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Article · February 2016

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Online First Publication, February 15, 2016. http://dx.doi.org/10.1037/stl0000055

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2332-2101/16/$12.00 http://dx.doi.org/10.1037/stl0000055

Mind Wandering During Lectures II: Relation to Academic Performance

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We explored whether students' ($N = 154$) engagement in mind wandering (both *intentional* and *unintentional* forms) throughout a 12-week undergraduate course was related to their performance on in-class quiz questions and later course exams. Intermittently presented thought-probes sampled mind-wandering rates during lectures, and retention of lecture information was gauged by later quiz and exam performance. A number of self-report measures including overall grade-point average (GPA), motivation to learn, and overall propensity to mind wander were also collected. Among the many results of our study, we found that at the group level students' bouts of intentional, $t = 2.37$, $p < .05$, but not unintentional, $t = 1.39$, $p = .17$, mind wandering resulted in poorer quiz scores than did periods of on-task focus. At the level of individual differences, regression and mediation analyses revealed that intentional mind wandering was most strongly linked to short-term performance costs, measured by quiz performance (intentional: $\beta = -.23$, $p < .01$; unintentional: $\beta = -.16$, $p = .06$). Conversely, unintentional mind wandering was most strongly related to longer term performance costs, measured by exam performance (intentional: $\beta = -.01$, $p = .90$; unintentional: $\beta = -.14$, $p = .06$). Interestingly, mind wandering was found to be associated with performance independently of other known determinants of performance (e.g., GPA, class attendance). Together these findings provide evidence that (a) mind wandering during university lectures is associated with significant performance costs, and (b) the nature of these costs depends on whether the mind-wandering episode was intentional or unintentional.

Keywords: mind wandering, attention, education, retention, lecture

Students do not always devote their attention entirely to the material presented in university lectures, instead drifting toward internal, unrelated thoughts or concerns. Whether intentional or unintentional, it seems likely that this inattention has consequences not only for students' short-term retention, but also for their long-term performance in course exams. Here, we examined these possibilities by measuring students' mind wandering and memory for course material throughout an entire semester of a large undergraduate class. As in previous research (e.g., Smallwood & Schooler, 2006), we use the term *mind wandering* to refer to the shifting of one's attention away from a focal external task, toward internal cognitions (cf. Antrobus, 1968; Giambra, 1989, 1995; Mason et al., 2007; Schooler, 2002; Schooler, Reichle, & Halpern, 2004; Smallwood, Obonsawin, & Heim, 2003).

In the literature, mind wandering is often assumed to be an unintentional phenomenon, occurring despite one's best efforts to remain focused on the current task (e.g., Bixler & D'Mello, 2014; Blanchard, Bixler, Joyce, & D'Mello, 2014; Carciofo, Du, Song & Zhang, 2014; Cohen, 2013; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Kane & McVay, 2012; Qu et al., 2015; Rummel & Boywitt, 2014; Wilson et al., 2014). Consistent with the unintentionality assumption, it has also been conjectured that mind-wandering episodes are the outcome of a failure of executive control (McVay & Kane, 2010; Schacter & Szpunar, 2015), rather than willful (i.e., controlled) shifts

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of attention toward task-unrelated thought. Contrary to this view, however, several recent studies have reported the occurrence of intentional (i.e., deliberately engaged) mind wandering across a variety of tasks (Carriere, Seli, & Smilek, 2013; Forster & Lavie, 2009; Seli, Carriere, & Smilek, 2015; Seli, Smallwood, Cheyne, & Smilek, 2015; Seli, Wammes, Risko, & Smilek, 2015; Shaw & Giambra, 1993). Perhaps most critically for the current work, researchers have reported intentional mind wandering to be more closely associated with levels of task-based motivation than is unintentional mind wandering (Seli, Cheyne, Xu, Purdon, & Smilek, 2015), and that easy, relative to difficult tasks are associated with greater intentional than unintentional mind wandering (Seli, Risko, & Smilek, in press). Taken together, these findings indicate that the underlying causes of these two conscious states might be quite different, and indeed that intentional and unintentional mind wandering might differentially affect performance in a lecture setting.

In previous work, mind wandering has consistently been associated with costs to performance, pervasive across a wide variety of tasks (Schooler et al., 2004; Seli, Carriere, Levene, & Smilek, 2013; for a review, see Mooneyham & Schooler, 2013), including tasks requiring one to attend to video lectures (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Seli, Wammes et al., 2015). Indeed several studies have explored the issue of mind wandering in classrooms, as well as potential performance costs of these cognitive states (for a review, see Szpunar, Moulton, & Schacter, 2013). For instance, Lindquist and McLean (2011) provide evidence that participants who reported high rates of mind wandering were also more likely to self-report that they took fewer notes, and performed more poorly on a later exam. Moreover, Risko et al. (2012) reported that an increase in mind wandering over the course of a video lecture was coupled with a decrease in retention of lecture material. Furthermore, in an examination of students' self-reports of their everyday attention failures, Unsworth, McMillan, Brewer, and Spillers (2012) found that most self-reported attentional lapses occurred either while studying or in class, and that these lapses predicted subsequent standardized test scores. Overall, the consensus in the literature on the topic seems to be that mind wandering/inattention during lectures is quite detrimental to later performance on tests of retention (Cameron & Giuntoli, 1972; Lindquist & McLean, 2011; Risko et al., 2012; Schacter & Szpunar, 2015). It is important to note, however, that many of these studies included video lectures, lectures staged for research purposes, or single lectures from a course.

Few studies, however, have examined the consequences of mind wandering on academic performance at a large scale in a live university lecture, and to our knowledge, there is no work in live lectures that has differentiated intentional from unintentional mind wandering in terms of their relative costs to performance. In Part 1 of this work (Wammes, Boucher, Seli, Cheyne, & Smilek, 2016), we demonstrated that, in contrast to previous laboratory studies (e.g., Risko et al., 2012; Szpunar, Khan, & Schacter, 2013), *rates of unintentional mind wandering* were relatively low, and did not increase over the course of a lecture. Critically, we suggest that these findings may have occurred as a result of higher levels of motivation that comes along with being enrolled in a veridical live class whereby heightened levels of motivation might have resulted in relatively low and steady rates of mind wandering over the course of each lecture. Given such contextual differences, one might expect that *the consequences of mind wandering* might also be less pronounced than effects documented in laboratory experiments.

In our study, students' mind wandering was measured using the probe-caught method (see Giambra, 1995; Smallwood & Schooler, 2006). Specifically, "thought probes" were pseudorandomly inserted into most of the students' regular lectures. Critically, quiz questions were presented at the end of each class. The questions tested retention of material that was presented either directly preceding or directly following each thought probe. Participants also granted us access to their scores on their midterm and final exams. In addition we collected and included several other measures of interest. In a short questionnaire administered before the start of the term, participants reported on their motivation to learn the material in the course, their prior knowledge of the course's subject matter, their predicted propensity to mind wander in class, how likely they were to read the relevant textbook passages before class, and their overall

grade-point average (GPA). We were also able to measure class attendance based on students' in-class responses. These features of our design allowed us to examine the relation between mind wandering and performance both at the group level and at the level of individual differences, while controlling for other performance-related factors (noted above).

The Relation Between Mind Wandering and Performance at the Group Level

One noteworthy feature of our design was the inclusion of quiz questions at the end of each class. As noted above, these questions tested material covered in lecture slides that appeared immediately before and immediately after each mind-wandering probe, either from the current class or the previous class. Interestingly, research has suggested that salient events can serve to reorient one's attention to the task at hand, as evidenced by improved performance in text comprehension after an error is committed (Smallwood, Riby, Heim, & Davies, 2006). Similarly, thought probes may serve as salient exogenous cues that reorient attention. Consistent with this view, previous work has examined the effects of varying the number of probes presented to participants during a sustained-attention task. This work provided evidence that presenting a large number of probes leads to fewer episodes of mind wandering than does presenting a relatively small number of probes, which provides empirical support for the notion that thought probes can lead to a reorientation of attention to the primary task (Seli, Carriere, Levene, et al., 2013). Thus, on the basis of this finding, *we hypothesized that thought probes would refocus students' attention to the lecture, which would consequently lead to improved accuracy on material presented after, relative to before the probes*. In addition, because some material was tested a few days after its initial presentation, *we expected that participants would perform more poorly on these questions than on material that was presented on the day of testing.*

By deriving quiz questions from material presented in close contiguity to the presentation of thought probes, we were able to assess the immediate consequences of intentional and unintentional mind wandering on later quiz accuracy, relative to reports of on-task thoughts. Numerous studies have shown that episodes of mind wandering are related to decreased performance relative to episodes of on-task attention. Indeed, mind wandering has been linked to poorer signal detection (Giambra, 1995), more variable response times in the Metronome Response Task (MRT; Seli, Cheyne, & Smilek, 2013), poorer performance in the Sustained Attention to Response Task (SART; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009), increased false alarms in a memory task (Smallwood, Baracaia, Lowe, & Obonsawin, 2003), and decreased narrative comprehension in a reading task (Smallwood, McSpadden, & Schooler, 2007).

Studies examining the effects of mind wandering on retention of information from video lectures have demonstrated that elevated mind-wandering rates are significantly associated with decreased quiz performance ($r = -.32$, Risko et al., 2012). Other work has corroborated this finding reflecting the negative effects of mind wandering on later retention in a lecture environment (see Szpunar, Moulton, & Schacter, 2013; Schacter & Szpunar, 2015 for a review). The foregoing provides compelling evidence to suggest that when one is mind wandering, retention of material is much poorer than when one is on task. However, most investigations of this phenomenon have been correlational and global in nature, specifically examining the relation of mind wandering and retention at the individual-differences level. The intricacies of our design allowed us to test this prediction at the event level with a relatively high degree of specificity. Indeed, because we included quiz questions that tested material presented just before and just after the thought probes, we were able to assess retention of lecture material that directly preceded and followed reports of either on-task, intentional, or unintentional mind wandering. As mentioned above, the presentation of a thought probe likely serves to reorient one's attention from mind wandering back to the primary task, thus interrupting the mind wandering episode (Seli, Carriere, Levene, et al., 2013). Thus, given that our aim was to test for potential detrimental effects of mind wandering, the most critical epoch is just *before* the thought probe, when the student was still engaged in his or her reported cognitive state. Based on the findings reviewed above, *we expected that knowledge of material*

presented before a probe would be better when participants report being on-task than when they report either type of mind wandering. To our knowledge, this degree of temporal specificity has not yet been explored in a live lecture setting.

The Relation Between Mind Wandering and Performance at the Level of Individual Differences

In addition to exploring how mind wandering affects performance at the group level, we were interested in the relation between mind wandering and performance at the level of individual differences. In examining the relations among mind wandering, quiz accuracy, and exam scores, we also assessed (and statistically controlled for) several factors that seemed conceptually and theoretically related to our primary variables of interest, including self-reported GPA, class attendance, amount of previous course-related knowledge, motivation to learn the course material, and preterm estimations of the degree to which a person would engage in mind wandering during the class. Whereas we predicted that several of these factors—especially motivation—would be related to mind-wandering rates and performance on quizzes and exams, the most critical prediction, which emerges from prior research (Seli, Wammes, et al., 2015), is that *both intentional and unintentional mind wandering will predict quiz accuracy and possibly influence exam scores*, even when statistically controlling for the aforementioned factors.

Summary

In summary, the present study explores the consequences of mind wandering, in terms of its association with retention of material in a more naturalistic lecture setting. Unlike previous work, our study did not employ one-shot, video, or staged lectures. Rather, mind wandering was observed, and retention of material was gauged, during normal live lectures in an actual academic course that had real implications for the students who participated. The presentation of lectures unfolded as it ordinarily would, except for the inclusion of thought probes embedded within the lecture, and most importantly for current purposes, quiz questions presented at the end of each lecture. The relations between mind wandering and performance were assessed both at the group level, and at the individual-differences level, while controlling for conceptually relevant factors, including attendance and motivation.

Method

As the data discussed in this part of the article were derived from the same experimental protocol as Part 1 (Wammes et al., 2016), the sections entitled 'Participants' and 'The course' below were taken *directly* from our report of Part 1 of this work. We include both again here for the reader's convenience. All subsequent sections are unique to this article.

Participants

Participants were 154 (97 female) undergraduate students enrolled in a Physiological Psychology course at the University of Waterloo. They ranged in age from 16 to 38 ($M = 20.117$, $SD = 2.092$), with 10 to 20 years of education ($M = 15.533$, $SD = 1.654$). Participants received partial course credit for their participation. In recruiting participants, *all* students that were enrolled in the course were contacted through e-mail and the course website. We aimed to recruit as many of the roughly 250 enrolled students as possible, but only data from the 154 students who agreed to participate in the study were included in our analyses. Participant identities remained confidential until grades were finalized and submitted, and this was made clear to students on every occasion when the option to participate was provided. This is of particular importance in the present study because, in the case that the professor had knowledge about which students were enrolled in the study and which students were not, the students enrolled in the study might attempt to present themselves favorably to the professor by reporting instances of "on-task" focus when they were in fact mind wandering.

Materials

The course. The study was conducted in the context of a second-year course on Physiological Psychology offered by the Department of Psychology at the University of Waterloo and

taught by Dr. Daniel Smilek (one of the coauthors of this paper). Each class began at 8:30 a.m. and lasted for 50 min. Classes were held on Mondays, Wednesdays, and Fridays. The lectures took place in a large lecture hall in the J. R. Coutts Engineering Lecture Hall, room 101 (RCH 101) on the University of Waterloo campus, which had a capacity of 352 students. There were roughly 250 students enrolled in the course.

The course was based on a traditional lecture-style format in which the instructor presented PowerPoint slides on a large screen at the front of the class and delivered an oration. The instructor interacted with the students intermittently, either to pose questions or to answer questions posed by students. Student evaluation was based on four equally weighted and spaced tests (each worth 23% of the course grade), participation in answering in-class quiz questions (worth 4% of the course grade, with points given for each response regardless of accuracy), and participation in other experiments offered by faculty in the Department of Psychology (worth 4% of final grade).

Thought probes and responses. Within *all* lectures, between zero and three thought probes were pseudorandomly embedded within the existing deck of slides for a given lecture. Thought probes consisted of a PowerPoint slide with white text on a black background asking about the participants' mental states just before the slide appeared. The specific question asked was: "Which of the following responses best characterizes your mental state JUST BEFORE this screen appeared?" The three possible response options were listed below the question: "A. On task", "B. Intentionally mindwandering", or "C. Unintentionally mindwandering". Participants were informed that intentional mind wandering meant that they were willfully thinking about things unrelated to the current lecture, whereas unintentional mind wandering meant that they were thinking about things unrelated to the lecture despite their best intentions to focus. Responses to thought probes were given by all students in attendance using i > clicker remotes (www1.iclicker.com). When compiled across all lectures (44 thought probes total), this measure gave us an estimate of the proportion of the time each student spent mind wandering, and how this proportion changed as a function of the time elapsed within a class, which day of the week it was, and how far into the term they were. For more detail on the thought probes and the corresponding rates of mind wandering we invite the reader to refer to Part 1 (Wammes et al., 2016).

Quiz questions. Participants' knowledge of the material presented in the lectures was tested via a series of quiz questions presented in the same fashion as the thought probes, though they were exclusively presented in the last few minutes of each class. These quiz questions were multiple-choice format with five alternatives that participants could choose from. Each question was presented on a separate PowerPoint slide. The text of the quiz slides was white and the background was black. The quiz questions for lectures in which there were probes tested either material from the slide just before a thought probe or from the slide just after the thought probe. In the case of control lectures, where there were no probes, questions tested material from a random pair of consecutive slides, to match with the before- and after-probe questions on probe days. Quiz questions gauging retention of material from a given day were presented either at the end of the lecture in which the material was presented, or at the end of the subsequent lecture. As was the case with the thought probes, responses to quiz questions were provided by all students in attendance using i > clickers (www1.iclicker.com).

The creation of multiple-choice questions unfolded as follows: The instructor, after referring to the predetermined schedule,[1] would create a new PowerPoint file containing the slides presented before and after each probe. To clarify, if, for example, a thought probe was to be inserted after slide 13, the instructor would copy slides 13 and 14 into a new file. Once this was done for all probes, the subset of slides was randomly arranged and emailed to the first or fourth author without identifying information regarding its relative position within the full slide set. A question was then written for each slide based on the content of that slide alone, and e-mailed back to the instructor, who then appended the multiple-choice questions at the

[1] Slight deviations from the predetermined schedule occurred in some cases. These exceptions were made only when the slide in question had no relevant content. These included title slides and transition slides between topics.

end of the existing deck of slides. This process was carefully orchestrated to prevent any bias in question design on the part of the researchers. The schedule created at the outset of the course indicated whether the quiz questions were to be tested on the same day as the material was presented, or the next day. The initial schedule called for a total of 112 questions to be presented. Owing to various technical difficulties in the early days of the study, time constraints, and a handful of errors in question writing, 91 questions of the originally intended 112 questions were successfully presented.

Preterm self-report measures. At the beginning of the course,[2] participants completed a series of self-report measures indexing variables of interest in the present study. These were provided via an electronic questionnaire that was completed immediately after the participants provided consent. All questions were presented on a 5-point scale. The questionnaire gauged the students' preexisting knowledge of the course's subject matter (*not knowledgeable at all* to *very knowledgeable*), their motivation to learn the material (*very unmotivated* to *very motivated*), and the likelihood that they would mind wander during class or that they would complete the assigned reading before the lecture (*never* to *always*). In this survey, participants also provided their student ID numbers and i > clicker numbers. This allowed us to map their clicker responses onto their broader academic record, including overall GPA, but perhaps more importantly, this also allowed us to map their clicker responses onto their performance in the course of interest.

Procedure

The study unfolded across a 12-week term (the beginning of January to the end of March), constituting the entirety of the Physiological Psychology course. Thought probes were presented on PowerPoint slides that were embedded in the existing deck of lecture slides, whereas quiz questions were presented at the end of the lecture. Before the class, the instructor generally reminded the students to turn on their i > clickers and to tune into the classroom response frequency. With roughly 6 to 8 min remaining in the allotted class time, the instructor was given a warning to indicate that he should work toward finishing up the current slide. Following this, the instructor advanced directly to the quiz questions, of which there were between two and six. When a quiz question was presented, the instructor read the question aloud, followed by the possible answers. Students were given 30 seconds to respond using their i > clickers. After all responses were collected, participants were shown the correct answer, along with a bar graph depicting the distribution of class responses to the question.

Results

Summary of Thought Probe Data

Because of the scope of this study, findings concerning participants' rates of mind wandering, and how these rates changed over a given lecture, week, or term, are provided in greater detail in Part 1 of this work (Wammes et al., 2016). However, we provide a brief summary of these findings here to help place the present findings in context. Owing to truancy, lateness, or equipment failure, students responded to a variable number of the 44 total thought probes (1 to 44, $M = 32.95$, $SE = 0.88$). Participants who responded to fewer than 10 of the probes were not included in the analyses of the rates of mind wandering. Findings indicated that the overall average level of mind wandering (intentional and unintentional combined) was 34%, and more than half of the participants' reported at least one mind-wandering episode that was intentional in nature, rather than unintentional. Further, our findings indicated that mind-wandering rates did not increase over time within an average live lecture, that mind-wandering proportions were highest at midweek, and that rates of mind wandering increased toward the end of the course and term. This increase over the course of the term was primarily driven by an increase in intentional, rather than unintentional mind wandering.

[2] Participants also completed an identical postterm questionnaire, which asked the same questions. This was included to determine the consistency of participants' responses from the beginning to the end of the term. However, responses to these questions were not included in any analyses, as any changes in the postterm reports were likely to be unduly contaminated or influenced by one's performance on the quiz questions, or recently completed exams.

The Relation Between Mind Wandering and Performance at the Group Level

We began our analysis of the relation between mind wandering and performance by considering quiz accuracy. Participants responded to a variable number of quiz questions, with the number of questions participants successfully responded to ranging from two to 90 ($M = 68.44$, $SE = 1.76$). In our prior analysis of thought-probe responses (Wammes et al., 2016), participants responding to fewer than 10 of the 44 probes were excluded. To maintain consistency with this criterion, we roughly matched exclusions between probe and quiz question analyses. Thus, participants responding to fewer than 20% of the quiz questions—which corresponded to a cutoff of 18 of the 90 quiz questions ($n = 8$)—were removed from analyses, leaving 146 subjects. We computed a mean overall quiz accuracy of .591 ($SE = 008$, CI_{95} [0.574, 0.607]), which was significantly greater than 0.200, $t(145) = 48.875$, $SE = .008$, $p < .001$, which represents chance performance, given that it was a five-alternative multiple-choice test. The first comparison of interest was that of quiz accuracy during lectures in which probes were presented, relative to control lectures in which probes were not presented. A paired-samples t test indicated that quiz question accuracy on control days ($M = .606$, $SE = 0.011$, CI_{95} [0.584, 0.628]) was not significantly different from quiz question accuracy on probe days ($M = .587$, $SE = 0.009$, CI_{95} [0.569, 0.604]), $t(145) = 1.864$, $SE = .010$, $p > .05$.

Next we analyzed accuracy on quiz questions that were presented on probe days, as a function of when material was presented and later tested (see Table 1). Recall that quiz questions included on probe days tested information that was presented on slides that occurred just before or just after a probe was presented. In addition, the quiz questions on a given day tested material learned on that same day or material covered in the previous lecture. Accordingly, we analyzed quiz question performance using a 2 × 2 repeated measures ANOVA with Position of Material (Before probe, After probe) and Day of Testing (Same, Next day) as within-participant factors. The analysis yielded a main effect of Day of Testing, such that accuracy was worse with Next-day, relative to Same-day testing, $F(1, 145) = 85.651$, $MSE = .014$, $p < .001$, $\eta^2 = .371$. However, the main effect of Position of Material was not significant, $F(1, 145) = 2.561$, $MSE = .014$, $p > .05$, *ns*, $\eta^2 = .017$. We also observed a significant Position of Material by Day of Testing interaction, $F(1, 145) = 6.796$, $MSE = .091$, $p < .05$, $\eta^2 = .045$. Follow-up analyses indicated that this interaction emerged because accuracy was higher on questions presented before than after a probe when tested on the same day, $t(145) = 2.914$, $SE = .014$, $p < .005$, while the corresponding advantage was absent on the next day, $t(145) = -.690$, $SE = .013$, $p > .05$ (see Table 1).

Table 1
Mean Accuracy on Quiz Questions Based on Material Presented Before or After a Thought Probe, Tested on the Same Day or the Next Day

	Question position					
	Before probe			After probe		
Day of testing	*M*	*SE*	*CI*	*M*	*SE*	*CI*
Same day	.659	.012	.024	.618	.013	.025
Next day	.532	.012	.024	.541	.013	.025

As previously outlined, the quiz questions tested information that was presented either directly before, or after a thought probe. Therefore, our next task was to explore the consequences of participants' mental states (the three possible thought-probe responses) on later question accuracy. Accordingly, quiz questions were sorted into three categories based on their associated probe responses (i.e., on task, intentional mind wandering, unintentional mind wandering). An accuracy score was then computed for both before and after each probe response. Because a given participant might never have chosen one of the probe responses (e.g., 'Intentionally mind wandering'), several participants had missing cells for this analysis. Forty-two participants were removed from the analysis for this reason. A 2 × 3 repeated measures ANOVA with Position of Material (Before probe, After probe) and Probe Response (On task, Intentional Mind Wandering, Unintentional Mind Wandering) as within-participant factors revealed only a main effect of Probe Response, $F(2, 206) = 3.122$, $MSE = .059$, $p < .05$, $\eta^2 = .029$, indicating that participants had higher accuracy on quiz questions when they reported being On Task than when they reported

Intentional Mind Wandering, $t(103) = 2.372$, $SE = .023$, $p = .02$. Quiz accuracy surrounding reports of Unintentional Mind Wandering was nominally, though not significantly, lower than reports of being On Task, $t(103) = 1.389$, $SE = .022$, $p = .17$, and not significantly different than reports of Intentional Mind Wandering, $t(103) = -.913$, $SE = .027$, $p = .36$. The main effect of Position of Material and the interaction were not significant, $ps > .71$.

As discussed, our a priori hypothesis was that there may be relevant differences between questions based on material presented *before*, rather than after a thought probe. This is because the presentation of a thought probe likely serves to reorient attention back to the lecture (Seli, Carriere, Levene, et al., 2013). The implication is that retention of material presented after this reorienting is unlikely to reflect the consequences of the preprobe cognition. Accordingly, we conducted repeated measures ANOVAs separately for questions based on material presented before and material presented after the probes, with Probe Response (On Task, Intentional Mind wandering, Unintentional Mind Wandering) as a within-participants factor. Figure 1 shows the mean accuracy scores associated with each of the probe responses for questions testing material before and after the probe. As can be seen in the figure, for questions testing material presented before a probe, there was a main effect of Probe Response, $F(2, 218) = 3.160$, $MSE = .066$, $p < .05$, $\eta^2 = .028$. Paired-samples t tests between Probe Response conditions showed that the aforementioned main effect was driven by lower accuracy associated with reports of Intentional Mind Wandering than for On task reports, $t(109) = 1.389$, $SE = .032$, $p = .01$. Reports of Unintentional Mind Wandering were associated with marginally lower accuracy than On task reports, $t(109) = 1.959$, $SE = .032$, $p = .053$, but performance did not differ from reports of Intentional Mind Wandering, $t(109) = .553$, $SE = .039$, $p = .582$. It is worth noting, however, that reports of Unintentional Mind Wandering were associated with nominally better performance than Intentional Mind Wandering reports. For questions based on material presented after a probe, the main effect of Probe Response was not significant, $F(2, 234) = 1.330$, $MSE = .069$, $p > .05$, *ns*, $\eta^2 = .011$.

The Relation Between Mind Wandering and Performance at the Level of Individual Differences

In 17 participants, there were missing data on exam scores and GPA, whereas in nine participants, there were missing data for the preterm self-report measures. These data were imputed using SPSS, and all correlational, regression, and mediation analyses included these imputed values.

Bivariate correlations. Correlational analyses were conducted to assess further the po-

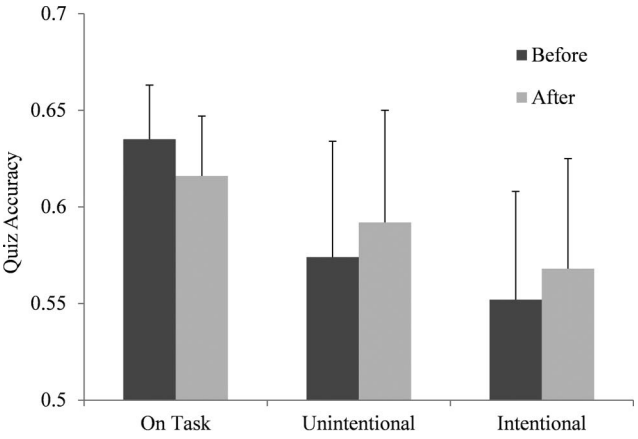

Figure 1. Mean accuracy on quiz questions associated with material presented before and after thought probe responses of on-task, unintentional, or intentional mind wandering. Error bars reflect 95% confidence intervals.

tential association between mind wandering and course performance, as well as the relation of mind wandering and performance to background variables relevant to performance.[3] We began by examining correlations among all variables (see Table 2). First, we found that intentional and unintentional mind wandering were significantly negatively correlated. As suggested in previous work (Seli, Cheyne, et al., 2015), such a result is likely (at least in part) attributable to the ipsative nature of the measures (i.e., as these are two of three forced-choice options, selecting one precludes selection of the other; for a detailed discussion of this topic, see Seli, Wammes, et al., 2015). Next, we observed that unintentional, but not intentional, mind-wandering rates were significantly negatively correlated with exam scores, whereas intentional, but not unintentional, mind-wandering rates were significantly negatively correlated with quiz accuracy. This finding is consistent with the results from the quiz accuracy analyses, indicating that when intentional mind wandering was reported, performance was poorer on associated material. Thus, intentional mind-wandering rates were significantly associated with more immediate or short-term deficits in performance, whereas unintentional mind-wandering rates were significantly associated with long-term outcomes. Moreover, unintentional, but not intentional, mind-wandering rates were significantly positively correlated with self-rated knowledge and anticipated in-class mind wandering. The latter result suggests that unintentional mind wandering is the more prototypical form of mind wandering and forms the basis for trait-level self-judgments of generic mind wandering.

Furthermore, rates of intentional, but not unintentional, mind wandering were negatively correlated with both preterm motivation levels, although this effect was marginal ($p = .08$), and preterm judgments of one's likelihood of completing the course readings. Given that motivation and prior knowledge were significantly positively correlated, it seems likely that lower ratings on these two variables reflect lower levels of interest in the topic, which would plausibly be related to the tendency to deliberately mind wander in class. It should be noted, however, that based on results from Williams' tests, only the difference between the pair of correlations (intentional vs. unintentional) with exam scores approached significance. Specifically, the unintentional correlation was marginally higher in magnitude, $t(154) = 1.88$, $p = .062$. No other correlation among unintentional/intentional mind wandering and other background variables differed significantly in magnitude (all other ps $> .17$).

Quiz accuracy and exam scores were significantly positively correlated, and both of these course performance variables were significantly positively correlated with GPA, whereas only quiz scores were positively associated with motivation. The correlation of GPA with exam scores was significantly greater than that between GPA and quizzes, $t(154) = 3.12$, $p = .002$, indicating that GPA was associated more strongly with long-term exam scores than with short-term quiz scores. Moreover, exam scores, but not quiz accuracy, were significantly positively correlated with attendance and prior knowledge. Also of interest was the finding that GPA and attendance were significantly positively correlated, and that prior knowledge and attendance were marginally positively related with GPA. More generally, the associations among the background variables were what might be expected. Perhaps the most surprising finding is that, contrary to what most would predict, preterm self-reports of mind wandering, motivation, and prior reading were not significantly correlated with exam scores, GPA, or attendance.

Predicting quiz accuracy. Because intentional and unintentional mind wandering were negatively correlated with one another, and because both tended be similarly (negatively) correlated with performance measures, we suspected statistical suppression. We therefore entered both mind-wandering measures into a multiple regression to assess their joint and independent contributions to performance. With regard to quiz accuracy, a stepwise multiple regression was carried out with mind-wandering measures entered on the first step and background variables on the second step. We reversed the conventional order of entry of these variables for two reasons: first, because we were

[3] All preterm measures were significantly correlated with their corresponding postterm measures, rs $> .29$, ps $< .001$, indicating that participants were consistent in their responses.

Table 2
Pearson Product-Moment Correlations Among Measured Variables

Variable	Intentional MW	Quiz	Exam	GPA	Attendance	Knowledge	Motivation	Mind wandering	Reading
Unintentional MW	**−.17**	−.10	**−.20**	−.09	−.03	**−.19**	.02	**.21**	−.06
Intentional MW		**−.21**	−.03	−.05	−.06	.02	−.14	.08	**−.21**
Quiz mean			**.29**	**.20**	.09	.05	**.17**	.02	.03
Exam scores				**.47**	**.31**	**.21**	.10	−.03	−.11
GPA					**.25**	.14	.07	−.02	−.03
Attendance						.14	.02	−.03	.09
Preterm knowledge							**.33**	**−.23**	.08
Preterm motivation								**−.28**	**.32**
Preterm mind wandering									**−.19**

Note. Coefficients in bold are conventionally significant, $p < .05$.

interested in the relations between the predictive effects of the two mind-wandering measures independently of other variables, and second, because our subsequent interest was to determine what effects, if any, the background variables might have on the statistical interplay between the two forms of mind wandering.

Interestingly, when intentional and unintentional mind wandering were entered in Step 1, both variables made unique contributions to the prediction of quiz accuracy, although the contribution of unintentional mind wandering was only marginal, $p = .088$. Further, the contributions were both numerically greater than their simple bivariate correlations (see Table 2), a result that is consistent with statistical suppression. Interestingly, the standardized beta weights were essentially unchanged when the background variables were added in Step 2. Indeed, of the background variables entered into the regression only GPA and motivation made independent contributions to quiz accuracy, though the contribution of GPA was only marginal, $p = .054$. Consistent with this, the R-square change at Step 2 was not significant (see Table 3). Thus, intentional mind wandering, independently of the background variables assessed in the present study, predicted quiz accuracy.

Predicting exam scores. A parallel stepwise multiple regression analysis was carried out predicting final exam scores with mind wandering, quiz accuracy, and background variables. At Step 1 unintentional mind-wandering

Table 3
Stepwise Multiple Regression Predicting Mean Quiz Accuracy With Mind Wandering and Background Variables

Model	DV: Quiz scores	*B*	*SE*	β	*t*	*p*
1	(Constant)	.64	.02		36.28	.000
	Unintentional MW	−.13	.07	−.14	−1.72	.088
	Intentional MW	−.15	.05	**−.24**	−2.96	.004
2	(Constant)	.28	.13		2.17	.031
	Unintentional MW	−.14	.08	−.16	−1.90	.059
	Intentional MW	−.15	.05	**−.23**	−2.77	.006
	GPA	.00	.00	.16	1.94	.054
	Attendance	.02	.04	.04	.51	.614
	Preterm knowledge	−.01	.01	−.04	−.47	.641
	Preterm motivation	.03	.01	**.19**	2.17	.032
	Preterm mind wandering	.02	.02	.11	1.31	.192
	Preterm reading	−.01	.01	−.07	−.83	.410
Initial model		$F(2, 151) = 5.13, p < .01$				
Final model		$F(8, 145) = 2.71, p < .01$				
R^2 change at step 2		$R^2_\Delta = .07, F(6, 145) = 1.85, p = .093$				

Note. Coefficients in bold are conventionally significant, $p < .05$.

rates significantly predicted exam scores, whereas intentional mind-wandering rates did not. On Step 2, the addition of quiz accuracy, which significantly contributed to predicting exam scores, produced a significant R-square change. Moreover, the standardized beta coefficient for unintentional mind wandering was somewhat reduced but remained significant. On Step 3, background variables of GPA, attendance and preterm reading made significant independent contributions to predicting exam scores. The beta for unintentional mind wandering was now of marginal significance. In contrast to the effects for quizzes, the addition of background variables did yield a significant R-square increment in the final step (see Table 4).

To summarize the regression analyses, intentional mind-wandering rates significantly predicted short-term within-class assessments of learning (quiz accuracy), which were closely temporally associated with the thought-probes. Apart from motivation, the general background variables had marginal or no associations with quiz accuracy. In contrast, only unintentional mind wandering was significantly associated with final exam scores and this effect became marginal upon the addition of the general background variables as predictors. The results for the analysis are rather clear, indicating no effect of in-class intentional mind wandering on exam scores. The effects for unintentional mind wandering are marginal, leaving open the possibility of a small direct effect on final grades.

Mediation analysis. Finally, to assess possible indirect effects of mind wandering (via local learning effects, as estimated by quiz accuracy) on exam scores, a path analysis was carried out with both mind-wandering measures as exogenous variables, quiz accuracy as a mediating variable, and exam scores as the outcome. A model excluding direct effects of mind wandering provided a reasonably good fit to the data, $\chi^2(2) = 4.48$, $p = .106$, CFI = 0.889, RMSEA = .090, *pclose* = .199. To assess the generality and reliability of our model, we aimed to determine whether the model would fit two separate subsets of our sample well. One straightforward way to achieve this was to apply the mediation model to males and females simultaneously and constrain the mind-wandering covariance and the three path coefficients to be equal between groups. While the fit was not

Table 4
Stepwise Multiple Regression Predicting Exam Scores With Mean Quiz Accuracy, Mind Wandering, and Background Variables

Model	DV: Exam scores	*B*	*SE*	β	*t*	*p*
1	(Constant)	.84	.02		37.83	.000
	Unintentional MW	−.20	.08	**−.21**	−2.54	.012
	Intentional MW	−.04	.06	−.06	−.74	.459
2	(Constant)	.65	.06		11.63	.000
	Unintentional MW	−.16	.08	**−.17**	−2.12	.035
	Intentional MW	.00	.05	.01	.06	.951
	Quiz accuracy	.29	.08	**.28**	3.45	.001
3	(Constant)	.15	.12		1.26	.208
	Unintentional MW	−.13	.07	−.14	−1.88	.062
	Intentional MW	−.01	.05	−.01	−.13	.899
	Quiz accuracy	.18	.08	**.18**	2.43	.016
	GPA	.01	.00	**.34**	4.76	.000
	Attendance	.09	.03	**.20**	2.82	.005
	Preterm knowledge	.01	.01	.10	1.29	.198
	Preterm motivation	.01	.01	.06	.80	.428
	Preterm mind wandering	.00	.01	.02	.20	.841
	Preterm reading	−.02	.01	**−.16**	−2.18	.031
Initial model		$F(2, 151) = 3.27$, $p < .05$				
Intermediate model		$F(3, 150) = 6.31$, $p < .001$				
Final model		$F(9, 144) = 8.33$, $p < .001$				
R^2 change at step 2		$R^2_\Delta = .07$, $F(1, 150) = 11.93$, $p < .01$				
R^2 change at step 3		$R^2_\Delta = .23$, $F(6, 144) = 8.40$, $p < .001$				

Note. Coefficients in bold are conventionally significant, $p < .05$.

as good as the general model, $\chi^2(8) = 14.81$, $p = .063$, CFI = 0.687, RMSEA = .075, *pclose* = .214, the difference between the constrained and unconstrained model was not significant, $\chi^2(4) = 1.51$, $p = .825$, indicating that the model fit replicates across groups.

The model depicted in Figure 2 is a saturated model that tests for the direct and indirect effects of intentional and unintentional mind wandering on exam scores. The standardized indirect effect for intentional mind wandering was −.07 and was significant, $p = .010$, whereas the indirect effect for unintentional mind wandering was −.04, and was marginal, $p = .096$. The effects of unintentional mind wandering on exam scores thus appear to be split between direct and indirect effects (see Figure 2). The total effects of intentional mind wandering on exam scores were approximately one third those of unintentional mind wandering, and they are exclusively indirect. We cautiously interpret these results as being consistent with the notion that unintentional mind wandering is automatic and relatively context independent. Specifically, unintentional mind wandering appears to have only a minor influence on quiz accuracy in the classroom, albeit less so than intentional mind wandering. On this view, unintentional mind wandering will likely be more ubiquitous and hence also operate in other contexts that affect performance (e.g., efficiency of home study) as evidenced by its direct effect on exam scores. Intentional mind wandering, on the other hand, is arguably more controlled and dependent on context and motivation. Hence, intentional mind wandering in class will specifically affect classroom performance. Nonetheless, as the material on the final exam is, in part, delivered in the classroom there is a predicted small residual indirect effect on the final exam.

Discussion

In the foregoing analyses, we examined the relation between mind wandering and performance at both the group and individual-difference levels. At the group level the most compelling finding was that performance was significantly poorer on material present before a probe when participants reported having been intentionally mind wandering, as compared to having been engaged in on-task thought. This is consistent with previous work showing that mind wandering is associated with reductions in performance in various tasks (Giambra, 1995; Risko et al., 2012; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Seli, Cheyne, et al., 2013; Smallwood et al., 2003, 2007). Our findings are also concordant with several studies that have demonstrated the detrimental effects that mind wandering has on retention in educational settings (e.g., Cameron & Giuntoli, 1972; Risko et al., 2012), and on later exam performance (Lindquist & McLean, 2011), as well as studies showing a negative association between mind wandering and SAT scores (Unsworth et al., 2012). Interestingly, however, in the current work, unintentional mind wandering led to only

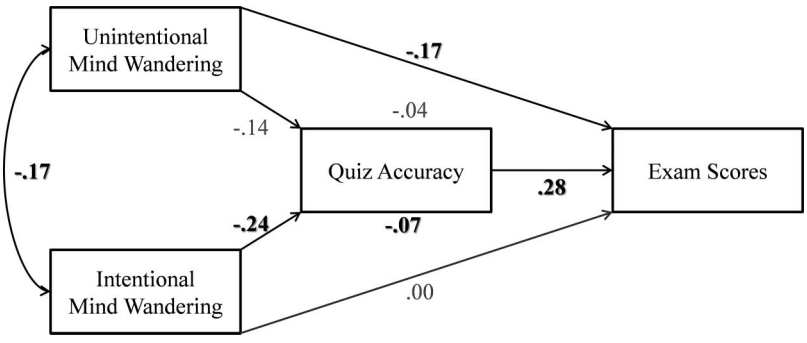

Figure 2. Saturated model depicting direct effects of intentional and unintentional mind-wandering measures, predicting quiz accuracy and exam scores, as well as indirect effects of mind wandering on exam scores, with quiz accuracy as the mediating variable. Path coefficients in bold are significant. Indirect effects are shown above and below the mediating variable.

nominal reductions in quiz performance relative to on task thoughts. In the aforementioned studies, the effects of mind wandering on retention were quite striking. Although we also found long-term performance consequences (i.e., in exam scores) as a result of reports of unintentional mind wandering, these effects were only marginal when background variables were included as predictors. There are two potential explanations for this. First, because there is substantial intervening time between lectures and exams, students might compensate for detrimental effects of in-class mind wandering by engaging in extra reading and studying outside of the classroom. Second, intentional and unintentional mind wandering were not distinguished from one another in previous studies. This may have confounded relatively weak short-term effects of unintentional mind wandering, with the relatively strong short-term effects of intentional mind wandering. Importantly though, in the mediation model, unintentional mind wandering had a significant direct effect on exam scores. Taken together with the marginal direct effect, which remained despite including contributing background variables, these findings suggest that unintentional mind wandering during lectures does indeed have influential detrimental effects on academic success.

Critically, in the extant literature, most discussions of mind wandering describe the origin of a mind-wandering episode as reflecting an unintentional failure of attentional control (e.g., Bixler & D'Mello, 2014; Blanchard et al., 2014; Carciofo et al., 2014; Cohen, 2013; Fox et al., 2015; Kane & McVay, 2012; Qu et al., 2015; Rummel & Boywitt, 2014; Wilson et al., 2014). In contrast, and consistent with recent work (e.g., Carriere et al., 2013; Forster & Lavie, 2009; Seli, Carriere, Levene, & Smilek, 2013; Seli, Smallwood, et al., 2015; Seli, Wammes, et al., 2015; Shaw & Giambra, 1993), a large proportion of the mind wandering reported in this study was intentional. Moreover, it is intentional mind wandering (rather than unintentional mind wandering) that leads to the starkest declines in quiz scores, our direct measure of retention. This latter finding is particularly important given that data from Part 1 demonstrated a linear increase in intentional mind wandering as the term progressed (Wammes et al., 2016). Although instructors' expectations may be that student retention is improving in anticipation of final evaluations, their rates of intentional mind wandering, which we demonstrated can be detrimental to immediate retention, are actually at their highest. Thus, an emphasis on educational interventions involving reducing mind wandering as it has often been portrayed—as unintentional drifts away from task-related thought—may be incomplete and simplistic. Indeed, the present findings suggest that reducing intentional disengagement, possibly resulting from declining levels of interest or motivation over the term, will be more productive. Moreover, under the reasonable assumption that intentional mind wandering is more likely to be under executive control, information about the detrimental effects of intentional mind wandering may be more usefully employed by students than information about unintentional mind wandering.

To target low motivation, instructors might consider including quiz questions in their lectures as we have, while taking into account student accuracy on these questions when calculating their overall course grades. This would likely serve to raise the perceived value of attending to the lecture, thus possibly reducing intentional mind wandering. In addition, there is ample evidence to suggest that interpolated testing can improve later performance on tests (McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011; Roediger, Agarwal, McDaniel, & McDermott, 2011; Schacter & Szpunar, 2015; Szpunar, Khan, & Schacter, 2013), lead to more veridical assessments of one's actual knowledge (Szpunar, Jing, & Schacter, 2014), and lead to better transfer of knowledge to novel contexts (Butler, 2010; Carpenter, 2012). Critically, the available evidence also suggests that interpolated testing is associated with (and might have its effects partly through) reduced levels of mind wandering (Szpunar, Khan, & Schacter, 2013). Thus, introducing quiz questions, performance on which impacts actual course grades, may tangibly benefit students. It is possible that such quiz questions would serve not only to increase motivation, and decrease intentional mind wandering, but also give participants a more accurate perception of how much of the required information they have retained.

At the group level, we also predicted that material presented after, relative to before, a thought probe would be better recalled. This hypothesis was grounded in evidence that thought probes may act as exogenous cues to reorient attention (Seli, Carriere, Levene, et al., 2013). This prediction was not supported. In fact, the pattern was

nominally, but not significantly, in the opposite direction. It is possible that the thought probes interfered with participants' ability to build an understanding of the lecture, thereby disrupting retention of post-probe information. Indeed, consistent with this view, it has been posited that comprehending an integrated stream of discourse requires the maintenance of a situation model (Zwaan & Radvansky, 1998), which is a mental representation of the concept being presented. In support of this idea, Smallwood and colleagues (2007) showed that mind wandering at critical junctures in a narrative can lead to an inability to build a coherent model of the narrative as a whole. Thus, it is possible that the insertion of thought probes at critical points in the lecture could produce similar disruptions in model maintenance. Indeed, visual analysis of Figure 1 shows that when participants reported being on task, performance was slightly, though not significantly, decreased as a result of the thought probe (i.e., after probe questions are higher than before). Conversely though, performance was nonsignificantly higher for material presented after, relative to before a thought probe with reports of either type of mind wandering, which is in the direction one would predict if thought probes served to reorient attention. We make these interpretations with a high degree of caution though, as the foregoing differences were not statistically significant.

At the individual-difference level, regression and mediation analyses revealed that intentional mind wandering seems to be more responsible for immediate short-term performance declines (quiz performance), whereas unintentional mind wandering has a larger influence over longer-term measures (exam scores). Nonetheless, the short-term effects of intentional mind wandering (on learning, e.g.) may themselves have effects on subsequent performance. Importantly, we found relations between intentional mind wandering and performance on quiz questions that occurred independently of other known drivers of class performance, such as motivation, attendance, and overall GPA. This being said, the long-term effects of in-class mind wandering on exam performance were less impactful when these background variables were included. Thus, the effects of mind wandering on long-term performance were not as dramatic as one might have expected based on the extant mind-wandering literature. As suggested, this is perhaps because studying that occurs outside of class can ameliorate some of the learning impairment caused by mind wandering during lectures. Thus, the finding that unintentional mind wandering remained marginally associated with exam scores *despite* controlling for relevant background variables, suggests the rate at which one engages in unintentional mind-wandering is likely a meaningful contributor to academic success.

We tentatively interpret our results as suggesting that the intentional–unintentional mind-wandering comparison may be analogous to a state–trait distinction. Specifically, unintentional mind wandering is more representative of one's general propensity for mind wandering, which has lasting broad effects on long-term performance (exam scores) and GPA, whereas intentional mind wandering likely reflects a state of low motivation, leading participants to deliberately disengage, which exerts stronger effects on more immediate measures, such as short-term retention and performance (quiz accuracy, and indirect effects through quiz accuracy on later tests). Together, these findings provide a useful characterization of the ebb and flow of student's attention in an actual live, lecture-based, university course, as well as the consequences of such cognitions on later academic performance.

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Received September 1, 2015
Revision received January 7, 2016
Accepted January 7, 2016 ■