Mind Wandering During Lectures I: Changes in Rates Across an Entire Semester

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Mind Wandering During Lectures I:

Changes in Rates Across an Entire Semester

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Abstract

It is a commonly held notion that in university lectures, the attention of a student wanes as time elapses. Despite widespread endorsement of this belief, research has not yet verified its accuracy in a real lecture setting. Here, we tested this common belief by examining rates of students' (N = 154, 97 females, 57 males) mind-wandering (both *intentional* and *unintentional* forms) throughout a twelve-week undergraduate course, collecting over five thousand individual observations of mind-wandering. Thought-probes were placed intermittently within lectures to assess mind-wandering rates on a large scale, and to evaluate how these rates changed over time within an average lecture, an average week, and the term. Among the many results of our study, we found, quite surprisingly, that unintentional mind-wandering rates were relatively low (14%) and that mind-wandering did not, as often assumed, increase over time during the lectures. Rather, the main effect over time in lectures ($F = 4.92$, $p < .01$) was driven by a slight *decrease* in mind wandering toward the end of a lecture ($t = 3.97$, $p < .001$). Moreover, we found that mind wandering was lowest at mid-week, relative to Monday ($t = 3.07$, $p < .01$) and Friday ($t = 3.21$, $p < .01$). Based on these results, we conclude that unwanted and steadily-increasing mind-wandering need not always manifest in traditional lecture settings. In addition to the foregoing, we provide extensive information about the fluctuations of mind-wandering in an ecologically valid lecture setting.

Mind Wandering During Lectures I: Changes in Rates Across an Entire Semester

Instructors and students alike will readily agree that students are not always paying attention to the material presented in class. In the first study of its scope, we examined students' mind wandering during live lectures in a large undergraduate class throughout the entirety of a full-semester course, collecting over 5000 individual observations of mind wandering. Following Smallwood and Schooler (2006), we use the term 'mind wandering' as a general term to denote the mental act of shifting one's attention away from a focal external task, inwards toward internal cognitions (cf. Antrobus, 1968; Giambra, 1989; 1995; Mason, Norton, Van Horn, Wegner, Grafton & MacRae, 2007; Schooler, 2002; Schooler, Reichler & Halpern, 2004; Smallwood, Obonsawin & Heim, 2003). We gauged students' mind wandering using a varying number of intermittent thought-sampling probes (the probe-caught method; see Giambra, 1995; Smallwood & Schooler, 2006) inserted pseudo-randomly into nearly all lectures. Our paradigm also included quiz questions at the end of each class, which tested retention of material that preceded and followed each thought probe. We also had access to midterm and final test scores, and we collected a number of self-report measures (e.g. motivation, prior knowledge) from all participants before the beginning of the term. To maintain a reasonable scope for this paper (Part 1) however, we reserve analyses of these measures for Part 2 (***[Authors omitted for masked review policy]***, submitted).

Our design was organized to address four specific areas of interest. Specifically, we examined (1) the prevalence of intentional mind wandering, unintentional mind wandering, and overall mind wandering (i.e., the combined reports of intentional and unintentional mind wandering) in an ecologically valid lecture setting, (2) changes in rates of intentional, unintentional, and overall mind wandering over time within a lecture, (3) within a week, and (4) within the term. It is important to keep in mind that our overarching goal was not to determine the manner in which mind wandering *always* manifests in the context of a live university lecture, but rather, how mind wandering *can* manifest in a live lecture. In what follows, we provide background for each of the four specific research aims described above.

(1) The prevalence of overall, intentional and unintentional mind wandering

Our first aim was to examine the prevalence of mind wandering in an actual live lecture setting. Using the thought-probe method, researchers have observed high rates of mind wandering (up to roughly 45%) across a wide array of laboratory tasks, ranging from simple vigilance tasks (e.g., Seli, Cheyne & Smilek, 2013) to more complex tasks such as reading (Schooler et al., 2004; Smallwood, McSpadden & Schooler, 2007; Varao Sousa, Carriere & Smilek, 2013) and attending to a video-recorded lecture ((***[Authors omitted for masked review policy]***, under review; Szpunar, Jing, & Schacter, 2014; Szpunar, Khan, & Schacter, 2013). Consistent with these laboratory-based findings, Killingsworth and Gilbert (2010) assessed mind wandering rates in everyday life by probing participants via their mobile devices, and found that the average person engaged in mind wandering roughly 47% of the time. Closer to the focus of the current work, early explorations of student attention during university courses found varying levels of attention, depending on the type of class and the activity that students were engaged in. For example, in one such study, Schoen (1970) asked student participants to report the contents of their consciousness every time a bell was rung during a college lecture, and found that students reported being in an inattentive state around 33% of the time. Later work however (Cameron & Giuntoli, 1972) reported substantially higher rates of inattention, between 54% and 60%. Using a similar methodology, Geerligs (1995) found that, in college discussion groups, participants' thoughts were task irrelevant about 28% of the time (Geerligs, 1995). In more recent work on the topic, Risko, Anderson, Sarwhal, Engelhardt and Kingstone (2012) found that students reported probe-caught mind wandering roughly 43% of the time when viewing 60-minute video lectures in the laboratory. In a much shorter study, employing a 21-minute video lecture, Szpunar, Khan and Schacter (2013) found a comparable rate of mind wandering (41%), indicating that rates of mind wandering in lecture studies are high and comparable to rates observed in simpler tasks.

Based on the foregoing, *we hypothesized that there would be a relatively high level of probe-caught mind wandering in real live lectures* (roughly 30-50%). However, there is evidence to suggest that mind wandering can be reduced by increasing motivation (Antrobus, Singer, & Greenberg, 1966; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Unsworth & McMillan, 2013), and research indicating slightly lower mind-wandering rates in college lectures (Schoen, 1970). Accordingly, we also considered the possibility that mind wandering rates might be lower in lecture settings, as student's ambition to achieve high grades might motivate them to diligently pay attention during lectures. Conversely, it may be possible that live lecture settings differ in how engaging they are to the student. The contribution of motivation is addressed in later sections.

Also of interest in the present study was the degree to which participants engaged in mind wandering that was intentional or unintentional in nature during a live lecture. Accordingly, the thought probes required students to report on whether their mind-wandering episodes were engaged intentionally (i.e., willfully) or unintentionally (i.e., despite their best intentions to focus on the lecture) (see Carriere, Seli & Smilek, 2013; Giambra, 1995; Seli, Carriere, & Smilek, 2015; Seli, Cheyne, et al., 2015; Seli, Smallwood, Cheyne, & Smilek, 2015; Shaw & Giambra, 1993). On the one hand, it seems plausible that, on some occasions, students might intentionally choose to mind-wander, perhaps because the lecture material is familiar to them, or because they lack sufficient motivation to maintain focused. On the other hand, as much of the literature on mind wandering appears to assume, students might sometimes find that their mind wandering is spontaneous and unintentional, and that it occurs despite their best efforts to maintain focus on the lecture.

One of our main interests in investigating these two states is to assess the validity of the widely held assumption in the mind-wandering literature that mind wandering occurs primarily as an unintentional event (e.g., Cohen, 2013; Kane & McVay, 2012) that, of highly important theoretical interest, reflects a failure of executive control (e.g., Kane & McVay, 2012; McVay & Kane, 2010). On this executive control view, the relatively high rates of mind wandering reported in laboratory tasks and in everyday life are interpreted as reflecting a cognitive failure that is inevitable, unwanted, and cannot be controlled by the individual. However, recent findings suggest that, in some cases, mind wandering is engaged in intentionally (Seli, Cheyne, et al., 2015; in press; Giambra, 1995; Carriere et al., 2013), which calls into question the commonly held view that mind wandering typically occurs in the absence of intention (e.g., Baars, 2010; Carciofo, Du, Song, & Zhang, 2014; Cohen, 2013; Kane & McVay, 2012; Klinger, 2009; Mason et al., 2007; McVay & Kane, 2010; O'Callaghan, Shine, Lewis, Andrews-Hanna, & Irish, 2014; Seli, Cheyne, & Smilek, 2013; Zavagnin, Borella, & De Beni, 2014; For an in depth discussion on the topic, see Seli, Cheyne, et al., 2015). On the basis of this research, here *one might expect that a notable proportion of mind wandering observed in a live lecture will be initiated intentionally*, perhaps due to lack of motivation. Critically, this finding would provide further evidence bearing on the recent claim that there are problems with the common assumption that mind wandering occurs in the absence of intention and reflects a failure of executive control (Seli, Cheyne, et al., 2015). In addition, such a finding would be practically informative when designing interventions aimed at reducing mind wandering in real-world settings, such as classrooms. For example, intentional episodes of mind wandering may be easier to curtail than unintentional ones. Indeed, there is evidence to suggest that intentional and unintentional forms of mind wandering are differentially affected by certain manipulations (e.g., Seli, Risko, & Smilek, in preparation). Thus, interventions aimed at reducing mind wandering in the service of improving academic performance may be most effective if each type of mind wandering is targeted separately. For instance, whereas mindfulness meditation training might exclusively assist in reducing unintentional mind wandering, adding incentives for learning might exclusively result in reduction of intentional mind wandering.

(2) Changes in mind wandering rates and intentionality over a 50-minute live lecture

Given the large number and strategic placement of probes in time across the duration of our study, we were able to assess mind wandering averaged within four epochs of time in an average lecture. Our investigation of changes in mind wandering over time within a lecture was based on a rather large body of research showing that in many tasks there is a marked vigilance decrement – such that participants are less able to sustain attention as time elapses – which leads to steady performance declines (Grier, Warm, Dember, Matthews, Galinsky, Szalma & Parasuraman, 2003; Helton, Hollander, Warm, Matthews, Dember, Wallaart, Beauchamp, Parasuraman & Hancock, 2005; Stroh, 1970; Teichner, 1974; for a review, see Warm, Parasuraman & Matthews, 2008). Vigilance decrements have also been shown in cases where participants are asked to attend to lectures (e.g., Stuart & Rutherford, 1978; Young, Robinson & Alberts, 2009), wherein attention begins to wane within 30 minutes of the start of a lecture (Young et al., 2009). The available evidence also shows that as performance decreases over time-on-task, mind wandering increases (e.g., Seli et al., 2012; Thomson, Seli, Besner & Smilek, 2014). This trend in mind wandering has also been shown to occur when students are required to watch video-recorded lectures in the laboratory (Farley, Risko & Kingstone, 2013; Risko et al., 2012; Risko, Buchanan, Medimorec & Kingstone, 2013). Indeed, Risko et al. (2012) have shown that mind wandering roughly doubles from the first half of a 60-minute lecture to the second half. Given the consensus of the aforementioned findings, the most obvious prediction with regard to time-on-task effects in a live lecture setting is that mind wandering should substantively increase over time in a lecture, reflecting a progressive disengagement of attention from the lecture material.

Notwithstanding the foregoing, it is possible mind wandering might not inevitably increase over time in a live lecture. Such a possibility is suggested by some accounts of the vigilance decrement, which posit that motivation and task value might play an important role in vigilance. For example, Kurzban, Duckworth, Kable and Myers (2013) suggest that as time-on-task increases, the subjective value of the primary task decreases and the value of other tasks increases, which leads to a greater likelihood that, over time, attention will shift to another task. According to accounts such as this, the vigilance decrement is not a necessary outcome of time-on-task, at least within the time frame of the current work, and could be curtailed if motivation to perform (or the perceived value of) the primary task remains high. Consistent with the view that a vigilance decrement is not a necessary outcome of time-on-task in relatively short-term tasks, Hancock (2012) argues that the vigilance decrement occurs only in specific circumstances, particularly when people are externally compelled to complete the primary focal task, and that the vigilance decrement is diminished or eliminated when people are internally motivated to perform well on their focal task (see p. 100, par 3). This suggests that if students are highly internally motivated to attend to a lecture, then they might not show an increase in the frequency of mind wandering over time. Indeed, as participants are aware that their knowledge will be tested, and moreover, that their test performance will have substantial (even lifelong) consequences, they might be far more motivated to maintain focus on course material during a real live lecture than during a video lecture presented in the laboratory (see Risko et al., 2012). Another reason that students might not show an increase in their mind-wandering rates as a function of time-on-task may be that, during real live lectures, instructors can modulate their delivery based on their perception of student attentiveness, which might help students to maintain a constant level of attention over time in a given class. For these reasons we might expect that mind wandering rates in the real live lectures might follow a different pattern than those observed in laboratory settings. Nevertheless, because of the large number of demonstrations of mind wandering increments over time in prior laboratory, and educational studies, *we hypothesize that there will be an increase in mind wandering over the course of a lecture*.

(3) Changes in mind wandering rates and intentionality over a typical three-lecture week

In the present study we were also able to assess mind wandering during lectures presented on Mondays, Wednesdays, and Fridays, which provided the opportunity to examine changes in mind wandering rates as a function of the day of the week. Unfortunately, it is difficult to make specific predictions regarding mind-wandering rate changes over days of a week because there are no published studies that examined mind wandering on this timescale. Nevertheless, there are some grounds for speculation, though we note that our study was not designed to differentiate between competing accounts. One possibility is that mind wandering might be greatest at the end of the week because the build-up of stress that occurs as the week progresses could lead to negative affect, which has been shown to be associated with mind wandering (Smallwood, Fitzgerald, Miles, & Phillips, 2009, Stawarczyk, Majerus, Van der Linden & D'Argembeau, 2012; Poerio, Totterdell & Miles, 2013). Another set of possible predictions comes from the 'Current Concerns hypothesis,' which states that mind wandering is primarily driven by the current concerns that are relevant to the individual (Klinger 1971; 1978; 1987; Klinger & Cox, 2004; Stawarczyk, Majerus, & D'Argembeau, 2013). Perhaps students' concerns are relatively high at the beginning of the week as they recall the past weekend's events and consider all of the tasks they must achieve during the week, and also at the end of the week as they begin to think about the weekend. This is in line with work showing that mind-wandering episodes often involve future planning (e.g., Baird, Smallwood & Schooler, 2011; McVay, Unsworth, McMillan & Kane, 2013). Thus, based on the Current Concerns hypothesis, *we hypothesized higher mind wandering rates early and late in the week compared to the middle of the week*. Of course, at this point, these possibilities are admittedly highly speculative, and we again note that our study was not designed to directly test these accounts.

(4) Changes in mind wandering rates and intentionality over the entire term

As is the case for trends over the week, studying mind wandering over an entire term is unprecedented, leaving little basis from which to derive predictions. However, research has suggested that familiarity and experience with material (Smallwood, Nind, and O'Connor, 2009; Unsworth & McMillan, 2013), as well as task difficulty (e.g., Thomson et al., 2013), may influence the rate and content of mind wandering. Within the course in which this study was conducted, each lecture largely built upon material learned in previous modules. Accordingly, it is possible that as students become more familiar with the general concepts of the course, the material might be easier to follow, and this might in turn lead to greater mind wandering as the semester progresses. Moreover, as the term progresses, deadlines for assignments and tests might become more salient, thereby increasing the number of personal concerns competing for attention at any given time. Previous work has suggested that the mind is known to wander toward personal concerns when goals are incomplete (Klinger 1971; 1978; 1987; Klinger & Cox, 2004; Masicampo & Baumeister, 2011; Stawarczyk et al., 2013). Accordingly, based on the conclusions from the foregoing research, *we hypothesized that as time passes throughout a term, mind wandering rates will systematically vary, and likely increase* as a result of growing personal concerns, including impending deadlines and final evaluations. As with our predictions regarding mind wandering changes over a typical week, these predictions are largely conjecture due to the absence of previous theoretical groundwork.

Summary

In summary, the present study extends laboratory studies of mind wandering and vigilance, examining these phenomena in a more naturalistic lecture setting. Our study did not attempt to manufacture an artificial lecture setting as has been done in previous work, but simply observed mind wandering within normal live lectures in an actual academic course with real consequences for participants (students). The lectures were delivered as in any standard university lecture, with the addition of randomly inserted thought probes, and post-lecture quiz questions. This allowed us to monitor (1) the prevalence of intentional mind wandering, unintentional mind wandering, and overall mind wandering (i.e., the combined reports of intentional and unintentional mind wandering) in an ecologically valid lecture setting, (2) changes in rates of intentional, unintentional, and overall mind wandering over time within a lecture, (3) within a week, and (4) within the term.

Method

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 data from only 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 ***[Authors omitted for masked review policy]*** (one of the co-authors of this paper). Each class began at 8:30 a.m. and lasted for 50 minutes. 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 percent of the course grade), participation in answering in-class quiz questions (worth 4 percent 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 percent of final grade).

Thought probes and responses. In-class thought probes were presented on the main projection screen, inserted intermittently within the regular lecture PowerPoint slides. Thought probes displayed the question, "Which of the following responses best characterizes your mental state JUST BEFORE this screen appeared?" The possible responses presented were "A. On task", "B. Intentionally mindwandering", or "C. Unintentionally mindwandering." The text on the thought probe screens was white and the background of the slide was black. Participants were informed that intentional mind wandering meant that they were willfully thinking about things unrelated to the current lecture, while unintentional mind wandering meant that they were thinking about things unrelated to the lecture despite their best intentions to focus. In the lecture, responses to thought probes were given by all students in attendance using i>clickers (www1.iclicker.com), and responses were collected using an i>clicker Base and software. i>clickers are response pads resembling television remotes, through which participants can quickly and seamlessly provide responses to multiple-choice questions during a live lecture. It is important to note here that responding to questions via i>clicker was a requirement for the course in general, not just for those who chose to participate in our study. Accordingly, all students had i>clickers, preserving the anonymity of those who chose to participate.

Lectures were pseudo-randomly assigned to have between 0 and 3 thought probes, which were embedded and subsequently presented within the lecture slides. The process of inserting thought probes with in the PowerPoint slide sequence was as follows: Assuming that roughly 16 slides would be covered in each lecture (based on the instructor's past experience), we randomly generated a slide number (between 1 and 16), repeating this process without replacement until the predetermined number of thought probes was reached (1 to 3). The thought-probe slides were then inserted after the selected slide numbers. A schedule was constructed for the course of the entire term, to strive for full coverage of material, and a full range of probe times and slide materials. Due to a number of factors, including but not limited to some technical difficulties with the i>clicker software, the variable nature of the timing of slide presentation in undergraduate lectures, and student participation delaying the pace of the lecture, the entire schedule was not fulfilled. The initial term battery scheduled for the inclusion of 50 thought probes, near evenly distributed among slide numbers. Our final data included 44 thought probes that were successfully presented.

Other materials. Given the scope of this study, there were several aspects of the methods that were not directly relevant to the current aims. Nevertheless, we briefly mention them here for purposes of full methodological disclosure, and unpack them entirely in Part 2 of this manuscript (see ***[Authors omitted for masked review policy]***, submitted). Participants' knowledge of the material presented in the lecture was tested via a series of five-alternative quiz questions presented in the last few minutes of class. In addition, at the beginning of the course participants completed a series of questions asking them to self-report their preexisting knowledge of the course's subject matter, their motivation to learn the material, and the likelihood that they will mind wander during class or do the reading before class.

Procedure

The core of the study unfolded across a twelve-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. Prior to the class, the instructor generally reminded the students to turn on their i>clickers and to tune into the classroom response frequency. The instructor then went on with teaching, making an effort to lecture naturally until the thought-probe slide appeared on the screen. When the thought-probe slide appeared, the instructor verbally noted that a thought probe was presented, saying something to the effect of: "Oh, a thought probe has appeared. Please take a moment to respond as accurately as you can." When a thought probe was presented, participants had approximately 45 seconds to respond to the probes using their i>clickers. The lecture resumed immediately after the thought-probe responses were completed.

Results and Discussion

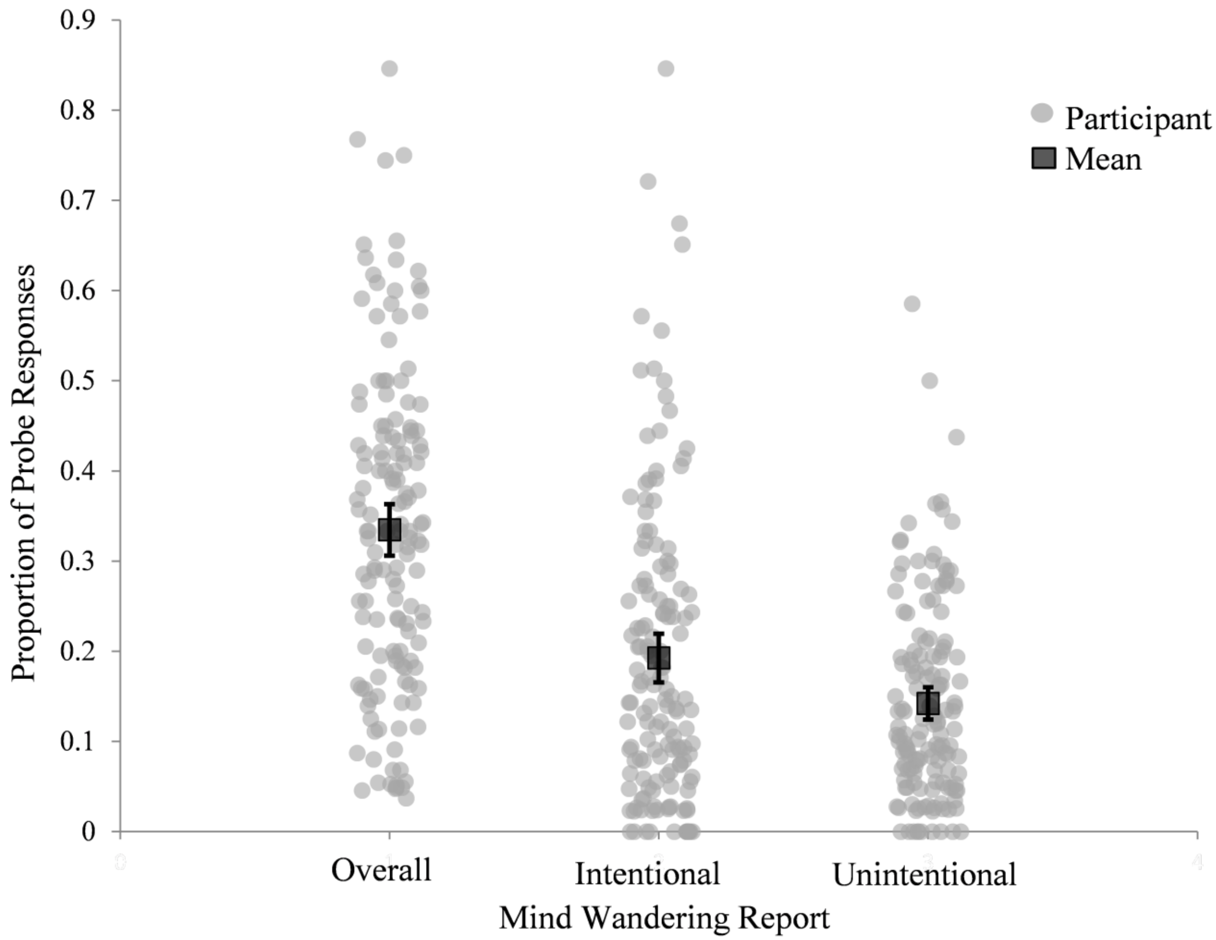
Our description of the results is organized into four main sections that correspond to the four aims described earlier. Both intentional and unintentional mind wandering were analyzed when exploring each of the aims. Because the intentional and unintentional responses were ipsative, we were unable to directly compare intentional and unintentional mind wandering.

Aim 1: The Prevalence of Overall, Intentional and Unintentional Mind Wandering

Results. Due to truancy, lateness, or equipment failure, students responded to a variable number of probes. The number of probes participants successfully responded to ranged from 1 to

44 (*M* = 32.95, *SE* = 0.88). Importantly though, student attendance rates were not correlated with overall, intentional or unintentional mind wandering, *p*s > .41, indicating that the findings presented below were not influenced by attendance (i.e. those who attended class infrequently were not inflating the mind wandering rates). Participants responding to under 10 thought probes (*n* = 9) were removed from our overall prevalence analyses. For each remaining participant, a proportion was computed for overall mind wandering (reports of intentional and unintentional mind wandering/total reports). Results indicated that the mean proportion of overall mind-wandering reports was 0.335 (*SE* = 0.015, CI_{95} [0.306, 0.363]) (Figure 1).

Next we computed the proportion of intentional and unintentional mind-wandering reports. The proportion of intentional mind wandering (reports of intentional mind wandering/total reports) was 0.193 (*SE* = 0.014, CI_{95} [0.166, 0.219]), whereas the proportion of unintentional mind wandering (reports of unintentional mind wandering/total reports) was 0.142 (*SE* = 0.009, CI_{95} [0.124, 0.160]) (Figure 1).



Discussion. Previous work indicated that the overall prevalence of mind wandering is upwards of 40% (e.g. Seli et al., 2013; Killingsworth & Gilbert, 2010) and that this high rate is also reflected in educational environments (41% to 43% in video lectures; Risko et al., 2012; Szpunar et al., 2013, 54% to 60% in college lectures; Cameron & Giuntoli, 1972; but see Schoen, 1970). The general assumption has been that these mind-wandering rates reflect unwanted bouts of off-task thought that are beyond a person's control (e.g., McVay & Kane, 2010). Our findings are in stark contrast to these previous reports and suggest that these rates may be inflated, as they may include intentional bouts of off-task thought as well. Our data indicated that when intentional and unintentional mind wandering are combined, participants reported mind wandering only about 33% of the time, which is lower than in previous work.

Critically, however, participants reported *unintentionally* mind wandering only about 14% of the time. Thus, at least in the context we studied, spontaneous and unwanted bouts of off-task thought, which have been of primary theoretical interest in the field, were actually mercifully rare on average (see also Seli et al., under review). Critically, these results provide evidence that high rates of unwanted mind wandering may be not an inevitable outcome in traditional lecture situations.

Also intriguing is our finding that over half of the overall mind-wandering rates were actually *intentional* in nature. Indeed, people reported intentionally mind wandering to roughly 19% of the thought probes. With this, it seems that students in the present study reported low basal rates of spontaneous mind wandering. This observation suggests several interesting possibilities. One is that students sometimes mind-wander strategically, particularly during parts of the lecture with which they are familiar or uninterested, to perform competing personal tasks or simply to conserve attentional resources for novel material. Another possibility is that the lion's share of mind wandering in the classroom is related to issues of motivation. The low rates of unintentional mind wandering suggest that, contrary to one of the dominant accounts of mind wandering (McVay & Kane, 2010), students are not failing to attend despite their best intentions to do so, but are instead purposefully shifting their focus toward internal thought. In this regard, our finding likely reflects an instance of motivation-related performance regulation, as has been shown in previous work on mind wandering (e.g., Seli, Cheyne, et al., 2015; Unsworth & McMillan, 2013). With this comes the corollary that increasing motivation, through increasing incentives and interestingness, may be a practical way to reduce mind wandering in the classroom.

Aim 2: Changes in mind wandering rates and intentionality over a 50-minute live lecture

On the surface, the type of factorial design employed in our current work appears well suited for an omnibus analysis, using repeated-measures ANOVA or multi-level modelling to compare all possible combinations of our units of time. However, such an analysis would spread our data too thin and make any conclusions drawn from these analyses substantially less meaningful. To interfere as little as possible with students' learning, we presented only 1.5 probes per class on average, for a total of 44 probes. We sought to explore changes in mind-wandering rates over three temporal factors: four quarters of a lecture, three days of a week, and four quarters of a term. Analyzing data in a fully factorial manner would yield 48 different combinations of levels, whereas only 44 total probes were presented. Inevitably, there were *no* probes presented for certain combinations of levels (e.g. first quarter of Wednesday lectures in the first quarter of the term).

To illustrate this point further, when divided across all three factors, none of the 154 participants had a full data set, and each combination of levels had an average of only 0.68 probes per participant. The sparseness of the extant data would make it rather difficult to conclude anything meaningful based on interpolation or imputation from these data. Accordingly, we sacrificed our ability to explore interactions between units of time across a lecture, week and term. Instead, we consider only main effects for each factor.

Results. Data were divided into four quarters of each lecture, excluding the final 2 minutes of class, as this was typically when the quiz was administered. As a result each quarter spanned 12 minutes of lecture time (Quarter 1: 0-12 minutes, Quarter 2: 12-24 minutes, Quarter 3: 24-36 minutes, Quarter 4: 36-48 minutes). There were 9, 9, 8, 19 total possible probes for the first, second, third and fourth quarter, respectively. The disproportionate representation of probes in

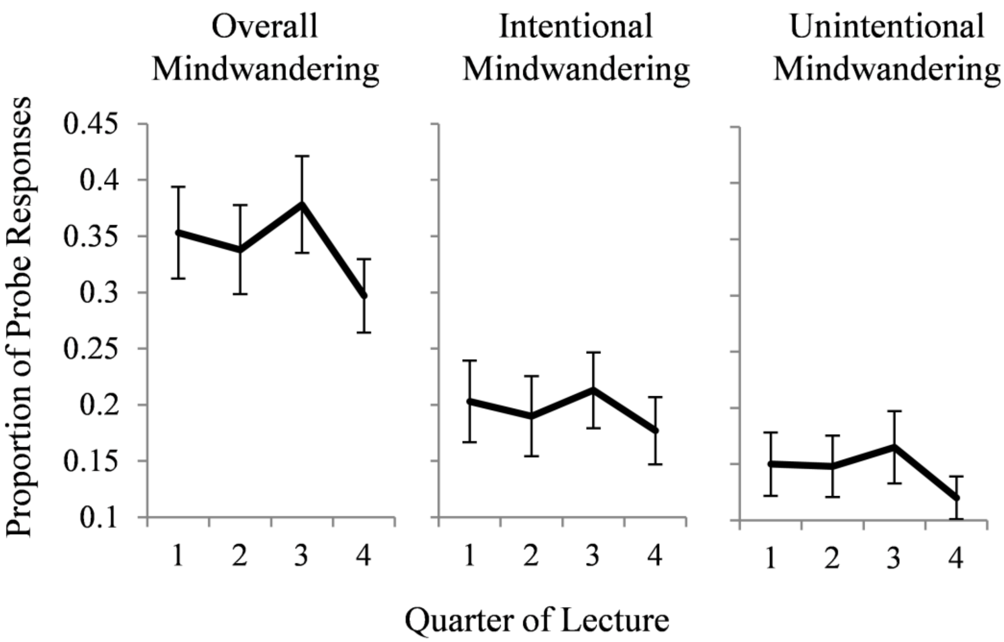
Quarter 4 is due to our probe assignment strategy. The probes were randomly placed based on slide number before the lecture was presented. However, the lecturer did not often cover all of the intended material, which meant that probes associated with earlier slides were often presented later in the lecture than intended, but probes associated with later slides were rarely presented earlier than intended[2]. All analyses were conducted using a one-way repeated-measures analysis of variance (ANOVA) with lecture Quarter (1, 2, 3, & 4) as a within-participants factor. Six participants were excluded from analysis because of a missing observation. For example, one participant failed to respond to any thought probes in the first quarter of lecture.

Overall mind wandering. To assess overall mind-wandering levels as a function of lecture quarter, we combined each participant's reports of both intentional and unintentional mind wandering and divided this value by the total number of thought probes they responded to within each of the four time ranges (Figure 2, left).

Mauchly's test of Sphericity was significant, X^2 (5) = 26.170, $p < .001$, so the Greenhouse-Geisser correction was used. There was a significant main effect of Quarter, F (2.682, 394.300) = 4.915, $MSE = .039$, $p < .005$, $\eta^2 = .032$, and results showed a significant quadratic pattern, F (1, 147) = 6.085, $MSE = .026$, $p < .05$, $\eta^2 = .040$. Paired-samples t-tests using Bonferroni adjusted alpha levels of .0083 per test (.05/6) revealed that the main effect was largely driven by a significant drop in proportion of reported mind wandering from the third quarter ($M = .378$, $SE = 0.022$, CI_{95} [0.335, 0.421]) to the fourth quarter ($M = .297$, $SE = 0.017$, CI_{95} [0.264, 0.330]) of the lecture, t (147) = 3.973, $SE = .020$, $p < .001$. All other differences, including comparisons with the first ($M = .353$, $SE = 0.021$, CI_{95} [0.312, 0.394]) and second ($M = .338$, $SE = 0.020$, CI_{95} [0.298, 0.378]) quarter, were not significant (all ps > .012).

Intentional mind wandering. We next assessed the rates of intentional mind wandering (Figure 2, middle). Mauchly's test of Sphericity was significant, X^2 (5) = 29.163, p < .001, so the Greenhouse-Geisser correction was used. The main effect of Quarter did not reach statistical significance, F (2.671, 392.626) = 1.641, MSE = .025, p > .05, *ns*, η^2 =.011. That is, rates of intentional mind wandering did not vary across time.

Unintentional mind wandering. Mauchly's test of Sphericity was significant, X^2 (5) = 29.144, p < .001, so the Greenhouse-Geisser correction was used. There was a significant main effect of Quarter, F (2.700, 396.948) = 2.809, MSE = .021, p < .05, η^2 =.019, and results showed a significant quadratic pattern, F (1, 147) = 4.175, MSE = .016, p < .05, η^2 =.028. Paired-samples t-tests using Bonferroni adjusted alpha levels of .0083 per test (.05/6) revealed that the main effect was largely driven by a significant drop in the proportion of reported unintentional mind wandering from the third quarter (M = .165, SE = 0.016, CI_{95} [0.133, 0.197]) to the fourth quarter (M = .120, SE = 0.010, CI_{95} [0.101, 0.139]) of an average lecture, t (147) = 2.996, SE = .015, p < .005. All other differences, including comparisons with the first (M = .150, SE = 0.014, CI_{95} [0.122, 0.178]), and second (M = .148, SE = 0.014, CI_{95} [0.121, 0.175]) quarter, were not significant (all *p*s > .017) (Figure 2, right).



Discussion. Strikingly, contrary to our predictions and numerous previous studies (e.g., Farley et al., 2013; Risko et al., 2012; 2013; Smallwood & Schooler, 2006; Thomson et al., 2014; Young et al., 2009), our results showed no indication of an increase in mind-wandering reports (either overall, intentional, or unintentional mind wandering) as a function of time-on-task. In fact, for both overall and unintentional mind wandering, there was actually a small *decrease* in mind wandering toward the end of lectures. The obvious inverse of this pattern of results is that there was no decrease in vigilance as time elapsed. We note that nearly all studies of attention during standard monologue lectures have shown an increase in attentional lapses over time (Farley et al., 2013; Frederick, 1986; Horgan, 2003; Risko et al., 2012; 2013; Young et al., 2009). Most pedagogical explorations of attention have taken the existence of this gradual decline in attention as a given, and argued the efficacy of making frequent changes in lecture format (Wankat & Oreovicz, 2003), or implementing ‘active learning’ methods (Burke & Ray, 2008; Kumar, 2003; Windschitl, 1999) in order to reduce, but not eliminate, the vigilance decrement.

What we have shown is a complete lack of a vigilance decrement in a standard monologue lecture format without the implementation of any of the aforementioned tools or interventions. Critically, we wish to clarify that our claim is *not* that increments in mind wandering over time do not occur in many contexts; rather, the present results provide evidence that mind wandering increments over time-on-task are *not necessary* outcomes of attention-demanding tasks, within the parameters that characterize traditional lectures.

Why is it that in our lecture context we found no evidence of a mind wandering increment? Several possibilities present themselves. First, live lectures – at least with a reasonably animated instructor – are likely experienced as being more dynamic and engaging than most laboratory-based talking-head video lectures. Indeed, previous research has suggested that the vigilance decrement can be attenuated by increasing the engagingness of tasks (Pop, Stearman, Kazi & Durso, 2012), and that self-reported engagement is a reliable predictor of vigilance (Finomore, Matthews, Shaw & Warm, 2009). Second, students are likely more motivated to sustain their attention during real lectures than they are during laboratory tasks. Whereas in real lecture settings students know that they will be tested and that their performance has enduring life consequences, in most laboratory situations (including video lecture viewing) participants know that their attentiveness and performance have no substantive consequences. Laboratory studies commonly require participants to view previously video-recorded lectures (Risko et al., 2012; Szpunar et al., 2013) or attend live lectures (Lindquist & McLean, 2011; Young et al., 2009) that are not actually part of their degree requirements. As such, it is reasonable to assume that participants in previous studies were considerably less motivated, and possibly less interested, than the participants in the present study. The third, and perhaps most intriguing, possibility is that in live lectures, it is possible for instructors to monitor the attentional states of students and to modify their presentation style (e.g., by becoming more animated or increasing the volume of their voice) to maintain students' attention when the instructor identifies that the students are becoming less attentive. Indeed, it has been shown that there are behavioral markers such as fidgeting (Carriere et al., 2013; Farley et al., 2013; Seli, Carriere, Thomson, Cheyne, Martens & Smilek, 2014) that are associated with mind wandering and inattention. While presumably not all instructors will be able to successfully make use of these cues to modulate their presentation to maximize engagement, some instructors might be able to do so. In fact, this ability might be a key differentiator between 'engaging' and 'boring' instructors.

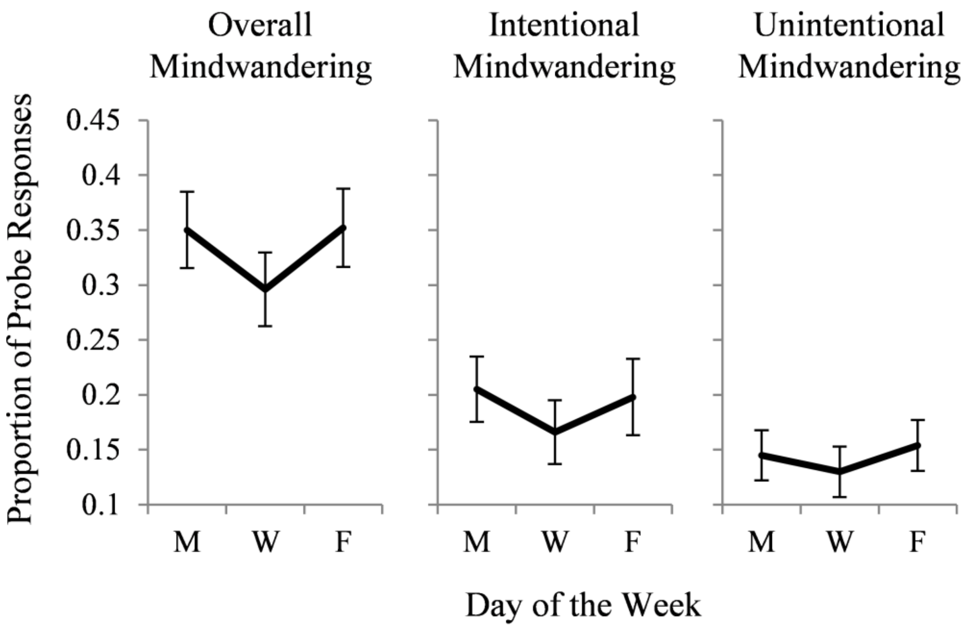
Aim 3: Changes in mind wandering rates and intentionality over a three-lecture week

Results. Mind-wandering rates were also analyzed to determine patterns of attention over the course of a week. The lectures for the course in which the current study was conducted took place on Mondays, Wednesdays, and Fridays, and there were 15, 16 and 14 total probes on each of those respective days. There were no systematic differences in attendance across the days of the week, F (1.844, 282.198) = 1.247, MSE = .006, p = .289, η^2 =.008, and the correlations between attendance and mind wandering rates were not significant within any day of the week, ps > .11. Accordingly, it appears that attendance had no significant influence on the findings. All analyses were conducted using a one-way repeated-measures ANOVA with Day of the week (Monday, Wednesday, and Friday) as a within-participants factor. Six participants were excluded from analysis due to missing data for at least one day of the week.

Overall mind wandering. There was a significant main effect of Day, F (2, 294) = 7.177, MSE = .021, p < .005, η^2 =.047, and results showed a significant quadratic pattern, F (1, 147) = 12.086, MSE = .025, p < .005, η^2 =.076. Paired samples t-tests using Bonferroni adjusted alpha levels of .0167 per test (.05/3) revealed that the main effect was driven by significantly higher proportions of reported mind wandering on Mondays (*M* = .350, *SE* = 0.018, CI_{95} [0.315, 0.385]), *t* (147) = 3.066, *SE* = .018, *p* < .005 and Fridays (*M* = .352, *SE* = 0.018, CI_{95} [0.316, 0.388]),), *t* (147) = 3.208, *SE* = .018, *p* < .005, relative to Wednesdays (*M* = .296, *SE* = 0.017, CI_{95} [0.262, 0.330]) (Figure 3, left). The comparison of mind wandering proportions on Mondays and Fridays was not significant, *t* (147) = .135, *SE* = .015, *p* > .0167, *ns*.

Intentional mind wandering. There was a significant main effect of Day, *F* (2, 294) = 4.453, *MSE* = .015, *p* < .05, η^2 =.029, and results showed a significant quadratic pattern, *F* (1, 147) = 8.715, *MSE* = .015, *p* < .01, η^2 =.056. Paired samples t-tests using Bonferroni adjusted alpha levels of .0167 per test (.05/3) revealed that the main effect was largely driven by a significantly higher proportion of reported intentional mind wandering on Mondays (*M* = .205, *SE* = 0.015, CI_{95} [0.175, 0.235]) relative to Wednesdays (*M* = .166, *SE* = 0.015, CI_{95} [0.137, 0.195]), *t* (147) = 2.838, *SE* = .014, *p* < .01 (Figure 3, middle). Comparisons of each of the other days with Fridays (*M* = .198, *SE* = 0.018, CI_{95} [0.163, 0.233]) were non-significant, *p*s > .024.

Unintentional mind wandering. The main effect of Day, *F* (2, 294) = 1.803, *MSE* = .012, *p* > .05, *ns*, η^2 =.012, was not significant (Figure 3, right).



Discussion. Consistent with the predictions made in the Introduction, participants reported more overall mind wandering on Mondays and Fridays than on Wednesdays. It is important to note that the current exploration of attention across a week was not designed with intentions to differentiate between any of the accounts presented in the Introduction; rather our goal was simply to observe how mind wandering rates change over an average week, as to date no studies have explored mind wandering rates across such an extended time frame. This being said, we do believe that our findings can readily be interpreted within the current concerns (e.g. Klinger, 1971) framework. Further, as we suggested, this increase in mind wandering on Fridays may be due either to increased future planning of weekend activities (Baird et al., 2011) or to negative affect from stress that might be greater near the end of the week (Smallwood et al., 2009). The explanation for Monday’s increased proportion is less clear, though it might be due to increased thoughts about the weekend that had just passed (‘current concerns’), or the stress of mentally preparing for a taxing week of school. Interestingly, the differences in the prevalence of mind wandering across days of the week were only significant when it came to overall and intentional mind wandering, but not unintentional mind wandering. This suggests that these differences might be driven primarily by motivation rather than cognitive limitations. Regardless, it is obvious that Wednesday is the day on which students are most focused on the material at hand. With this in mind, it is possible that the traditional technique of equally spacing material across lectures should be eschewed in favor of a disproportionate material density in mid-week lectures, relative to beginning or end of week.

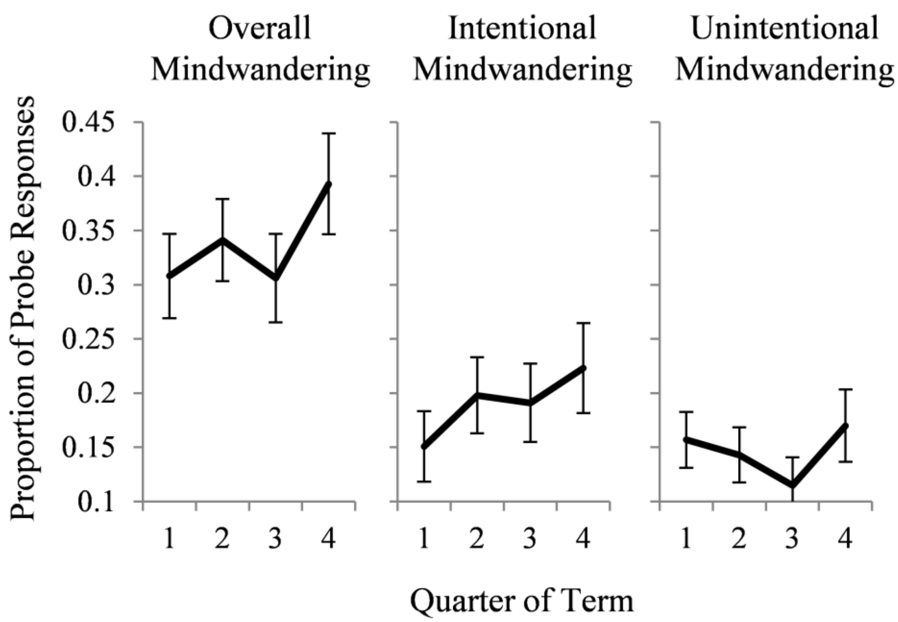
Aim 4: Changes in mind wandering rates and intentionality over the entire term

Results. Next, we analyzed how mind-wandering rates changed over the course of the term. The course included four tests, which served to divide the course into roughly equal quarters. These quarters served as a natural way to bin thought probes into four periods of the term. When the thought probes were divided into the four testing periods, there were 8, 13, 14 and 10 total probes for the first, second, third and fourth periods, respectively. Each participant's proportions of overall, intentional, and unintentional mind wandering were computed within each testing period and the corresponding mean proportions are shown in Figure 4. There was a linear decrease in attendance rates across the term, F (1, 153) = 21.806, MSE = .044, p < .001, η^2 =.125. However, the correlations between attendance and mind wandering rates were not significant within any quarter of the term, ps > .09. Accordingly, it again appears that attendance had little bearing on the findings presented. All subsequent analyses were done using one-way repeated-measures ANOVA with testing Period (1, 2, 3 and 4) as a within-participants factor. Eighteen participants were excluded from the analyses due to missing data in at least one period of the course.

Overall mind wandering. There was a significant main effect of testing Period, F (3, 405) = 6.197, MSE = .038, p < .001, η^2 =.044. Paired samples t-tests using Bonferroni adjusted alpha levels of .0083 per test (.05/6) revealed that the main effect was largely driven by a significant increase in proportion of reported mind wandering from the third testing period (M = .306, SE = 0.021, CI_{95} [0.265, 0.347]) to the fourth testing period (M = .393, SE = 0.024, CI_{95} [0.347, 0.439]) of the term, t (135) = 3.806, SE = .023, p <.001, as well as from the first testing period (M = .308, SE = 0.020, CI_{95} [0.269, 0.347]) to the fourth testing period of the term, t (135) = 3.348, SE = .025, p <.005. All other differences, including comparisons with the second (M = .341, SE = 0.019, CI_{95} [0.303, 0.379]) testing period, were not significant, ps > .04 (Figure 4, left).

Intentional mind wandering. Mauchly's test of Sphericity was significant, X^2 (5) = 14.891, p < .05, so the Greenhouse-Geisser correction was used. There was a significant main effect of testing Period, F (2.783, 375.693) = 4.632, MSE = .028, p < .005, η^2 =.033, and results showed a significant linear pattern, F (1, 135) = 8.592, MSE = .034, p < .005, η^2 =.060. Paired samples t-tests using Bonferroni adjusted alpha levels of .0083 per test (.05/6) revealed that the main effect was largely driven by a significant increase in proportion of reported intentional mind wandering from the first testing period (M = .151, SE = 0.017, CI_{95} [0.118, 0.184]) to the fourth testing period (M = .223, SE = 0.021, CI_{95} [0.182, 0.264]) of the term, t (135) = 3.152, SE = .023, p <.005. All other differences, including comparisons with the second (M = .198, SE = 0.018, CI_{95} [0.163, 0.233]) and third (M = .191, SE = .018, CI_{95} [0.155, 0.227]) testing period, were not significant, ps > .013 (Figure 4, middle).

Unintentional mind wandering. There was a significant main effect of testing Period, F (3, 405) = 3.749, MSE = .020, p < .05, η^2 =.027, and results showed a significant quadratic pattern, F (1, 135) = 8.140, MSE = .020, p < .005, η^2 =.057. Paired samples t-tests using Bonferroni adjusted alpha levels of .0083 per test (.05/6) revealed that the main effect was largely driven by a significant increase in proportions of reported unintentional mind wandering from the third period (*M* = .115, *SE* = 0.013, CI_{95} [0.089, 0.141]) to the fourth period (*M* = .170, *SE* = 0.017, CI_{95} [0.137, 0.203]) of the term, t (135) = 3.258, *SE* = .018, $p < .005$. All other differences, including comparisons with the first (*M* = .157, *SE* = 0.013, CI_{95} [0.131, 0.183]), and second (*M* = .143, *SE* = 0.013, CI_{95} [0.118, 0.168]) quarter, were not significant, *p*s > .016 (Figure 4, right).



Discussion. Curiously, over the course of the term, overall mind wandering increased. A rather interesting aspect of our finding is the timeline over which the mind-wandering increment is observed. In most previous laboratory situations, mind-wandering increments have been considered over relatively short time intervals, often involving time frames of tens of minutes to roughly one hour (Thomson et al., 2014; Risko et al., 2012). The literature concerning performance declines over time-on-task (the vigilance decrement; e.g., Helton & Warm, 2008; Mackworth, 1948; Parasuraman & Mouloua, 1987) also often considers tasks that last a relatively short amount of time, in the range of minutes to hours. The present findings, however, show an attentional decrement that manifests over a three-month period. It seems difficult to explain such a long-term effect with existing theories of vigilance decrement, such as the Resource Depletion Account (Helton & Warm, 2008; Smit, Eling & Coenen, 2004), which posits that inattention increases because working memory resources are reduced over time. Resource theory is most relevant for, and generally applied at shorter time frames. Indeed, it seems challenging to formulate an argument whereby working memory resources diminish over a three-month time frame. However, one might speculate that the longer-term phenomenon of burn-out, where students feel increasing fatigue over the course of a term because of the demands of higher education, may occur as a result of depleted resources. It is also possible that mind wandering might have increased due to a growing number of student concerns as the term progressed, such as worries about upcoming assignments or exams. As noted earlier, the 'Current Concerns Theory' of mind wandering posits that a current concern is a state of goal pursuit that persists until the end result of the goal is attained (Klinger, 1987). So, this goal pursuit continues to be prioritized, even when an individual has other goals set before them. People tend to gravitate towards current concerns in various circumstances particularly when the content of their concerns is anxiety producing or stressful (Antrobus et al., 1966; Stawarczyk et al., 2013). However, current concerns are generally thought to influence unintentional mind wandering, and so it is not clear why in our case, unintentional mind wandering did not progressively increase as well.

Given that the Resource Depletion account and Current Concerns Theory are not sufficient in explaining the incremental increase in mind-wandering observed in the present study, it is clear that an alternative explanation for this finding is necessary. Critically, the mind wandering increment that we observed seems to have been driven primarily by intentional mind wandering, which showed a steadily increasing linear trend, rather than unintentional mind wandering, which showed a quadratic trend, without a strong difference between the first and fourth periods of the term. The intentional nature of the mind-wandering increase is perhaps best explained in the context of the well-documented finding that mind wandering increases as task difficulty decreases (Smallwood et al., 2007; Thomson, Besner, & Smilek, 2013; but see Feng, D'Mello & Graesser, 2013). As we suggested earlier, the course might become progressively easier as the term goes on because students become more familiar with the structure of the course, the nature of the tests, and the cumulative contents of the course material. This decrease in subjective difficulty may selectively increase intentional mind-wandering, as students become aware that they can afford to strategically disengage when familiar material is presented.

Foreshadowing Performance Outcomes

As mentioned, we also collected quiz scores within each lecture, midterm and final exam scores, as well as a number of other self-report measures prior to the beginning of the term. To maintain a reasonable scope in the current manuscript, more detailed methodological information and the full analyses are presented in Part 2 of this manuscript (see ***[Authors omitted for masked review policy]***, submitted). To anticipate the findings presented in Part 2, our results indicated that episodes of intentional mind wandering were associated with poorer quiz scores on associated lecture material than periods of on-task focus. Further, regression and mediation analyses indicated that intentional mind wandering was linked with short-term impairments on in-class quizzes and had only indirect effects on long-term exam scores. Conversely, unintentional mind wandering showed a greater impact on long term midterm/final exam performance, and was not linked with reductions in quiz performance. Notably, these relations largely held even when other relevant predictors of performance, including attendance and GPA, were taken into account.

General Discussion

Theoretical Contributions

The present study generated several notable findings. First, our overall levels of mind wandering were comparable to those reported in previous studies in lecture contexts, but at the lower end of the range expected based on previous reports (about 33%). While this relatively low rate of mind wandering, in and of itself, is not particularly surprising, we observed that a strikingly large proportion of overall mind wandering was intentional in nature (19%), and that a smaller proportion was reported as unintentional in nature (14%). Theoretically, this is notable in light of the fact that mind wandering has previously been largely or exclusively construed as unintentional, unplanned shifts in attention from task to internal ideation (e.g. Giambra, 1995; Kane & McVay, 2013; Smallwood & Schooler, 2014). Very likely, intentional and unintentional mind wandering have been conflated in a large proportion of previous work. Accordingly, it would be worthwhile to revisit earlier studies with an eye towards separating intentional and unintentional mind wandering in order to assess the true level of unintentional drifts of attention to internal thinking, which has been of primary interest to those who study mind wandering (see Seli et al., 2015; Seli, Cheyne, et al., 2015).

Second, in our full-term, ecologically-based exploration in a university undergraduate course of how mind-wandering rates change over time in lecture, conspicuously absent was the common observation that mind wandering almost invariably increases over time in laboratory settings (Farley et al., 2013; Risko et al., 2012; 2013; Seli et al., 2012; Stuart & Rutherford, 1978; Thomson et al., 2014; Young et al., 2009). One hypothesis suggested by this finding is that being enrolled in a class with real implications for participants' performance in learning and retaining lecture material introduces a motivational component not present in typical laboratory studies. Our findings here are consistent with previous results, indicating that motivation can be a powerful determinant of sustained attention (Antrobus et al., 1966; Seli et al., 2015; Unsworth & McMillan, 2013). As the pervading conclusion from laboratory-based studies is that vigilance or attention decline over time, it is necessary for researchers to consider the importance of context (e.g.. simulated versus actual classroom), and the differing levels of motivation that different contexts might afford.

Third, we presented estimates of how mind wandering changed over time both across days of the week and over the course of the term, showing that mind wandering is most prevalent during lectures held on Mondays and Fridays, relative to Wednesdays, and that mind wandering increases substantially as the term progresses. Theoretically, these latter two findings are consistent with the ‘current concerns’ theory of mind wandering (Klinger, 1987). Specifically, current concerns were likely more salient on Mondays, due to preparation for the school week; on Fridays, due to future planning; and later in the term, due to mounting deadlines and upcoming exams. While we did not directly manipulate or test whether current concerns are driving the effects observed, our findings are readily integrated into a ‘current concerns’ framework. We propose that it is this amplification of current concerns that likely led to the observed increases in mind wandering rates.

Implications for Pedagogy

While the present study was not designed to directly explore potential interventions or strategies for reducing mind wandering in the lecture setting, we offer several speculations in this regard. First, given our finding that, contrary to widely held beliefs, most mind wandering that occurs in lectures is intentional rather than unintentional in nature, we suggest that instructors would do well to focus on minimizing this particular form of mind wandering. Importantly, the interventions for reducing intentional mind wandering might be quite different than those aimed at reducing unintentional mind wandering. As we suggested earlier, mind wandering of the intentional sort might be curtailed through interventions that increase students' motivation to perform, or their perceived value of attending to the lecture material. One way to increase students' motivation to attend might be to include quiz questions in the lecture, with the accuracy of students' responses counting towards their final grades. In the current work, completion of the quiz questions contributed to the students' attendance grade, but the accuracy of their specific responses was not graded, which might have led participants to undervalue the need to pay attention. Grading participants' accuracy might motivate students to remain on task and attend more carefully to the lecture. In addition, a simple method to increase the perceived value of the task might be to present students with modified versions of presented slides that are missing some vital information. This might increase students' motivation to avoid intentional mind wandering, as they would be unable to simply rely on their slides to obtain all of the necessary information. Lastly, given our demonstration that mind wandering rates were lowest during mid-week classes, instructors might consider presenting a greater volume of material, or presenting the most important material, mid-week, rather than spreading material equally across a week.

It is also possible that students engage in a high rate of intentional mind wandering simply because they are unaware of the detrimental effects that this inattention might cause. If this were the case, a straightforward method of reducing intentional mind wandering would simply be educating students about the large body of literature, which indicates that when one is mind wandering, this behavior is usually coupled with much poorer performance on many tasks.

Perhaps just being aware of the consequences of such cognitions might reduce students' tendency to engage in them.

Limitations and Directions for Future Research

While our first foray into studying mind wandering in an undergraduate course across an entire term has led to several important discoveries, it is worth noting that our study also had several limitations that suggest some directions for future research. First, because we investigated one lecturer in one course, generalizations to other undergraduate classes are clearly constrained. The present study illustrates what is possible, and not necessarily what is common. For instance, it shows that a mind-wandering increment *is not a necessary byproduct* of time-on-task, but it *does not* show that mind-wandering increments *never occur* or even that they do not occur often. Future studies could compare mind-wandering reports across more than one undergraduate course to determine whether these patterns are consistent across lecturers, courses, and/or faculties. Second, our thought probes might have not been sufficiently sensitive to capture nuanced changes in mind wandering. We required participants to make a decision between three options (on task, intentional mind wandering, and unintentional mind wandering). However, it has been shown that a more sensitive and graded index of mind wandering can be obtained by asking people to report the depth of their mind wandering on a seven-point scale (e.g., Seli, Carriere, Thomson, et al., 2014). Future work could test whether our sample's ability to sustain attention is mirrored in a measure that obtains a more fine-grained ledger of mind wandering. Finally, because we tested mind wandering exclusively in a live lecture, it is difficult for us to make direct comparisons with studies that have used video-recorded lectures in laboratory settings. In future studies it would therefore be useful to compare levels of mind wandering in a live lecture with levels of mind wandering during viewing of a video of the same live lecture presented in the laboratory.

Conclusion

To summarize the critical findings, mind wandering does not necessarily increase across the course of a live university lecture and the mind wandering that we observed was primarily intentionally initiated, rather than unintentional. Also, consistent with the current concerns hypothesis (Klinger, 1971), mind wandering rates were higher on Mondays and Fridays, and increased over the course of the term. Our findings are important to consider when extrapolating conclusions from laboratory studies, with the implication that laboratory studies investigating mind wandering during lectures may not be fully characterizing the dynamic relations between mind wandering and academic performance. Together, the foregoing findings provide a critical and necessary characterization of the ebb and flow of student's attention in an actual live, lecture-based, university course.

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Footnotes

[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.

[2] In light of the disproportionate representation of probes in the fourth quarter of lectures, repeated-measures ANOVAs were also conducted including only the first three quarters of the lecture. Here, results also indicated no significant effects of Quarter or lecture or linear trends, and thus no evidence for an increase in mind wandering over time within 36 minutes. This is in contrast with previous work showing decreases in attention within comparable or shorter time frames (Farley et al., 2013; Young et al., 2009).

Figure Captions

Figure 1. Mean proportion of the thought probes to which participants responded that they were engaging in overall (either intentional or unintentional), intentional, or unintentional mind wandering (Squares), as well as individual data points for each student included in the analysis (Circles). Error bars reflect 95% confidence intervals.

Figure 2. Mean proportion of the thought probes to which participants responded that they were engaging in overall (either intentional or unintentional), intentional, or unintentional mind wandering in each of the four quarters (1, 2, 3 and 4) of an average lecture. Quarters 1, 2, 3, and 4 corresponded to 0-12, 12-24, 24-36, and 36-48 minutes of the lecture, respectively. Error bars reflect 95% confidence intervals.

Figure 3. Mean proportion of the thought probes to which participants responded that they were engaging in overall (either intentional or unintentional), intentional, or unintentional mind wandering as a function of day of the week (Monday, Wednesday and Friday lecture). Error bars reflect 95% confidence intervals.

Figure 4. Mean proportion of the thought probes to which participants responded that they were engaging in overall (either intentional or unintentional), intentional, or unintentional mind wandering in each of the four testing periods of the term. Error bars reflect 95% confidence intervals.