2.87, SD_{RPL} = 2.75, SD_{diff} = 2.80).

Procedure

This experiment had three parts: (1) pretest, (2) study phase, and (3) final test. The pretest enabled the categorization of word pairs into the easy, RPL (medium), and difficult categories for study. In the study phase, participants were asked to study the word pairs, blocked by difficulty, while from time to time reporting whether they were on task or mind wandering. Finally, at the end of the experiment, participants were tested on their learning.

Pretest Participants were instructed to provide Spanish translations for the 155 English words presented one at a time onscreen. They were then shown the correct translation. Whenever they provided either an incorrect or no translation, they were asked to make a JOL following the corrective feedback. Item presentation was randomized, and participants had up to 25 s to provide the translation for each item. Feedback in the form of the correct Spanish translation was given in either green, when they were correct, or red, when incorrect. JOLs were made on a slider scale ranging from *not at all learned* to *completely learned*. Strict scoring was used on the spelling of each response

Materials were sorted into three levels of difficulty, based on each participant's individual pretest response accuracy and JOLs: *easy* (close to accurate or accurate), *RPL* (inaccurate but high JOLs), and *difficult* (inaccurate and lowest JOLs). Thirty-five items were sorted into each level of difficulty. Of these, 25 items at each difficulty level were presented for study, and the remaining ten were used as unstudied control items on the final test. When participants did not have 35 items to which they had given the correct translation, pairs to which they had given wrong answers but with the highest JOLs were added to the easy condition. In total, 20.3 out of the 35 word pairs had been correct on the pretest in the easy condition, which meant that, unfortunately, quite a few of the easy items had not been fully mastered a priori.

Study phase Participants were asked to study the English–Spanish word pairs, one at a time, with the English word on the top and the to-be-learned Spanish word on the bottom. Individual word pairs were presented sequentially on screen for 900 ms, with a 100-ms interstimulus interval (ISI). Participants were also instructed that they would be asked to report their attentional state as either *on task* or *mind wandering* from time to time, when a probe appeared. Mind wandering was operationalized as "when [one is] not paying attention to the task (i.e., learning the word pairs) or [when one was] thinking of something other than the task." As we noted above, pairs were blocked at the time of presentation, such that items solely within one difficulty level appeared together in a sequence, followed by an attentional probe that could occur after 15, 30, 60, or 90 s of study at a particular difficulty level.

The probes were designed to imitate the word pair presentation, but with the terms MIND WANDERING and ON TASK being displayed instead of a word pair. Probes were shown for 900 ms with a 100-ms ISI repeatedly, with MIND WANDERING randomly alternating at either the top or the bottom, until the participant had provided his or her attentional report. We recorded both participants' reported attentional states and the amount of time it took for them to provide the response.

Final test Participants were provided with each English term and asked to recall the Spanish translation. No feedback was given. A total of 105 cue words were presented, with 35 cues per difficulty level (25 studied and ten unstudied). Presentation order was randomized, and participants had up to 25 s to provide a translation. Recall performance was strictly scored for accuracy. All experimental procedures were conducted using MATLAB 2013a and Psychtoolbox Toolbox on Macintosh computers.

Results

For all experiments, the criterion for significance was set at $p <$ .05. Partial eta-squared (η_p^2) was used as the measure of effect size for all analysis of variance (ANOVA) data. Post-hoc t tests were computed for follow-up comparisons on significant effects, and the associated p values and 95 % confidence intervals (CI) are directly reported. Cohen's d was used as a measure of effect size for the t tests.

Final test performance

To ensure that participants were performing the task—that is, actually studying—we compared final test performance between the studied pairs and the unstudied controls. We found an overall effect of studying, such that participants' test performance was significantly better on pairs they had studied, M = .47, SD = .13, than on the unstudied control pairs, M = .35, SD = .14; $t(21)$ = 6.81, p < .001, 95 % CI [.02, .08], d = 1.46. Note, though, that "unstudied" is something of a misnomer: even items that were designated as "unstudied" were given

Table 1 Pretest and final test performance means for categorized word pairs in Experiments 1 and 2

	Pretest	Final Test		Learning
		Unstudied	Studied	
Experiment 1				
Easy	.58 (.32)	.71 (.23)	.86 (.14)	.27 (.25)
RPL	0	.35 (.22)	.50 (.25)	.50 (.25)
Difficult	0	0 (.02)	.05 (.07)	.05 (.07)
Experiment 2				
Easy	1.00	.87 (.15)	.92 (.07)	—
RPL	0	.39 (.20)	.56 (.19)	.56 (.19)
Difficult	0	.02 (.07)	.06 (.09)	.06 (.09)

Standard deviations are in parentheses. Learning was calculated by taking the difference between final test and pretest performance on studied items. Learning was not calculated for the easy word pairs in Experiment 2, because items were sorted on the basis of being accurate at pretest. In Experiment 2, there was one participant who had only five word pairs in the easy condition, but this participant was still included

corrective feedback immediately following the pretest response, so some learning could be attributed to that single study opportunity.

We also observed a significant difference in final test performance among the studied items at the three difficulty levels, $F(2, 42) = 226.29$, $p < .001$, $\eta_p^2 = .92$. Participants performed best on the easy pairs, then on the RPL (medium) pairs, and worst on the difficult pairs, as is shown in Table 1. As we noted previously, 58.3 % of the easy pairs had been correct on the pretest, whereas none of either the RPL or the difficult pairs had been correct. If we take the measure of learning to be proportion correct on the final test minus proportion correct on the pretest, for the RPL and difficult word pairs, learning simply corresponded to the final test performance. For easy items, though, the difference between final test and pretest performance is not the same as the final test performance. With this difference as a measure of learning, a significant effect of difficulty was found, $F(2, 42) = 21.65$, $p < .001$, $\eta_p^2 = .51$. As is shown in Table 1, participants learned more RPL items ($M = .50$, $SD = .25$) than either easy items ($M = .27$, $SD = .25$), $t(21) = 2.49$, $p = .021$, 95 % CI [.04, .41], $d = 0.91$, or difficult items ($M = .05$, $SD = .07$), $t(21) = 9.24$, $p < .001$, 95 % CI [.35, .55], $d = 2.46$. They also learned significantly more easy word pairs than difficult word pairs, $t(21) = 3.87$, $p = .001$, 95 % CI [.10, .34], $d = 1.22$.

Mind wandering

Participants' minds wandered an average of .36 of the time ($SD = .15$). A significant effect of difficulty on mind wandering emerged, $F(2, 42) = 4.33$, $p = .02$, $\eta_p^2 = .17$, as is shown in the left panel of Fig. 1. Participants reported significantly more mind wandering when they were studying difficult items than when studying RPL (medium) items, $t(21) = 2.66$, $p = .015$, 95 % CI [.05, .38], $d = 0.57$. There was no difference in the rates of mind wandering when studying easy versus RPL items, $t(21) = 0.70$, $p = .49$, 95 % CI [−.18, .09], $d = 0.15$. We did observe a trend for minds to wander less when studying easy items than when studying difficult items, $t(21) = 2.02$, $p = .06$, 95 % CI [−.01, .35], $d = 0.43$.

Mind wandering–learning relation: Between-participants

We found no correlation between participants' proportions of mind wandering in the experiment and their average test performance, $r = .19$, $t_r(20) = 0.88$, $p = .39$, 95 % CI [−.25, .57]. In this experiment, then, people who mind wandered a lot did not perform worse than those who rarely mind wandered.

Mind wandering–learning relation: Within-participants

The data were divided into items that were presented just before people reported being on task or just before they reported that they were mind wandering. Although how far back in time the state reported at the time of the probe extended is not known precisely, previous studies have used time windows of approximately 9–12 s when binning data on the basis of attentional state (e.g., Braboszcz & Delorme, 2011; Kam

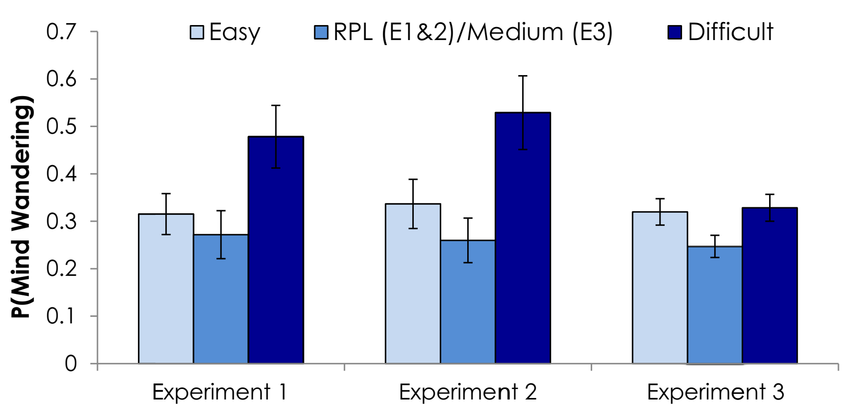

Fig. 1 Proportions (P) of mind wandering by difficulty in Experiments 1, 2, and 3, with standard error bars

et al., 2011; Kam et al., 2014). We therefore looked at performance for word pairs presented within the 10 s preceding each attentional report. Because many of the easy items had already been learned, we only looked at learning for the RPL and difficult word pairs, in which all of the items had been unlearned at the pretest. Because there were only four attentional reports per difficulty condition, and they would sometimes all be in one state or the other, we collapsed over the RPL and difficult bins. Because particular items were repeated (on average, 7.7 times) in the experiment, some pairs ended up being included in both the mind-wandering and on-task conditions in this analysis. Items were not weighted on the basis of distance to the probe. Performance on all items included in the 10-s preprobe interval were identified, and the proportions correct at test were computed. If a particular item happened to occur twice or three times within a given interval, the item was still counted. In other cases, an item might have been included in both the mind-wandering and on-task bins, and thus contributed to both the proportion correct for items presented before a mind-wandering response and the proportion correct for items presented before an on-task response. Learning was significantly better for items that had been studied when participants reported that they had been on task, M = 34, SD = .18, as compared to when they reported that they had been mind wandering, M = .22, SD = .24, $t(21)$ = 2.21, p = .038, d = 0.47, 95 % CI [.01, .23].

Discussion

These results indicate that participants mind wandered less when studying items in their RPL than when they were studying pairs of words that were very difficult. Participants' learning of materials "studied" when mind wandering was also worse.

The findings of poorer performance *within* participants when mind wandering and no correlation between mind wandering and performance do not necessary contradict each other. The between-participant correlation analysis suffers from several problems, which was why we also computed a metric to look at the effect of mind wandering on learning *within* each participant. First, the sample provided an insufficient number of participants, and therefore a lack of power (cf. Cohen, 1992) to detect between-participants correlations. Second, attention fluctuates, such that a participant might have been focused at the beginning of each study block, but might have ended up mind wandering right before the probe appeared. This would have led to a weaker association between proportion mind wandering and overall performance.

In this experiment, we observed no difference in reported mind wandering when studying RPL (medium) versus easy items. However, because of the manner in which we allocated items to the easy condition, it is likely that a number of the nominally "easy" pairs might in fact have been RPL items. The RPL is thought to consist of materials that are close to being, but are not quite, mastered, whereas "too-easy" items that are not in the RPL are those that have already been fully mastered. Insofar as a number of the easy items in Experiment 1 were not correct on the pretest, the lack of a difference in mind wandering between the easy and RPL items might have resulted because the easy items were not easy enough—that is, they were not completely mastered. We conducted Experiment 2 to replicate our basic findings and in an effort to address this issue.

Experiment 2

We made two main changes in Experiment 2. First, the criterion for an item to be considered to be "easy" was changed—only pairs of items that the participant got correct on the pretest were considered easy. Second, to obtain enough "easy" items that people would answer correctly, the number of conjugates was increased.

Method

The method used was identical to that of Experiment 1, except for the details below.

Participants

A total of 26 Columbia University undergraduates (ten males and 16 females; M = 22.23 years old, SD = 6.88) participated for partial course credit. Two participants reported being native Spanish speakers, but because RPL was computed on the basis of each participants' own prior learning, they were not eliminated from the data. We did, however, reanalyze the data without them, and the results did not change.

Materials

An additional 35 perfect Spanish–English conjugates were added to the previous set, for a total of 179 word pairs. This allowed participants to provide a larger number of accurate translations during the pretest, yielding enough materials for an "easy" category without having to use items on which people had been incorrect on the pretest.

Design

We used a within-participants design to investigate the effect of item difficulty (easy, RPL, or difficult, as determined by the pretest) on (a) the proportions of mind wandering reported during the study phase and (b) the proportions correct on the final test. Duration of study block was, again, manipulated to have four different levels (15, 30, 60, 90 s).

Procedure

Three changes were made to the procedure. First, participants were given only 10 s to provide a response on the pretest and final test. This was done so the experiment could be completed within an hour. Second, only pairs that participants got correct in the pretest were categorized as "easy." Both the "RPL" and "difficult" categories comprised 35 items each; 25 of these were presented during the study phase, and ten were not included in the study phase. Participants had 25 easy word pairs to study (except for one participant, who provided only five correct translations). An average of 8.52 (SD = 2.83) pairs were used as the control, nonstudied easy condition, because not all participants provided up to 35 correct translations. Third, the blocks in the study phase were counterbalanced using a Latin square rather than randomly. In the whole experiment, word pairs were presented an average of 7.79 times each (SD = 3.18 times).

Results

Because of a programming error, the final test data were lost for one participant. However, that person's data were included in the mind-wandering results, and the results did not change after analyzing the data without that participant's data.

Final test performance

Participants performed significantly better on pairs they had studied, $M = .51$, $SD = .07$, than on those they had not studied, $M = .39$, $SD = .11$; $t(24) = 5.64$, $p < .001$, 95 % CI [.07, .16], $d = 1.13$. As is presented in Table 1, we observed a main effect of difficulty, such that the proportion correct on the final test was highest on easy items ($M = .91$, $SD = .06$), followed by the RPL items ($M = .51$, $SD = .18$), and then the difficult items ($M = .05$, $SD = .08$), $F(2, 48) = 309.36$, $p < .001$, $\eta_p^2 = .93$. Interestingly, people did not have perfect performance on the final test on the easy items, even though they had been correct on all of those items at pretest. When they had no opportunity to study the easy items further, their performance was .88; it was .92 when they did have the opportunity to study.

Final test performance on the studied word pairs was taken as an index of learning for the RPL and difficult word pairs, because all items in those categories had been incorrect on the pretest. Participants learned significantly more RPL pairs ($M = .56$, $SD = .19$) than difficult pairs ($M = .06$, $SD = .09$), $t(24) = 11.74$, $p < .001$, 95 % CI [.41, .59], $d = 2.35$. A measure of learning could not be taken for the easy items, since they had all been correct on the pretest.

Insofar as all of the items in the "easy" category had been correct on the pretest, the fact that performance was less than 1.0 on the final test provides a strong indication that some of those items had been correct, initially, because of guessing. We cannot determine how many were guesses, however, because the final performance data for easy items no doubt reflect a mix between items that were learned a priori, items that were learned during the experiment, and items that were never learned but were correct guesses on the final test.

Mind wandering

The overall reported rate of mind wandering was .38 (SD = .24). Four participants did not report any mind wandering. We found an effect of difficulty on the probabilities of mind wandering, $F(2, 50) = 9.23$, $p < .001$, $\eta_p^2 = .27$ (see Fig. 1, middle panel), such that participants mind wandered less when they were studying items in the RPL category than when they were studying items in the difficult category, $t(25) = 3.97$, $p < .001$, 95 % CI [.13, .41], $d = 0.78$. There was also a trend for people to mind wander less when they were studying RPL items than when they were studying the easy items, $t(25) = 1.78$, $p = .088$, 95 % CI [−.01, .17], $d = 0.35$. It is likely that this effect was not stronger because although we tried to make sure that the easy pairs had been fully learned a priori, we were not entirely successful in ensuring that people had actually fully mastered them. Participants mind wandered more when studying difficult than when studying easy pairs, $t(25) = 2.48$, $p = .02$, 95 % CI [.03, .35], $d = 0.49$.

Mind wandering–learning relation: Between-participants

We computed correlations between overall mind wandering and average test performance. In this experiment, there was a significant negative correlation, $r = -.46$, $t_r(23) = -2.47$, $p = .022$, 95 % CI [−.72, −.08], such that participants who mind wandered more performed worse on the test. Caution should be used when interpreting the negative correlation found here, insofar as no analogous significant correlation emerged in Experiment 1. However, the between-participants correlations in both experiments were underpowered.

Mind wandering–learning relation: Within-participants

The proportions correct on the final test were evaluated when people had been mind wandering and when they had been on task, for the RPL and difficult items combined. As had been the case in Experiment 1, learning was better for items presented before "on-task" reports, $M = .36$, $SD = .19$, than before "mind-wandering" reports, $M = .19$, $SD = .21$, $t(18) = 2.86$, $p = .01$, $d = 0.66$, 95 % CI [.05, .30].

Discussion

Consistent with Experiment 1, we found that participants mind wandered more when studying difficult items as compared to items in their RPLs. The analyses investigating the relations between mind wandering and learning also indicated that learning is adversely affected by mind wandering. Additionally, the data in this experiment suggest that studying items that are very easy might result in more mind wandering than studying items that are in one's own RPL.

Experiment 3

Previous research has shown that materials that are in an individual's RPL differ on the basis of the expertise of the learner (Metcalfe, 2002). For example, when people who spoke Spanish fluently chose items to study, they avoided the easiest items (since they already knew those items) and chose the difficult items. Novices, however, tended to choose the easier items over the more difficult ones. These choices suggested that the materials in the RPLs of the more expert learners were normatively more difficult than the materials in the RPLs of the novices. We hypothesized that people with greater mastery of the materials in the present experiment—those people who exhibited higher performance levels—would show a similar result in terms of attentional state: they would mind wander more on easier items, and focus attention instead on more difficult items. In contrast, we expected that people with less knowledge of the materials might be more on task on easier materials and tend to mind wander on the more difficult items. To investigate this hypothesized difference, we again used materials that were easy, of medium difficulty, or difficult, but we investigated both patterns of mind wandering that were tailored to the mastery of those materials by individual participants, and we also looked for mind wandering to shift, over the course of the experiment, as people successively mastered the materials.

As before, participants studied word pairs that were blocked by difficulty. In this experiment, however, we included a test in the middle of the experiment and one at the end, to allow an evaluation of each participant's mastery. We predicted that low performers, as determined by proportions correct on these two tests, would mind wander most when studying difficult items, because those materials would be farthest away from their RPL. In contrast, we predicted that high performers might mind wander more when studying easy items and be more on task on materials of higher difficulty—those that posed just the right amount of challenge for them.

Method

Participants

A total of 89 Columbia University undergraduates participated for partial course credit or for $15 in cash, but three could not complete the task due to a computer error, resulting in 86 participants (31 males; M = 21.08 years old, SD = 4.27). Because this was an investigation of individual differences and we wanted to examine the relation between mind wandering and learning, we followed the criterion of a minimum of 85 participants set by Cohen (1992) to look at medium-sized correlational effects. One participant did not fill out the detailed demographic questionnaire, and six reported being native Spanish speakers. The native Spanish speakers were kept in our data. Analyses were also computed with these participants removed and did not change.

Materials

We constructed a list of 45 word pairs of widely varying difficulties, based on the performance of the participants in Experiments 1 and 2. In all, 15 of the pairs were very easy, 15 were of medium difficulty, and 15 were very difficult. No perfect Spanish–English conjugates were included in the present experiment. Because there might still be personal idiosyncrasies in prior knowledge, however, these pairs were sorted into the three difficulties—easy, medium, and difficult—on the basis of participants' ease-of-learning judgments (EOLs). During a pretest, participants were given the 45 English words (without the Spanish translation) one at a time. They were asked to say via a slider scale ranging from *extremely easy* to *extremely difficult* (which was scored from 0 to 1, with 0 being *difficult* and 1 being *easy*, which the computer scored to two decimal places) how easy it would be to learn the Spanish translation. The 15 items with the highest EOLs were assigned to the easy condition; the 15 items with the middle judgments were assigned to the medium condition; and the 15 items with the lowest EOLs were assigned to the difficult condition. We measured no difference in the EOL judgments among people at different levels of mastery, $F(1, 84) = 1.52$, $p = .221$, $\eta_p^2 = .02$, perhaps because people took the judgment task to be a "relative" ease-of-learning judgment in which they contrasted the items within the set with one another (rather than taking it as an absolute judgment task concerning whether they, personally, could or could not learn the items in question). We also found no difference as a function of mastery in the gamma correlations between the EOLs and the final test performance, $r = -.05$, $t_r(84) = -0.49$, $p = .626$, 95 % CI [−.26, .16].

Design

A 3 (Difficulty: easy, medium, and difficult) × 2 (Experiment Half: first and second) × 4 (Study Block Duration: 15, 30, 60, and 120 s) within-participants design was used, in which difficulty level was treated as if it were an independent variable. As in the previous experiments, we collapsed over the Duration variable for the analyses. The primary dependent variables of interest were the proportions of mind wandering reported during study (Experiment Half 1 and 2) and the proportions correct on the tests.

To examine the impact of mastery on mind wandering during study, we averaged performance across Tests 1 and 2 and computed *Z* scores for each participant. These scores were used as the covariate for an analysis of covariance (ANCOVA). Analyses computed using Test 1 and Test 2 performance and *Z* scores as a metric of mastery were also performed and showed the same pattern of results.

Procedure

The experiment was split into two halves. In each half, participants were presented with word pairs to study and then later tested on their learning. In each experiment half, word pairs in each of the easy, medium, and difficult blocks were presented one at a time for 1,400 ms, with a 100-ms ISI. Participants were instructed to study the pairs so that later, when they were presented with the English word, they could produce the correct Spanish translation. They were queried with a probe at the end of each block asking about their attentional state. The attentional probe at the end of each block presented the words MIND WANDERING and ON TASK, as in the previous experiments. The same word pairs were presented in both the first and second experiment halves, with each pair being presented an average of 19.82 times (SD_{easy} = 3.95, SD_{med} = 3.82, SD_{diff} = 3.97) for each participant.

Tests Participants were asked to provide Spanish translations for the English words presented as cues. All word pairs were tested, with randomized presentation in each test, such that participants were tested twice on each word pair. No feedback was given, and participants had up to 10 s to respond. Strict scoring was used to determine accuracy.

Results

Test performance

The ANCOVA showed an effect of difficulty, with proportions correct on the final test being highest for the easy items, followed by the medium-difficulty items, and lowest for the difficult items, $F(2, 168) = 889.59$, $p < .001$, $\eta_p^2 = .91$. There was a main effect of experiment half, such that participants performed better on Test 2 than on Test 1, $F(1, 84) = 232.51$, $p < .001$, $\eta_p^2 = .74$. We also observed a significant Difficulty × Experiment Half interaction, $F(2, 168) = 19.60$, $p < .001$, $\eta_p^2 = .19$, such that participants improved more on the medium and difficult items from Test 1 to Test 2 than they did on easy items (see Table 2). This interaction presumably happened because most of the easy pairs were already well learned by the first test, resulting in a ceiling effect that prevented further improvement for those items. To further examine this interaction,

Table 2 Ease-of-learning judgments (EOLs) and test performance for each level of difficulty in Experiment 3, as proportions with standard deviations in parentheses

	EOLs	Test Performance	
		Test 1	Test 2
Easy	.88 (.10)	.83 (.15)	.88 (.11)
Medium	.47 (.16)	.39 (.19)	.54 (.22)
Difficult	.17 (.11)	.12 (.11)	.20 (.14)

we computed the difference in performance between Test 1 and Test 2 for each level of difficulty. Participants showed significantly greater improvement for medium-difficulty items, $M = .14$, $SD = .11$, than for easy item, $M = .05$, $SD = .11$, $t(85) = 5.37$, $p < .001$, 95 % CI [.06, .13], $d = 0.58$, and they also showed more improvement for medium-difficulty than for difficult items, $M = .08$, $SD = .09$, $t(85) = 4.55$, $p < .001$, 95 % CI [.04, .09], $d = 0.49$. The amount of improvement did not differ between easy and difficult items, $t(85) = 1.65$, $p = .103$, 95 % CI [−.01, .06], $d = 0.18$.

Most importantly, we found both a Difficulty × Mastery interaction, $F(2, 168) = 21.00$, $p < .001$, $\eta_p^2 = .20$, and a three-way Difficulty × Experiment Half × Mastery interaction, $F(2, 168) = 11.87$, $p < .001$, $\eta_p^2 = .12$. To further examine the three-way interaction among difficulty, experiment half, and mastery, difference scores were computed for each participant by subtracting Test 2 from Test 1 performance, at each difficulty level, and a proportion was then computed by dividing each participant's difference score for each difficulty, by the total change in performance across all three levels of difficulty. Post-hoc correlations between mastery and the proportion of change in test performance in each condition were then computed (see Fig. 2). A significant negative correlation was apparent between mastery and change in test performance on easy items, $r = -.37$, $t_r(84) = 3.60$, $p < .001$, 95 % CI [−.54, −.17], such that lower performers showed more improvement from Test 1 to Test 2 on easy items than on medium or difficult items. This pattern of results suggests that the interaction(s) might have resulted, in part, from a ceiling effect on the performance for easy materials. Conversely, a significant positive correlation emerged between mastery and the proportion of change in performance for difficult items, $r = .31$, $t_r(84) = 2.95$, $p = .004$, 95 % CI [.10, .49], such that higher performers improved more on difficult items than on items of easy or medium difficulty. The correlation between mastery and the proportion change in test performance for items of medium difficulty did not reach significance, although there was a trend in the direction of higher mastery relating to more change in performance, $r = .19$, $t_r(84) = 1.78$, $p = .079$, 95 % CI [−.02, .39]. Analyses completed using the raw difference scores between Test 1 and Test 2 performance showed the same pattern of results, except that the correlation between

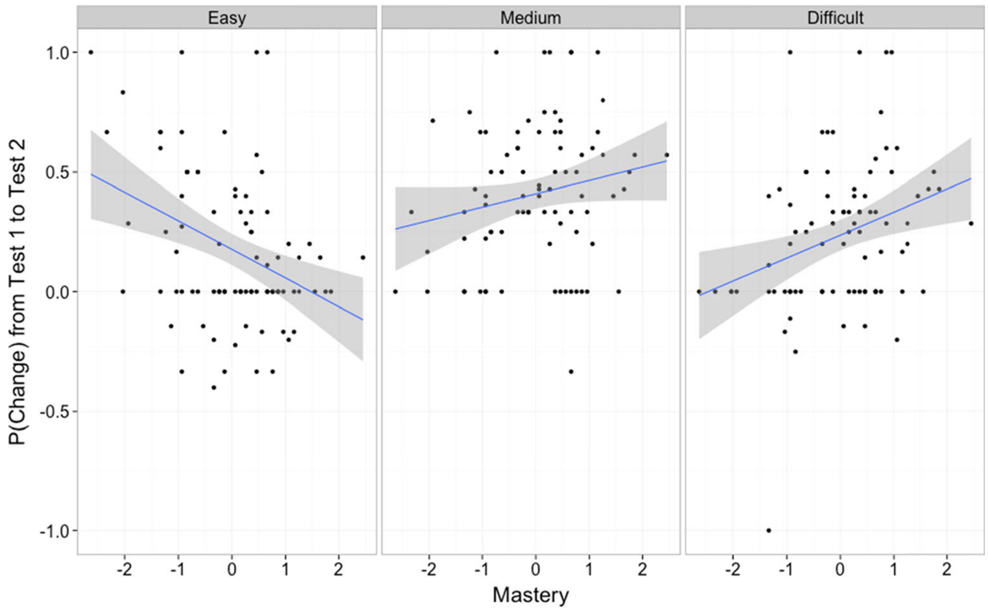

Fig. 2 Changes in test performance from Test 1 to Test 2 as proportions over mastery levels across the three levels of difficulty for all participants. The lines represent the regression lines of best fit, and the gray shaded areas reflect the 95 % confidence intervals of the regression lines. A negative value reflects that a particular participant did worse on Test 2 than on Test 1 for that particular condition. For example, a change of −1 (see the bottom left corner of the Difficult panel) reflects a case in which a particular participant's test performance worsened only for difficult items, but did not change for easy and medium items

mastery and the difference score for medium difficulty was then significantly positively correlated.

No interaction emerged between experiment half and mastery, $F(1, 84) = 0.70$, $p = .405$, $\eta_p^2 = .01$. The "effect" of mastery could not be computed, since mastery was derived from test performance.

Mind wandering

Overall, the proportion of reported mind wandering was .30 ($SD = .18$). Two participants did not report any mind wandering. To examine the impact of mastery, we treated difficulty as if it were an independent variable and computed a 3 (Difficulty Level) × 2 (Experiment Half) × Mastery ANCOVA on mind wandering. Mastery was computed from averaged and standardized test performance across both Tests 1 and 2, although the reported statistics hold regardless whether Test 1, Test 2, or averaged *Z* scores were used.

There was a main effect of difficulty on mind wandering, $F(2, 168) = 4.53$, $p = .017$, $\eta_p^2 = .05$. This main effect is illustrated in the right panel of Fig. 1. We observed an overall U-shaped pattern in which participants mind wandered less when studying medium-difficulty items, in comparison with either easy or difficult items. As can be seen from Fig. 1, this pattern was similar to those shown in Experiments 1 and 2. Post-hoc tests showed that participants mind wandered significantly less when studying medium-difficult than when studying easy items, $t(85) = 2.63$, $p = .010$, 95 % CI [.02, .13], $d = 0.28$, and than when studying difficult items, $t(85) = 3.07$, $p = .003$, 95 % CI [.03, .13], $d = 0.33$. There was no difference in the rates of mind wandering between easy and difficult items, $t(85) = 0.23$, $p = .817$, 95 % CI [−.07, .08], $d = 0.03$. We also found the expected main effect of experiment half, such that participants reported more mind wandering during Experiment Half 2 ($M = .35$, $SD = .24$) than during Experiment Half 1 ($M = .24$, $SD = .18$), $F(1, 84) = 26.07$, $p < .001$, $\eta_p^2 = .24$. Note that the effect of experiment half might be associated with item repetition, since the same items were repeated over time. However, it is not possible to distinguish these two possibilities, given the present data.

The most interesting results of this experiment, however, concern the effects of mastery. We found a trend toward an effect of mastery, $F(1, 84) = 3.82$, $p = .054$, $\eta_p^2 = .04$. More importantly for the present purposes, we also found a significant Difficulty × Mastery interaction, $F(2, 168) = 8.41$, $p < .001$, $\eta_p^2 = .09$, as is shown by the ANCOVA results. Participants with higher test scores mind wandered the most on easier items, whereas participants who had lower test scores mind wandered the most on items that were the most difficult. The figure illustrating this interaction is presented in Fig. 3. A significant three-way interaction also emerged among difficulty, experiment half, and mastery, $F(2, 168) = 4.03$, $p = .02$, $\eta_p^2 = .05$.

No interactions were apparent between difficulty and experiment half, $F(2, 168) = 0.49$, $p = .613$, $\eta_p^2 = .01$, or between experiment half and mastery, $F(1, 84) = 0.22$, $p = .641$, $\eta_p^2 = .003$. To more clearly illustrate the three-way interaction of difficulty, experiment half, and mastery, we separated

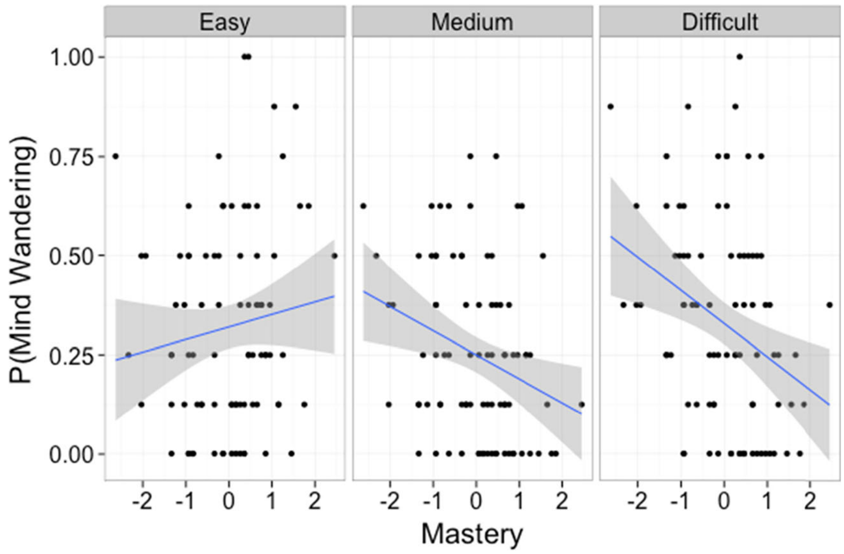

Fig. 3 Proportions of mind wandering across different mastery levels, separated by difficulty in Experiment 3. The lines represent the regression lines of best fit, and the gray shaded areas represent the 95 % confidence intervals. Because there were only eight probes per difficulty per participant, the proportions are factors of .125

participants into three groups based on standardized test performance and computed the proportion of mind wandering for each group across difficulties and by experiment halves. Low performers had test scores below $Z = -0.43$; high performers had scores above $Z = 0.43$; and middle performers had scores in the range $-0.43 < Z < 0.43$. As is shown in Fig. 4, there was a clear shift in the tendency to mind wander as a function of mastery, as the items became more difficult. High-scoring participants mind wandered on the easy items, whereas low-scoring participants mind wandered on the difficult items. Interestingly, the pattern shown in the overall data—with mind wandering being highest on both easy and difficult items and lowest when studying the medium-difficulty items—was shown only by the middle third of participants: neither the high nor the low performers showed this pattern. The statistics for the breakdown of the data illustrated in Fig. 4 are described below.

The statistics for the breakdown of the data illustrated in Fig. 4 were derived from a 3 (Difficulty) × 2 (Experiment Half) × 3 (Mastery) ANOVA, in which mastery was treated as if it were an independent variable. The three mastery levels—low, middle, and high—were grouped according to *Z* scores, such that approximately one-third of participants fell into each group. Low performers had *Z* scores below −0.43 ($n = 27$), high performers had *Z* scores above 0.43 ($n = 32$), and middle performers had *Z* scores between −0.43 and 0.43 ($n = 27$). Similar to the results from the ANCOVA, we observed a main effect of difficulty, $F(2, 166) = 4.41$, $p = .019$, $\eta_p^2 = .05$,

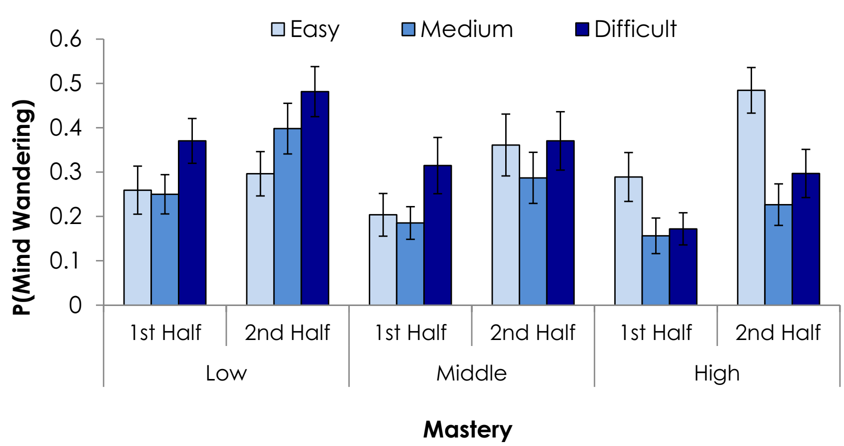

Fig. 4 Proportions of mind wandering across difficulty, experiment half, and mastery levels for Experiment 3, with standard error bars. For illustrative purposes, participants were split into three groups based on standardized average test performance. The data from the lowest performers ($n = 27$, $Z < -0.43$, test performance from .20 to .43) are shown in the left panel; the middle panel ($n = 27$) depicts participants whose average performance was between .46 and .53; and the data from the highest performers ($n = 32$, $Z > 0.43$, test performance from .54 to .77) are shown in the right panel

and a main effect of experiment half, $F(1, 83) = 25.15$, $p < .001$, $\eta_p^2 = .23$, on mind wandering. There was no effect of mastery, $F(2, 83) = 1.21$, $p = .303$, $\eta_p^2 = .03$, suggesting that low ($M = .34$, $SD = .17$), middle ($M = .29$, $SD = .20$), and high ($M = .27$, $SD = .17$) performers did not differ in their overall rates of mind wandering. Figure 4 shows mind wandering as a function of difficulty, experiment half, and mastery. There was only a trend toward a three-way interaction in this analysis, however: $F(4, 166) = 2.04$, $p = .092$, $\eta_p^2 = .05$. The difference between the ANOVA and ANCOVA concerning the significance of this interaction may have been due to a decrease in power when the continuous factor of mastery was transformed into a nominal variable with three levels.

Nevertheless, even in the ANOVA, we obtained a significant Difficulty × Mastery interaction, $F(4, 166) = 5.31$, $p = .001$, $\eta_p^2 = .11$. Consequently, post-hoc tests examining the effect of difficulty were computed at each level of mastery. The low performers showed a significant effect of difficulty, $F(2, 52) = 5.52$, $p = .007$, $\eta_p^2 = .18$, such that they mind wandered more on difficult than on easy items, $t(26) = 2.94$, $p = .007$, 95 % CI [.04, .25], $d = 0.57$, or medium-difficulty items, $t(26) = 2.44$, $p = .022$, 95 % CI [.02, .19], $d = 0.47$. They showed no difference in mind wandering between easy and medium-difficulty items, $t(26) = 1.04$, $p = .306$, 95 % CI [−.14, .04], $d = 0.20$. We found no effect of difficulty on mind wandering for middle performers, $F(2, 52) = 1.62$, $p = .208$, $\eta_p^2 = .06$. The high performers did show an effect of difficulty, $F(2, 62) = 9.15$, $p = .001$, $\eta_p^2 = .23$, such that they mind wandered more when studying the easy items than when studying the medium-difficulty items, $t(31) = 4.74$, $p < .001$, 95 % CI [.11, .30], $d = 0.84$, or when studying the difficult items, $t(31) = 2.55$, $p = .016$, 95 % CI [.03, .27], $d = 0.45$. They showed no difference in mind wandering when studying medium as compared to difficult items, $t(31) = 1.07$, $p = .295$, 95 % CI [−.13, .04], $d = 0.19$.

No interactions were apparent between experiment half and mastery, $F(2, 83) = 0.20$, $p = .821$, $\eta_p^2 = .01$, or between difficulty and experiment half, $F(2, 166) = 0.39$, $p = .677$, $\eta_p^2 = .01$.

Mind wandering-learning relation: Between-participants

Collapsing data across participants, correlations were computed between mind wandering in each of Experiment Halves 1 and 2 and the corresponding test (e.g., mind wandering in Experiment Half 1 with performance on Test 1). There was a negative correlation between mind wandering in Experiment Half 1 and performance on Test 1, $r = −.25$, $t_r(84) = −2.33$, $p = .022$, 95 % CI [−.44, −.04], but no correlation between mind wandering in Experiment Half 2 and performance on Test 2, $r = −.16$, $t_r(84) = −1.52$, $p = .133$, 95 % CI [−.36, .05]. This might have resulted because learning occurred in the first half of the experiment, such that participants would study materials they had not learned and mind wander on already-learned items (which would be correct on Test 2). However, overall mind wandering and final test (i.e., Test 2) performance were negatively correlated, $r = −.22$, $t_r(84) = −2.02$, $p = .047$, 95 % CI [−.41, −.001]. Participants who mind wandered more, learned less and performed worse.

Mind wandering-learning relation: Within-participants

The within-participants effect of mind wandering on learning was not computed in this experiment, because there had been no pretest, so it was not possible to be sure which items were known a priori and which ones were learned during the experiment. Furthermore, because each word pair was presented almost 20 times during this experiment, almost all word pairs would necessarily be binned into both the "on-task" and the "mind-wandering" categories, obscuring any differences.

Combined analyses of mind wandering across experiments

To investigate the generality and replicability of these effects of difficulty level on mind wandering, we decided to compare the three experiments presented here. To do so, we basically ignored the many differences among the three experiments and looked simply at mind wandering as a function of the three levels of difficulty in each. For the combined analysis, then, we used the data from all three experiments, in a 3 (Experiment: between participants) × 3 (Difficulty: within participants) mixed-model analysis.[1] There was no significant difference in the overall rates of mind wandering across the three experiments, $F(2, 131) = 2.09$, $p = .128$, $\eta_p^2 = .03$, but a significant effect of difficulty on mind wandering did emerge, $F(2, 262) = 18.20$, $p < .001$, $\eta_p^2 = .12$. Post-hoc tests showed that participants mind wandered more on easy items ($M = .32$, $SD = .25$) than on medium-difficulty items ($M = .25$, $SD = .22$), $t(133) = 3.11$, $p = .002$, $d = 0.27$, 95 % CI [.03, .11], and also more on difficult items ($M = .39$, $SD = .31$) than on the items of medium difficulty, $t(133) = 5.39$, $p < .001$, $d = 0.47$, 95 % CI [.09, .19]. They also mind wandered more on difficult than

[1] Because the variances for the difficult items differed among the three experiments, the assumption of homogeneity of variances was violated according to Levene's F test, $F(2, 131) = 8.45$, $p < .001$. Therefore, Welch's ANOVA was computed and Games–Howell was used as a post-hoc procedure to ensure that the effects were robust. Consequently, some degrees of freedom are estimates with decimal places. For simplicity in describing the effects, the label of "medium difficulty" refers to the RPL items in Experiments 1 and 2, and to the medium items in Experiment 3.

on easy items, $t(133) = 2.20$, $p = .029$, $d = 0.19$, 95 % CI [.01, .13]. The main effect of difficulty was qualified by a significant Experiment × Difficulty interaction, $F(4, 262) = 3.16$, $p = .021$, $\eta_p^2 = .05$. Post-hoc tests showed no effect of experiment on mind wandering for the easy items, $F(2, 46.58) = 0.05$, $p = .955$, $\eta_p^2 = .001$, or for the medium-difficulty items, $F(2, 41.78) = 0.11$, $p = .894$, $\eta_p^2 = .02$. However, we did find a significant effect of experiment on the difficult items, $F(2, 38.99) = 4.66$, $p = .015$, $\eta_p^2 = .08$. Participants mind wandered marginally less on difficult items in Experiment 3 ($M = .33$, $SD = .26$) than in Experiment 1 ($M = .49$, $SD = .31$), $t(29.02) = 2.21$, $p = .087$, $d = 0.55$, 95 % CI [−.02, .34], and Experiment 2 ($M = .53$, $SD = .40$), $t(31.95) = 2.43$, $p = .054$, $d = 0.60$, 95 % CI [−.003, .40]. There was no difference in mind wandering on difficult items between Experiments 1 and 2, $t(45.82) = 0.39$, $p = .696$, $d = 0.11$, 95 % CI [−.29, .21]. Overall, though, the results of the three experiments—taken as replications with sometimes rather extreme variations from one another—were strikingly similar.

General discussion

Experiments 1 and 2 showed that studying materials in a participant's RPL was associated with reduced levels of mind wandering, whereas Experiment 3 demonstrated that what qualifies as the RPL depends on an individual's mastery of the material. We also found in Experiment 3 that mind wandering increased over experiment halves. These data provide evidence that the simple effect of mind wandering based on the difficulty of the materials—the U-shaped pattern of less mind wandering for "medium" items, and more for much easier and too-difficult items—can and should be unpacked. The simple effect of difficulty in the third experiment—showing that participants mind wandered least for medium-difficulty items—masked the fact that individuals at different levels of knowledge or skill have different RPLs and show distinctively different patterns of mind wandering. Aggregating the data across all participants made it seem that all participants had focused on items of moderate difficulty, but this was an illusion. Instead, the pattern was dependent on the extent to which a given participant had already mastered the materials. One size does not fit all, as our data illustrate.

Task difficulty and mind wandering

Many conflicting findings exist in the literature, some of which suggest that mind wandering increases with task difficulty (Dixon & Bortolussi, 2013; Feng et al., 2013), whereas others suggest the opposite (Antrobus et al., 1966; Antrobus, Coleman, & Singer, 1967; Filler & Giambra, 1973; Grodsky & Giambra, 1990–1991; McKiernan, D'Angelo, Kaufman, & Binder, 2006; McVay & Kane, 2012; Smallwood, Obonsawin, & Reid, 2003; Teasdale et al., 1995; Thomson, Besner, & Smilek, 2013). For example, Feng et al. (2013) and Dixon and Bortolussi (2013) found that mind wandering *increases* when an individual is reading difficult texts. In contrast, the data from Antrobus et al. (1966), Filler and Giambra (1973), McKiernan et al. (2006), Smallwood et al. (2003), Teasdale et al. (1995), and Thomson et al. (2013) all suggest that mind wandering *decreases* as task difficulty and demand increase. Our data provide a potential reconciliation for these seemingly contradictory findings.

In the case in which mind wandering increased with task difficulty, the RPL account suggests that participants may have had low or no mastery of the tasks. Consequently, the easiest readings (in those experiments) would have been in the RPL. As task difficulty increased, the task would have become further removed from the learner's "sweet spot," resulting in increased mind wandering. On the other hand, studies showing that mind wandering decreased with task difficulty were most likely at the other end of the spectrum. Those tasks may have been too easy, and therefore outside of people's RPLs. Increasing the difficulty of those tasks would have brought them into range of the RPL and resulted in less mind wandering. Furthermore, the difficulty level of the task that corresponds to the RPL depends upon the individual. If a well-read philosopher were to read a children's book, he or she would most likely mind wander. If presented with a more abstruse text, this philosopher might well remain focused and on task. In contrast, a layperson might stay engaged when reading a summary of a philosophy essay rather than the abstruse essay itself, but mind wander when presented with the exact same material that would engage a philosopher's undivided attention. Our findings suggest that there is a delicate balance between difficulty and mind wandering, a balance that is reliant both on the difficulty of the task itself and on the individual's current levels of mastery and knowledge. Of course, other factors, such as working memory capacity, the importance of the task, the preferred reward for learning, one's state of fatigue or stress, and so forth, can also play a role in how often one's mind goes offline. But, even so, using the RPL to examine mind wandering affords an opportunity not only to maximize learning gains, but also to simultaneously keep one's mind focused on the task at hand.

Our results also suggest that students may sometimes mind wander not because of an inherent lack of motivation or an inability to learn, but rather because the difficulty of the to-be-learned materials is inappropriate. Individuals might want to remain focused when attempting to learn materials more difficult than their RPL, but be unable to remain engaged. Conversely, there is no challenge in studying already-mastered information, and the boredom that ensues may lead even highly skilled learners to mind wander. In all, these findings imply that studying materials appropriately titrated to an individual's current expertise—that is, those in the RPL—can reduce mind wandering, and consequently, enhance learning.

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