EXPLORING HOW MIND WANDERING IMPACTS LEARNING

UNDERSTANDING HOW MOTIVATION IMPACTS LEARNING THROUGH MIND WANDERING

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LAY ABSTRACT

Our minds wander multiple times a day—during work, school, leisure time, meals, and countless other activities. When mind wandering occurs during lectures, it negatively impacts our ability to learn information. If we are motivated, we are likely to learn more, and some researchers have suggested that this happens because we are better able to pay attention while learning. The research presented in this thesis used three reward types in an attempt to reduce two types of mind wandering (intentional vs. spontaneous) and, therefore, produce better learning. This thesis demonstrated that outside rewards can increase motivation, and that these changes in motivation appear to affect intentional mind wandering more than spontaneous mind wandering. Reducing mind wandering by properly motivating our students should promote better learning; as educators, effective lectures must play that role for students.

ABSTRACT

The current thesis intersects cognition and education to study the mental experience of mind wandering and its consequences. This research examines attention and memory using materials, methodologies, and research questions drawn from authentic classroom environments. The overarching question driving this thesis centres on when and why students mind wander during lectures, and how we can reduce its negative impact on learning. The hypothesis underpinning all the presented research proposes that stronger motivation reduces mind wandering, thus improving learning outcomes. The current thesis examines how three different motivational manipulations affect reports of intentional mind wandering—when participants deliberately choose to redirect their attention away from the lecture—and unintentional mind wandering—when participants find their attention to be off-task despite their best efforts to stay focused. Quizzing, monetary rewards, and time-based rewards affected mind wandering reports, particularly reports of intentional mind wandering. Although, throughout this thesis, there was no direct impact on learning, there was consistent evidence of a negative correlation between mind wandering reports and learning. Based on these findings, this thesis discusses implications for the enterprise of mind wandering research, principles of motivation to leverage in education, and pedagogies to improve the classroom learning experience.

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DECLARATION OF ACADEMIC ACHIEVEMENT

The *General Introduction* to this thesis was written and conceptualized by Amy Pachai, with edits from her supervisory committee: Dr. Joseph Kim, Dr. David Shore, and Dr. Bruce Milliken.

The methods used in *Chapter 2* were conceptualized by Amy Pachai, with input and feedback from Michelle Ogrodnik and Dr. Joseph Kim. Data collection was conducted during lectures by the course instructors: Dr. Joseph Kim, Dr. Michelle Cadieux, and Dr. Ellen MacLellan. Data analysis was completed by Amy Pachai and Michelle Ogrodnik. Most of the writing for this manuscript was completed by Amy Pachai, with initial drafts of the methods and results completed by Michelle Ogrodnik.

The methods used in *Chapter 3* of this thesis were conceptualized by Amy Pachai, with input from Dr. Joseph Kim and Dr. David Shore. All programming for these experiments was coded by Amy Pachai. Data collection was completed primarily by Wid Yaseen and Jack Lawrence. Data analysis was completed by Amy Pachai. Wid Yaseen wrote initial drafts of the methods and results for Experiment 1. The remainder of the writing was completed by Amy Pachai with feedback from Wid Yaseen, Jack Lawrence, and Dr. Joseph Kim.

The methods used in *Chapter 4* were conceptualized by Amy Pachai, with input from Jack Lawrence, Dr. Joseph Kim, and Dr. David Shore. All programming for these experiments was coded by Amy Pachai. Data collection was completed by Jack Lawrence, Jhanahan Sriranjan, and Amy Pachai. Data analysis was completed primarily by Amy Pachai, with support from Dr. David Shore. Jack Lawrence wrote initials drafts of the methods and results for Experiment 1, in addition to contributing ideas to the introduction and discussion. Jhanahan Sriranjan wrote drafts of the methods and results for Experiment 2. Amy Pachai compiled, edited, conceptualized, and wrote the balance of the manuscript, with edits from Dr. Joseph Kim, Dr. David Shore, Jack Lawrence, and Jhanahan Sriranjan.

The *General Discussion* to this thesis was written and conceptualized by Amy Pachai, with edits from her supervisory committee: Dr. Joe Kim, Dr. David Shore, and Dr. Bruce Milliken.

CHAPTER 1

GENERAL INTRODUCTION

The education system historically relies on classroom teaching to facilitate learning in students. However, classroom learning is subject to countless variables: instructor presentation style, physical classroom configuration, audience number and demographics, distractor presence, and learning session length, to name a few. In a review of 800 meta-analyses, John Hattie identified more than 130 factors that may affect academic achievement (Hattie, 2009). The context of the classroom differs dramatically between a morning of music lessons for 20 third-grade students and a 50-minute auditorium lecture for 200 third-year undergraduate biology students. Yet, the goal of these classrooms is arguably the same: to impart durable learning on its students.

Learning is the process by which environmental interactions lead to modifications in behaviours (Lachman, 1997). Although learning often is described as a relatively permanent change in behaviour based on experience, this conflates the *process* of learning with the *consequences* of having learned (Lachman, 1997). It is not enough to impart knowledge on others if this knowledge is transient and easily forgotten (Bahrick, 1979). The goal of educators should be to impart durable learning: long-term memory retention or ease of re-learning (Rawson & Dunlosky, 2011). Even with the identification of over 130 factors that may affect achievement, the conditions under which durable learning occur remain elusive. The present thesis contributes to this pursuit by exploring failures of attention—mind wandering—and their impact on learning and subsequent test performance.

Learning as a Case Study in Cognitive Principles

At its most basic level, classroom learning relies on the principles of attention and memory. Attention selects stimuli from the complex signals continuously present in the environment (Deutsch & Deutsch, 1963). Attention can be described as the direction or deployment of ‘cognitive resources’ (Reisberg, 2015) and can be directed automatically, without influence by the person whose attention is being directed, or it can be controlled by the subject, which case it is limited in capacity (Schneider & Shiffrin, 1977). Tasks that initially require directed, controlled attention may become well-practiced enough to rely on automatic attention.

When considering a divided attention demand, such as the Stroop task, automatic and controlled processes are in conflict (MacLeod, 1991). The Stroop task pits the automatic drive to read printed words against the controlled attention demand created by the instructions to name ink colour. This research supports a distinction between automatic and controlled processes of attention. However, automatic versus controlled attention is potentially an oversimplification of a complex system of directing cognitive resources.

Recent research has taken an increasingly nuanced look at attention by considering how memory and attention support one another. Continued attention requires at least short-term memory of what one’s goals or instructions are, and what has already been enacted or perceived—referred to as *working memory* (Engle, 2002). For example, successfully completing a Stroop task requires maintenance of the instructions to name ink colour. But not only does memory support sustained attention, attention is necessary for subsequent memory. Much of what we perceive in a given moment is not encoded and, thus, not remembered. Attention facilitates the process of encoding information for later retrieval, making it crucial for learning to take place. When attention is divided, memory for that information suffers (e.g., Fernandes &

Moscovitch, 2000). Participants recalled 31–37% fewer words encoded under conditions of divided attention (i.e., dual task conditions) than those encoded with full attention. Shifting attention away from the primary task of encoding words led to distraction at encoding that significantly hindered memory (Fernandes & Moscovitch, 2000). Attention demands at the time of learning can have a significant impact on one's ability to learn information for later use, making the study of cognition critical to understanding classroom learning.

Mind Wandering and Attention

Attentional focus can shift from a primary task to a secondary task, as in dual task experiments, but it may also shift towards internal thoughts, described as mind wandering. The present field of mind wandering stems from 20th century research on vigilance and sustained attention (Mackworth, 1948; 1950). Vigilance research was prompted by interest in professions such as radar monitoring during war times, which requires consistent monitoring for rare but important events. As such, a typical vigilance task may include watching a clock face as the second hand ticks, responding only to rare instances when the hand moves two positions in a single tick (Mackworth, 1948). Vigilance research typically measures missed targets (omission errors) or false alarms (commission errors) as an objective indication of waning vigilance. Performance tends to suffer as time on task progresses (termed the *vigilance decrement*; Mackworth, 1948). These initial studies of the vigilance decrement were the foundation for the sustained attention literature, which explores similar questions using shorter tasks such as monitoring a stream of numbers, only to respond with a button press to a rare target number presented during that stream (Sustained Attention to Response Task; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). As time on task increases, attention tends to shift from the external task to an internal train of thought, which results in poorer task performance.

In laboratory experiments of mind wandering, a similar finding emerges—greater mind wandering with increased time on task (e.g., Cunningham, Scerbo, & Freeman, 2000; Helton & Warm, 2008; Krimsky, Forster, Llabre, & Jha, 2017; Thomson, Seli, Besner, & Smilek, 2014). For example, when completing two common attention tasks, a singleton search and a Flanker task, reports of mind wandering increased in each subsequent block of the experiment (Thomson et al., 2014). Error rates also increased as the experiment progressed, which indicates that, as time on task increases, increasing levels of mind wandering interfere with task performance.

During demanding tasks, error-proneness is related to mind wandering propensity (Kane & McVay, 2012). The limited ability of individuals with low working memory capacity to maintain task goals in the face of distraction leads to an overall error-proneness (Kane & Engle, 2003). Low working memory capacity is also typically associated with the propensity to mind wander (Kane & McVay, 2012). If the current task goals cannot be maintained over time, off-task thought is likely to prevail, which may further explain the high mind wandering rates typical as time-on-task increases.

Given the attentional demands of classroom learning and the length of a typical lecture, mind wandering research has gained traction in educational psychology circles. A seminal study by Risko, Anderson, Sarwal, Engelhardt, & Kingstone (2012) asked participants to watch a video-recorded lecture while responding to intermittent mind wandering probes that prompted participants to self-report whether or not they were mind wandering at the time just prior to the probe's presentation. Participants then completed a comprehension test on the information presented within the lecture. Mind wandering reports were higher during the second half of the lecture compared to the first, and comprehension performance was similarly worse for material from the second half compared to the first. This study is consistent with the findings of the original vigilance literature and demonstrates the relevance of cognitive research in understanding educational contexts.

Most mind wandering research, including Risko et al. (2012), relies on self-reported mind wandering. Interrupting a task with a *mind wandering probe* has been used in the laboratory (e.g., Risko et al., 2012; Seli et al., 2013, 2016a; Smallwood et al., 2008; Szpunar et al., 2013; Thomson et al., 2014), the classroom (e.g., Wammes, Boucher, Seli, Cheyne, & Smilek, 2016; Wammes & Smilek, 2017), and personal contexts (e.g., Killingsworth & Gilbert, 2010). These probes ask a variety of questions, from simply "Were you mind wandering?" (Smallwood et al., 2008) to ratings of the content of mind wandering bouts (Seli, Ralph, Konishi, Smilek, & Schacter, 2017).

Corroborating these self-report questions with objective data is met with varying levels of ease. If a participant reports "yes, I was mind wandering", considering dual task research, a decrement in performance should be observable (although, see Thomson et al., 2014 for a discussion). However, it is much more challenging to verify participants' responses to questions about their conscious experiences of mind wandering, such as whether they were intentionally engaging in off-task thought or if their thoughts were future- vs. past-oriented. Efforts have been made to quantify mind wandering using physiological measures, such as fidgeting (Carriere, Seli, & Smilek, 2013; Seli et al., 2014), pupil dilation (Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013), or EEG (Braboszcz & Delorme, 2011). These methods do not produce data that clearly map on to mind wandering and, thus, require significant interpretation depending on the researcher's specific conceptualization of mind wandering.

The exact conceptualizations of mind wandering can differ dramatically between researchers. Perhaps, a family resemblance approach can be used to understand the characteristic features of mind wandering (Seli et al., 2018). This approach is rooted in the categorization literature—defining the category through a pattern of overlapping features that adhere to the prototype to varying degrees (see Rosch, 1987 for a discussion of Wittgenstein's contributions to the field). For example, some experiments may characterize mind wandering as unintentional, task-unrelated, and unguided, while others consider both unintentional and intentional thoughts to be classified as mind wandering. These descriptors of mind wandering add complexity to the measurement of mind wandering, but have the potential to add richness to the discussions of this human experience.

The dichotomy between intentional and unintentional mind wandering forms a foundational concept in this thesis. Intentionally mind wandering, or deliberately choosing to direct one's attention to task-unrelated thoughts, is empirically dissociable from unintentional mind wandering, where task unrelated thoughts occur despite one's best efforts to maintain attention on task. For example, difficult tasks produce more reports of unintentional mind wandering, while easy tasks produce more reports of intentional mind wandering (Seli, Risko, & Smilek, 2016b). Rereading a section of text, which can be particularly easy, is specifically associated with increased reports of intentional mind wandering, but not unintentional mind wandering (Phillips, Mills, D'Mello, & Risko, 2016). The intentionality of mind wandering is also present to differing degrees in specific populations. For example, Obsessive Compulsive Disorder (OCD) and Attention Deficit Hyperactivity Disorder (ADHD) symptomology are selectively related to unintentional mind wandering reports (Seli, Risko, Purdon, & Smilek, 2017; Seli, Smallwood, & Cheyne, 2013; Shaw & Giambra, 1993). This dimension of mind wandering is a theoretically and empirically fruitful area of research.

Many factors can affect intentional and unintentional mind wandering levels, including the motivation or engagement with the primary task. Given the goal of information retention during a lecture, the inter-relations between mind wandering and motivation are particularly important. Students reporting low task motivation engage in more mind wandering, which subsequently reduces their retention (Unsworth & McMillan, 2012). Participants who self-reported higher levels of motivation tended to report fewer off-task thoughts during a video lecture and, in turn, achieved higher scores on a lecture comprehension quiz (Seli, Wammes, Risko, & Smilek, 2016). The positive correlation between motivation and comprehension performance was mediated by both intentional and unintentional mind wandering reports. These researchers argue that if:

> "at least some of the mind wandering that occurs in educational settings is engaged with intention, … researchers and pedagogical practitioners should also focus on methods of intervention aimed at reducing intentional, controlled mind wandering (e.g., by increasing incentives to focus on the lecture rather than intentionally disengage from it)" (Seli, Wammes, et al., 2016, p. 1282).

The relation between mind wandering and motivation is critical in educational contexts.

Motivation: Theories and Applications

The scientific study of motivation, at its most basic level, strives to answer the question: What do people want? Motivation drives people to act. Goals, rewards, physiological and psychological needs, and beliefs can all motivate thoughts and behaviours. Determining what motivates certain behaviours requires interpretation through the lens of what factors may be important in a given situation.

One of the most influential theories in the field of motivation is Self-Determination Theory (SDT; Deci & Ryan, 1980). SDT proposes that what drives action is "the degrees to which basic psychological needs for autonomy, competence, and relatedness are supported versus thwarted" (Deci & Ryan, 2008, p. 182). SDT characterizes autonomy as the experience of perceiving an internal locus of causality (Deci & Ryan, 2000). The competence need is met when there is evidence of being able to meet the challenges of a task. Relatedness is described both as a motivator and as a foundation for intrinsic motivation to exist, in that "a secure relational base" allows the pursuit of challenging goals and overall growth (Deci & Ryan, 2000). Specific actions are perceived as intrinsically or extrinsically rewarding based on previous experiences with these or similar actions satisfying the three basic needs. Intrinsic motivation encourages the pursuit of a behaviour for its own enjoyment, as compared to extrinsic motivation, which elicits behaviours as a means to obtain a reward (Deci, Vallerand, Pelletier, & Ryan, 1991). For example, an artist who creates a unique painting may do so out of a sense of intrinsic motivation, because the behaviour strongly satisfies the need for autonomy and competence. However, that artist may be extrinsically motivated to create a painting that has been commissioned by a buyer, because this action thwarts a sense of autonomy, although may still satisfy the competence need. SDT is supported by a vast literature showing the universality of the three proposed psychological needs and the applicability of its predictions to diverse domains, including health and wellbeing, relationship development, work performance, and most importantly for the purposes of this thesis, education (see Deci & Ryan, 2000; 2008 for reviews).

Motivation determines academic achievement to a large degree. Students with low motivation consistently achieve poorer educational outcomes than those with high motivation (see Pintrich, 1999). Students may pursue education at the encouragement of their parents or loved ones, to earn a professional position, because they are interested in the topic, or for a variety of other reasons. The motivation underlying educational pursuits can range from fully intrinsic to fully extrinsic, as they satisfy one's innate needs to varying degrees. Just as the student's initial motivations may vary, so do the rewards inherent to the educational context. Educational settings provide opportunities for knowledge and learning, which may satisfy an intrinsic motivation, but most also provide grades, certificates, or degrees, which can act as extrinsic motivators. Deci and Ryan (2000) propose that intrinsic and extrinsic motivation are not dichotomous, however, and that external motivators can be internalized, which creates more stable and long-lived motivation.

Intrinsic and extrinsic motivation can interact and compete. The presence of extrinsic motivators, like external rewards, erodes intrinsic motivation (Deci, Koestner, & Ryan, 1999). A student who receives high grades for each homework assignment may not complete optional, ungraded work even if that student began the course with a high level of interest in the content and intrinsic motivation to learn. Not all rewards have the same consequences, however. Tangible external rewards (e.g., money, grades) tend to be more detrimental to intrinsic motivation than verbal rewards (e.g., praise; Deci et al., 1999). Tangible external rewards are salient, which make them effective at altering behaviour (Klinger, 1975). This characteristic also means that it is obvious when the reward is no longer present, however, resulting in the cessation of that target behaviour (Ferster & Skinner, 1957).

Educators can manipulate the motivators present in the learning environment to the benefit or detriment of their students. The research by Seli, Wammes, and colleagues (2016), for example, espouses the possibility that attention during lectures and the resultant learning are affected by a student's motivation to learn. The challenge is introducing rewards that increase motivation sustainably without undercutting intrinsic motivation in the long-term. An educator can tap into a student's intrinsic motivation to learn interesting content or closely align the course outcomes to the student's values (Deci & Ryan, 2000). These efforts may not be effective for all students, however. Encouraging engagement in the course through solely external rewards may benefit learning in the short-term, such that even those students without intrinsic motivation complete the tasks needed to acquire mastery of the course content, but may create a situation where all learning activities must be rewarded or students will not complete them.

Other Factors Influencing Learning

The motivations of each student differ, and interact with their instructor and with the broader environment. Motivation is just one of the many characteristics on which students differ, with others including personality, mental health indicators, affective state, working memory capacity, and more.

33% of students surveyed reported that anxiety affected their academic performance within the previous 12 months; 22% reported the same of depression (American College Health Association, 2016). Mental health and affective state can impact learning through changes to motivation or attention. In fact, the diagnostic criteria of Major Depressive Disorder include "markedly diminished interest or pleasure in all, or almost all, activities" and "diminished ability to think or concentrate" (American Psychiatric Association, 2013). Generalized Anxiety Disorder is also characterized by difficulty concentrating. As such, mental health and affective state have become important topics of study for mind wandering researchers.

Consistent with the diagnostic criteria for depression, inducing a negative mood increases mind wandering (Smallwood, Fitzgerald, Miles, & Phillips, 2009). In a naturalistic setting, participants report being more unhappy when they are mind wandering than when they are not

(Killingsworth & Gilbert, 2010). This finding is consistent with research showing that a propensity for attention failures has significant consequences on affective well-being (Carriere, Cheyne, & Smilek, 2008). When participants who are in a highly negative mood experience a high stress situation, they report more off-task thought and have poorer task performance than those with low levels of negative affect (Vinski & Watter, 2013). Negative mood can exacerbate the attentional consequences of stress or anxiety. Stress-reduction procedures particularly benefit those with high anxiety in reducing their mind wandering (Xu, Purdon, Seli, & Smilek, 2017).

Interestingly, mind wandering differs in both frequency and type when studying participants reporting anxiety or depression. Unhappy moods are associated with a bias towards retrospective thinking (Smallwood & O'Connor, 2011), particularly towards a recent stressor (Vinski & Watter, 2013). Furthermore, OCD symptomology correlates specifically with reports of unintentional mind wandering (Seli, Risko, et al., 2017).

The many individual differences that students bring to the classroom complicate the overall relation between attention and learning. Motivation, mood, and anxiety level significantly impact the amount and type of mind wandering reported, which may differentially affect a student's ability to learn.

Scope of the Present Thesis

The work presented in this thesis applies the cognitive principles of the mind wandering literature to an education setting. Assuming the framework that motivation affects learning through its influence on attention (Seli, Wammes, et al., 2016), this thesis asks: what interventions increase motivation to reduce mind wandering and promote learning? To achieve this goal, we used three different motivation manipulations and examined reports of intentional and unintentional mind wandering and comprehension measures. This research began in the classroom, which then informed the laboratory research conducted.

Chapter 2 uses quizzing as a motivator. This chapter compared interpolated quiz questions and quizzing at the end of lecture with no quizzing by presenting these conditions across multiple sections of a large undergraduate introductory psychology course. Each lecture included mind wandering probes that asked participants to report their mental state as being on task, intentionally mind wandering, or unintentionally mind wandering. To assess the effect of this motivational manipulation on academic performance, we examined scores on the quiz questions presented in class, in addition to weekly online quizzes and the final cumulative exam. If quizzing is an effective motivator in this context, we expect reports of mind wandering to decrease and short-term academic performance to increase. This chapter explores the connection between motivation and learning, as mediated by intentional and unintentional mind wandering, in an authentic classroom setting.

Unlike the real-time allocation of grades in Chapter 2, most laboratory research on mind wandering does not provide any incentive to minimize off-task thought. Participants often receive compensation in the form of partial course credit or money for attending but not for their performance. Given that motivation is related to attention, these conditions should impact mind wandering reports and, thus, the conclusions drawn from this research. Chapter 3 aims to bridge the gap between the classroom and laboratory by introducing performance-contingent monetary rewards to a paradigm where participants watch a video lecture and subsequently complete a comprehension test. The two experiments reported in this chapter sought to determine whether performance-contingent monetary rewards would differentially affect reports of intentional and unintentional mind wandering during a lecture and the consequence on comprehension performance, and whether this pattern changes if participants are re-tested when the reward contingency is no longer valid.

Intangible rewards are less detrimental to intrinsic motivation than tangible external rewards like the money used in Chapter 3. Using monetary rewards in laboratory research as a proxy for grades may not appropriately match the classroom environment. Chapter 4 presents an experiment using time-based rewards, such that demonstrating a certain level of performance allows participants to leave early. In other words, students can save time by learning course content more efficiently, which realistically mimics the education system. Chapter 4 also discusses what constitutes a reward for different people, which leads to an exploration of how negative affect and anxiety influence the relation between rewards and mind wandering.

The current thesis intersects cognition and education. It studies attention and memory using materials, methodologies, and research questions drawn from authentic classroom environments. The hypothesis underpinning all the research presented here is that stronger motivation reduces mind wandering, thus improving learning outcomes.

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CHAPTER 2

CHECKING IN TO AVOID CHECKING OUT: USING QUIZZING TO SUSTAIN ATTENTION IN LECTURES

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Abstract

When attention wanders away from a lecture towards internal thoughts, academic performance can suffer. Quizzes presented at unexpected intervals throughout a lesson reduce these off-task thoughts in students learning from video lectures; however, in-person lectures continue to dominate higher education. The present study aimed to apply interpolated quizzing in an authentic classroom. Using probes to assess mind wandering, three different quizzing conditions were assessed in a psychology course: interpolated quizzing, quizzing at the end of lecture, or no quizzing. Quizzing, regardless of placement within the lecture, reduced overall reports of mind wandering. When mind wandering was separated into *intentional* or *unintentional*, interpolated quizzing actually increased reports of *intentional* mind wandering. Both intentional and unintentional mind wandering reports predicted poorer academic performance, including weekly tests and the final exam. Our findings contribute to a growing body of research that aims to understand what underlies mind wandering and optimize instructional design principles.

Introduction

Inattention often interferes with classroom learning, particularly as time on task increases. A manifestation of inattention during learning is mind wandering, defined as internal thoughts that detract focus from the current external task (Smallwood & Schooler, 2006). Laboratory experiments have repeatedly demonstrated that inattention during video lectures or readings impairs comprehension (e.g., Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Smallwood, McSpadden, & Schooler, 2008; Szpunar, Khan, & Schacter, 2013). However, in-class lectures remain the primary mode of information transmission, making it critical to both theoretical and practical interests to determine how mind wandering progresses during an authentic classroom lecture and how instructional design can be manipulated to reduce inattention. The current research uses an introductory psychology course to explore how reports of mind wandering relate to academic performance, specifically as a consequence of introducing quizzing to lectures. This research also aims to explore further the heterogeneity of thoughts characterized as mind wandering by differentiating between intentionally initiated or continued mind wandering and unintentional or spontaneous mind wandering.

Students are required to attend to and learn content presented within a lecture and retain this information for a test that may occur weeks or months later. However, mind wandering can lead to poorer information encoding, which is detrimental to learning and later retrieval (Smallwood, Fishman, & Schooler, 2007; Wammes, Seli, Cheyne, Boucher, & Smilek, 2016a). In one study by Risko and colleagues (2012), participants watching a one-hour video lecture reported more mind wandering in the second half of the lecture and had poorer comprehension performance for content drawn from the second half compared to the first. When the goal is to understand and retain information, mind wandering is clearly a hindrance (see Pachai, Acai, LoGiudice, & Kim, 2016 for a recent review).

However, this may not be universally true depending on what students are mind wandering about and why. Mind wandering can include vastly different internal thoughts, from deliberately planning a to-do list for the rest of the day, to drawing connections between lectures, to day-dreaming about a vacation out of boredom. Consequently, mind wandering has been defined along a number of dimensions, including whether it is future- or past-oriented, self- or other-relevant, positive or negative, task relevant or irrelevant, and, critically for the present research, intentional or unintentional (Seli, Ralph, Konishi, Smilek, & Schacter, 2017).

Intentional mind wandering is typically characterized by a deliberate disengagement of attention from the external task to instead focus on internal thoughts (Seli, Risko, Smilek, & Schacter, 2016). This may be driven by a lack of motivation to engage in the external task or an assessment that internally directed thought is more valuable than external focus. Unintentional mind wandering, on the other hand, is reported when participants find themselves to be mind wandering despite their attempts to stay on-task, indicating that they did not initiate or continue this bout of mind wandering deliberately. The intentionality of mind wandering has been shown to be differentially correlated with Obsessive Compulsive Disorder (OCD) and Attention Deficit-Hyperactivity Disorder (ADHD) symptomology (Seli, Risko, Purdon, & Smilek, 2017; Seli, Smallwood, & Cheyne, 2013), mindfulness (Seli, Carriere, & Smilek, 2015), and manipulations of task difficulty (Seli, Risko, & Smilek, 2016b). Because motivation and other traits vary between students in a classroom, this distinction may be especially important.

One recent study explored the intentionality of mind wandering in an authentic classroom setting, rather than in the controlled laboratory (Wammes, Boucher, Seli, Cheyne, & Smilek, 2016; Wammes, Seli, Cheyne, Boucher, & Smilek, 2016). Using self-report probes assessing both intentional and unintentional mind wandering, Wammes and colleagues found that unintentional mind wandering was only reported on approximately 14% of the probes, and that total mind wandering did not increase as time on task increased—contrary to much laboratory research (e.g., Risko et al., 2012; Seli et al., 2017; Szpunar et al., 2013; Thomson, Seli, Besner, & Smilek, 2014). This finding makes it uncertain whether laboratory research using video lectures is a valid proxy for classroom learning. Furthermore, intentional and unintentional mind wandering differentially affected academic performance, with intentional mind wandering being related to more short-term deficits (i.e., in-class quizzes), while unintentional mind wandering was related to longer-term deficits (i.e., midterms and final exams). This recent research by Wammes and colleagues highlights the importance of separating intentionality and conducting mind wandering research in an authentic classroom setting. Lab research appears to have overestimated the prevalence of mind wandering and the extent to which it increases over time, possibly due to the inherent motivation to learn in classrooms that is often lacking in laboratory studies (Wammes et al., 2016).

Some laboratory research has looked at strategies to motivate students and, consequently, reduce the amount of mind wandering during lectures. For example, in a lab study using video lectures, interpolated testing reduced reports of mind wandering compared to restudy breaks (Szpunar et al., 2013). Interpolated testing involves quizzing students at unexpected intervals throughout the lecture. When using interpolated quizzing in video lectures, compared to no-quiz conditions, participants self-reported significantly fewer bouts of mind wandering and, in turn, had improved comprehension (Szpunar et al., 2013). Notably, these interpolated quizzes had the benefit of introducing retrieval practice, which is the practice of frequently testing students, resulting in improved ability to later recall information more so than restudying the information (e.g., Roediger & Karpicke, 2006). These quizzes had no incentive value for participants, which is in contrast to common practice in classrooms where quizzes would be worth grades.

The current study builds on previous lab and classroom research focused on the theoretically rich distinction between intentional and unintentional mind wandering. To achieve this objective, we introduced an interpolated quizzing manipulation into multiple sections of a large first year introductory psychology course. The aim was to examine whether this quizzing manipulation differentially affected intentional and unintentional mind wandering reports. Three conditions were implemented throughout the semester: interpolated quizzing, quizzing at the end of the lecture, and no quizzing. Over nine weeks, seven different lecture sections (with an average class size of 320 students) were exposed to all three conditions. Each condition lasted 2–3 weeks and all groups were exposed to all conditions in a fully counterbalanced manner. To assess mind wandering, students were given self-report probes during the lecture similar to those used in other laboratory and classroom research (e.g., Risko et al., 2012; Wammes, Boucher, et al., 2016).

Based on the lab results of Szpunar et al. (2013), we expected that students would report fewer bouts of mind wandering during the interpolated quizzing condition compared to quizzing at the end of lecture and no quizzing conditions. Further, we predicted that this reduction in mind wandering may carry over into subsequent lectures because students were not informed of the conditions or their presentation order, such that differences between mind wandering reports would vary depending on the order the conditions were presented. Those in the no-quizzing condition were expected to have the highest reports of mind wandering. Based on the recent work by Wammes and colleagues (2016), we also expected intentional mind wandering reports to be negatively predictive of performance on the questions presented within the lecture, and unintentional mind wandering to be negatively predictive of performance on the weekly quizzes and final exam.

Method

Participants

All 2216 students enrolled in Introductory Psychology at a large, selective research university in Canada were exposed to the experimental conditions as part of their course and were given bonus credits for completion of the study. Students who did not give informed consent for researchers to analyze their data or did not properly register their iClicker device were removed from the analysis, leaving a total of 1515 students in the final analysis (68% participation rate).

Design

Participants were quizzed in class throughout the semester on new course content presented within the week's lecture according to one of three quizzing conditions. During an interpolated interval, participants were exposed to two intermittent quiz questions throughout a 50-minute lecture. Quiz questions were moved to the end of the lecture during the quizzing at the end condition. In the no quizzing condition, participants did not complete any quiz questions during or at the end of class. Regardless of condition, all students were familiar with the use of iClicker devices to input answers as each lecture started with a multiple-choice question based on content they were asked to learn prior to attending class (as opposed to new content taught within the class lecture). This opening question was featured in all weeks of the course and was used to encourage students to come prepared to lecture. The order in which each participant was exposed to the three conditions was fully counterbalanced across the seven sections of the course so all conditions were tested in any given week. There were three instructors for the course, one of whom is the last author on this paper, but the individualized data were kept confidential from the instructors until after the semester had ended. Within each lecture, participants were probed twice on the focus of their attention regardless of condition. Within a given week, the mind wandering probes appeared at approximately the same points in the lecture for all sections of the course, but these points varied between weeks. In the interpolated condition, quiz questions appeared directly after the probe.

Mind wandering reports are collapsed across all probes presented within a given condition across the term (e.g., percent of the probes on which intentional mind wandering was reported, collapsed across all lectures with interpolated quizzes). As measures of academic performance, we analyzed performance on in-class quiz questions, weekly online tests, and the final cumulative exam to determine whether mind wandering reports in lecture predicted short- and long-term academic performance. The in-class quiz questions were multiple choice questions that drew only on content presented within that lecture. Weekly tests and the final exam included recall- and application-style multiple choice questions that drew on content presented in online web modules, in-person lectures, and assigned readings.

Procedure

Participants were exposed to each of three conditions for a three-week interval: interpolated quizzing, quizzing at end of lecture, or no quizzing. Due to a technology issue, the first week of classes had to be excluded from the study, and the remaining weeks were redistributed so the no quizzing condition only occurred for two weeks.

At the beginning of the term, students were briefed on the operational definition of mind wandering, which was described as thoughts unrelated to the task at hand. The instructor explained that mind wandering could be divided into two different types: intentional and unintentional. With intentional mind wandering, participants choose to go off-task, whereas during bouts of unintentional mind wandering, the unrelated thoughts occur without conscious choice. Throughout each lecture, intermittent probes appeared asking, "*Which of the following responses best characterizes your mental state just before this screen appeared?"*. Three possible responses were given: on task, intentionally mind wandering, or unintentionally mind wandering (Wammes, Boucher, et al., 2016; Wammes, Seli, et al., 2016). Participants chose one of the three options and their responses were submitted through the iClicker system. Participants were informed that reporting mind wandering would have no negative impact on their course grade.

Results

Placement of quiz questions during live lecture was manipulated in order to measure the effect on intentional and unintentional mind wandering. Probe responses and proportion of correct responses on in-class quiz questions, weekly tests, and the final exam were measured as dependent variables. An alpha level of .05 was used for all statistical comparisons except where otherwise noted.

Across all conditions, intentional and unintentional mind wandering was reported for 15% and 16% of probes, respectively (see Figure 1). Two separate mixed model ANOVAs were conducted to assess amounts of intentional mind wandering and unintentional mind wandering reported across lecture quizzing conditions (interpolated, end, or no quizzing) for each of the counterbalanced condition presentation orders. Condition (interpolated, end, or no quizzing) was treated as a within subjects factor, while the order in which the conditions were presented (e.g., one order might consist of interpolated first, then all at the end, and then no quizzing) was treated as a between subjects factor.

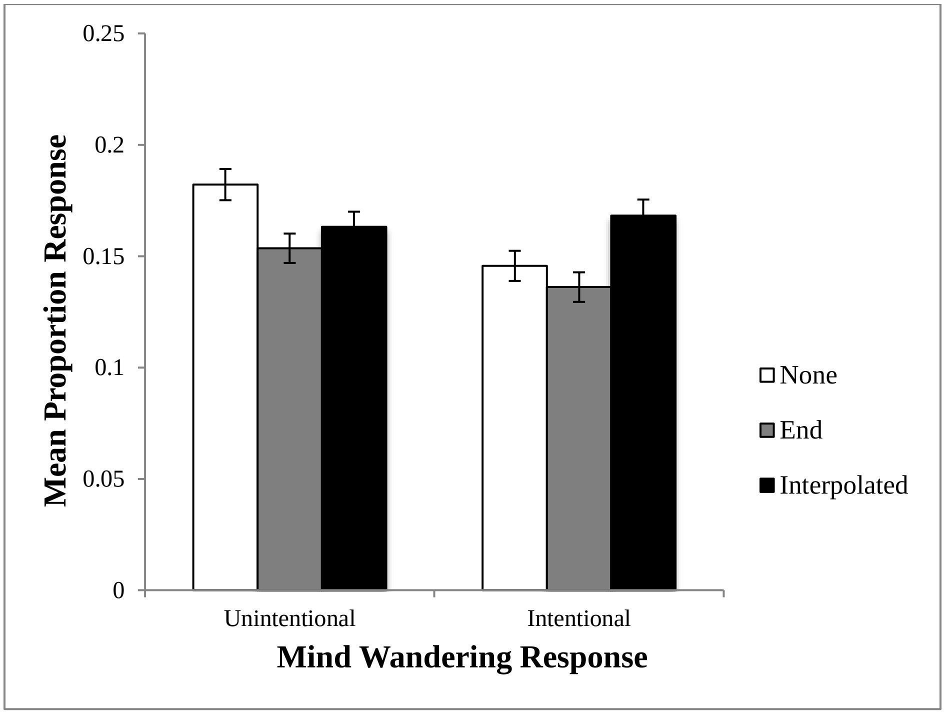

Figure 1. Mean proportion of mind wandering probes for which each response was given as a function of quizzing condition. Two separate mixed model ANOVAs were conducted for unintentional and intentional mind wandering, with condition as a within-subjects factor and order as a between-subjects factor (N=1514). Error bars represent standard error of the mean.

A statistically significant main effect of quizzing condition on unintentional mind wandering was found, $F(2,1509)=6.22$, $p<.01$, $f^2=0.06$. To assess the nature of this effect, three paired samples t-tests were conducted comparing each pair of quizzing conditions. A statistically significant difference was noted in mean proportion of unintentional probe responses between no quizzing (M=.19, SD=.23) and interpolated (M=.17, SD=.20), $t(1,1514)=2.97$, $p<.001$, and no quizzing and quizzing at the end (M=.16, SD=.20), $t(1,1514)=4.46$, $p<.001$ (see Figure 1). In other words, quizzing reduced unintentional mind wandering both when quizzes were presented intermittently within the lecture and when presented at the end of the lecture. There were no statistically significant effects involving the order of quizzing conditions.

A statistically significant effect of quizzing condition on intentional mind wandering reports was also found $F(2,1509) = 8.21$, $p < .001$, $f^2 = 0.07$. To evaluate this effect further, three paired samples t-tests were conducted. Results showed a statistically significant difference between interpolated (M=.17, SD=.21) and end conditions (M=.14, SD=.211), $t(1,1514) = 4.09$, $p < .001$, and between interpolated and no quizzing conditions (M=.14, SD=.23), $t(1,1514) = 4.50$, $p < .001$. Students reported higher amounts of intentional mind wandering when quizzed intermittently throughout the lecture compared to the other two groups. There were no statistically significant effects involving the order of quizzing conditions.

Both types of mind wandering were then correlated with measures of academic performance. Both intentional and unintentional mind wandering were significantly negatively correlated with all measures of academic performance (*r* coefficients ranging from .068 to .096), but not correlated with each other. These results suggest that both types of mind wandering hinder academic performance separately and further validates the importance of this distinction.

To assess how intentional and unintentional mind wandering contributed to the variance in each academic measure, we conducted multiple regression analyses. We first examined in-class quizzing performance by submitting both types of mind wandering and condition order to a multiple regression. We found that condition order, intentional mind wandering, and unintentional mind wandering all were significant predictors of poorer in-class quiz performance (all *p*s < .001; see Table 1).

Table 1. Multiple Regression Predicting In-Lecture Question Performance

DV: In-Lecture Scores	*B*	*SE*	ß	*t*	*p*
(Constant)	0.83	0.012		67.32	0.000
Condition Order	-0.021	0.003	**-0.18**	-77.09	0.000
Intentional MW	-0.088	0.027	**-0.081**	-3.23	0.001
Unintentional MW	-0.096	0.03	**-0.081**	-3.24	0.001

Note. Coefficients in bold are statistically significant at $p < 0.05$. Condition order, intentional mind wandering reports, and unintentional mind wandering reports all predicted performance on in-lecture multiple choice questions. The unique influence of condition order and unintentional mind wandering on weekly quiz performance are both eliminated when including in-lecture question performance as a factor. Final exam performance only is predicted uniquely by in-lecture question performance and weekly quiz performance.

To follow up on this analysis and determine whether in-class mind wandering reports would continue to predict academic performance throughout the semester, we conducted a stepwise multiple regression. The first step included condition order, intentional mind wandering rates, and unintentional mind wandering rates, with the second step adding in-class quiz performance. Weekly test performance was predicted uniquely by condition order, intentional mind wandering, and unintentional mind wandering in the first step (ß ranging from .071 to .1; all *p*s < .005). When including in-class quiz performance in the second step, condition order and unintentional mind wandering no longer predicted weekly test performance.

Similarly, for final exam performance, we conducted a stepwise multiple regression with condition order, intentional mind wandering rates, and unintentional mind wandering rates in the first step, and in-class quiz and weekly test performance added to the second step. Condition order, intentional mind wandering, and unintentional mind wandering all independently predicted exam performance when included in the first step (ß ranging from .087 to .12; all *p*s <

.001), but only in-class quiz and weekly test performance continued to predict the variance in exam performance when included in the second step (ß=.19 and ß=.51, respectively).

Discussion

The present study sought to determine whether quizzing students could reduce mind wandering in an authentic classroom setting. The rates of intentional and unintentional mind wandering (15% and 16%, respectively) were comparable to the reports by Wammes and colleagues (2016) of 19% for intentional mind wandering and 14% for unintentional mind wandering. Regardless of quiz placement within a given lecture, quizzing significantly reduced reports of unintentional mind wandering. Significantly higher reports of intentional mind wandering occurred when quiz questions were placed intermittently throughout a given lecture, compared to quizzing at the end of the lecture or no quizzing. When assessing academic performance, intentional and unintentional mind wandering were negatively correlated with all measures of academic performance—in class quizzes, weekly tests, and the final exam—but not correlated with each other. Intentional mind wandering and unintentional mind wandering both were significant predictors of performance on all academic measures.

Though our results seem to indicate that interpolated quizzing proved detrimental to students since it increased intentional mind wandering reports, this may not be the case. Recent work by Wammes et al. (2016) suggested fundamental differences between intentional and unintentional mind wandering in how they impact academic performance, such that intentional mind wandering resulted in the greatest deficits on short-term academic measures, while unintentional mind wandering had the greatest detriment on long-term measures. Their differing impact may be best understood by assessing the content of students' mind wandering to gain insight into why they went off-task. Intentional mind wandering may cause students to miss content within a given moment in the lecture, but may allow students to reflect on relevant material and foster connections between ideas presented earlier in the lecture, allowing for better long-term understanding. The mind wandering probe only assessed the intentionality of the mind wandering bouts, collapsing across other potentially important dimensions, like task-relevance. Given that interpolated quizzing intermittently tested students' knowledge on lecture material, this intervention may actually lead to strategic (or at least less detrimental) mind wandering. The current study is unable to speak to this hypothesis, but future research could employ more nuanced mind wandering probes that include an option for content-related mind wandering.

Intentional and unintentional mind wandering is one distinction that has gained traction in the literature (Seli, Carriere, & Smilek, 2015; Wammes, Boucher, et al., 2016; Wammes, Seli, et al., 2016), but content-relatedness may be another key distinction in an educational setting. When only given the option to report yes or no to the question of whether they were mind wandering, participants may be classifying a diverse range of experiences all as being 'mind wandering', which may misrepresent their mental state (Smallwood & Andrews-Hanna, 2013). Students may report mind wandering because they are not actively listening to incoming information, but they may be strengthening their understanding of potentially more important information that was previously presented. Clearly, different 'classes' of mind wandering will affect learning in different ways.

Critically for the field of research on mind wandering in education, the present study adds to other recent work calling into question the external validity of laboratory mind wandering research. Learners do not often find themselves to be mind wandering without deliberate intention. Unintentional mind wandering was only reported approximately 16% of the time that students were probed about their attention. Mind wandering research conducted in the lab may be overestimating mind wandering, leading to recommendations for the classroom that are fundamentally flawed.

The motivational context surrounding real classroom learning may be qualitatively different from the context created in a laboratory. Motivation has been repeatedly shown to influence attention and related cognitive constructs like working memory and executive control (Heitz, Schrock, Payne, & Engle, 2008; Locke & Braver, 2008; Slusarek, Velling, Bunk, & Eggers, 2001). Still, little research on mind wandering takes place under authentic learning conditions or acknowledges the potential role of motivation. Academic performance relies on motivation to learn course content and complete course work. Laboratory work that discounts the influence of motivation on student learning cannot make informed recommendations to improve teaching and learning.

The present study aimed to bridge this gap by taking a laboratory recommendation and introducing it to course lectures. This study built on the findings reported by Szpunar et al. (2013) by extending their manipulation to an authentic classroom setting and further differentiating mind wandering reports into intentional or unintentional. In an introductory psychology classroom, quizzing within a lecture promoted on-task thoughts, although, interestingly, interpolated quizzing increased intentional mind wandering relative to no quizzing or quizzing at the end. Regardless of the instructional techniques used, students will still mind wander in class, but there is much left to do to determine when and why students are inattentive in the classroom and what instructors can do to promote long-lasting learning.

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CHAPTER 3

WHAT'S IN IT FOR ME? MOTIVATING ON-TASK THOUGHT AND LECTURE COMPREHENSION IN THE LAB

Amy A. Pachai, Wid Yaseen, Jack Lawrence, & Joseph A. Kim

ABSTRACT

Learning requires focused attention, but often, attention shifts to internal thoughts. This phenomenon is referred to as mind wandering. Mind wandering has repeatedly been shown to impair learning in laboratory experiments (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Thomson, Besner, & Smilek, 2015). However, the lab differs from the classroom in countless ways, including in the motivation to effortfully engage in the required task. The current experiments manipulated motivation in the lab to approximate classroom learning, where learning is rewarded with good grades. In both experiments, participants watched a video lecture before completing a comprehension test. Prior to the lecture, half of the participants were told that $0.50 would be awarded per correct response on this test. We examined reports of intentional and unintentional mind wandering during the lecture (Wammes, Seli, Cheyne, Boucher, & Smilek, 2016), along with comprehension performance. In Experiment 1, rewarded participants reported similar levels of unintentional mind wandering as controls, but less intentional mind wandering. Experiment 2 replicated the benefit of reward, and demonstrated that the pattern of reduced intentional mind wandering is maintained in a second session even when rewards are removed. We conclude by discussing the importance of using generalizable methods in laboratory mind wandering research that consider the relevant dimensions of this mental experience.

INTRODUCTION

Efficient learning relies heavily on motivation. Educators often try to impose learning on unwilling students, leaving both parties frustrated. However, when content is intrinsically interesting, students remain on-task, leading to better learning outcomes. Off-task thought, often referred to as mind wandering, hinders learning within a lecture setting.

Mind wandering occurs when attention shifts from the primary task toward the processing of internal thoughts (Smallwood & Schooler, 2006). Decoupling attention between the external task and internal thoughts results in a diminished awareness of the external world (Smallwood, 2013). In the classroom, this state of decoupled attention between the lecture and internal goals, such as thinking about later dinner plans, impairs comprehension, leading to poor academic outcomes. In a seminal study by Risko, Anderson, Sarwal, Engelhardt, & Kingstone (2012), students' mind wandering during a video lecture increased with time on task, and as mind wandering increased, comprehension of the lecture material decreased. Performance deficits due to mind wandering have been well established through laboratory studies (for a review, see Mooneyham & Schooler, 2013).

Mind wandering encompasses a diverse group of mental experiences (Seli et al., 2018). One dimension on which these experiences can be divided is the level of intentionality. Mind wandering can occur with deliberate intention or spontaneously despite one's best efforts to stay on task (Wammes, Boucher, Seli, Cheyne, & Smilek, 2016; Wammes, Seli, Cheyne, Boucher, & Smilek, 2016). This dimension describes the difference between sitting through a lecture and repeatedly finding your attention drawn to the memory of a difficult conversation you had yesterday, as opposed to realizing that the lecture is not particularly important or interesting and instead deciding to generate a shopping list for later. Importantly, different contexts can separately affect rates of intentional and unintentional mind wandering. For example, difficult tasks have been shown to elicit more reports of unintentional mind wandering than intentional mind wandering, while the opposite is true of easy tasks (Seli, Risko, & Smilek, 2016b). Intentionality is also correlated with different individual factors such as mindfulness (Seli, Carriere, & Smilek, 2015), ADHD symptomology (Seli, Smallwood, & Cheyne, 2013), and OCD symptomology (Seli, Risko, Purdon, & Smilek, 2017). Within a classroom, intentional and unintentional mind wandering reports have been shown to predict different aspects of course performance, with intentional mind wandering predicting worse performance on in-class comprehension questions, and unintentional mind wandering predicting worse performance on midterms and final exams (Wammes, Seli, et al., 2016).

However, data collected from live lectures in undergraduate classes revealed that reported rates of unintentional mind wandering are relatively low, and that mind wandering reports did not increase over time during the lecture (Wammes, Boucher, et al., 2016). These results contradict a plethora of laboratory findings (Risko, et al., 2012; Thomson, et al., 2015). This may suggest that a substantial portion of the mind wandering being reported in other studies includes students intentionally shifting their attention away from the lecture to engage in competing internal thought.

Context (simulated laboratory versus real classroom) and motivation level seem to play a role in students' mind wandering during a lecture. In authentic lecture settings, academic consequences likely motivate students to sustain attention, whereas such consequences do not exist in a laboratory setting. Mind wandering, or inattention, has been shown to mediate the relation between motivation and learning (Seli, Wammes, Risko, & Smilek, 2016).

Grades are a salient reward for attention: the more a student pays attention to a lecture, the better they learn the material and the higher grades they receive. Grades are an example of performance-contingent rewards, which are granted based on how well an individual performs (Deci, Koestner, & Ryan, 1999). Performance-contingent rewards stand in contrast to the type of reward participants receive in a lab setting, typically partial course credit as compensation for participation. These task non-contingent rewards are awarded based on attendance and do not depend on performance. As a result, participants in the lab do not suffer the same consequences for inattention.

Although grades are likely to motivate more attention and subsequent learning, performance-contingent rewards tend to inadvertently decrease intrinsic, or internally-generated, motivation to learn (Deci et al., 1999). People are more inclined to believe that they were motivated by the reward than by a genuine investment in the task, which can undermine motivation when rewards are no longer present. However, in addition to controlling behaviour, rewards can also offer behaviourally relevant information. If a reward is interpreted as feedback (e.g., "this reward demonstrates that I am relatively competent at this task"), it can foster intrinsic motivation (Deci et al., 1999). Selecting appropriate external rewards is critical to ensuring that extrinsic motivational strategies are not counter-productive.

Current Research

The current research investigates the role of external rewards in promoting academic success in higher education. We ask whether external motivators drive students' ability to regulate their attention and limit levels of mind wandering during a lecture. We further consider whether external monetary motivators impact intentional and unintentional mind wandering to the same degree. Given that unintentional mind wandering occurs without conscious choice, it may be less influenced by external incentives than intentional mind wandering. In a second experiment, we further explore whether the effects of external rewards remain in a second session when no reward is present.

In both experiments, university students were asked to watch a video lecture on psychology concepts (Hunger and the Chemical Senses, or Form Perception) while reporting their levels of mind wandering throughout the lecture. Following a short distractor task, participants completed a comprehension test based on the lecture material. Half of the participants, those in the reward group, were informed that they would be given a monetary reward for each correct response given on their comprehension test. The control group was not provided with an external monetary incentive. We compared both groups in their reports of mind wandering and performance on the comprehension test. Experiment 2 used the same procedure, but with a second session in which participants repeated these tasks with a new lecture and no reward present.

To minimize the divide between classroom and laboratory research, the current research attempted to explore the benefits of motivation on students' learning. We hypothesized that the extrinsic reward group would demonstrate higher levels of motivation, which would result in less mind wandering than the control group. Given that unintentional mind wandering occurs without conscious choice, we predicted that intentional mind wandering might be more influenced by external motivators. We further predicted that these levels of mind wandering would be related to comprehension test performance. In Experiment 2, we hypothesized that mind wandering reports and comprehension performance would return to the levels of the control group in a second session when no reward was offered.

EXPERIMENT 1

Method

Participants. All participants (N=77; Female=56) were undergraduate students enrolled in the first year introductory psychology course, but had not yet learned the content presented within the experiment. Participants were recruited through an online psychology research portal system and were granted partial course credit for the completion of the experiment.

Procedure. Participants were randomly assigned to either the reward or control condition. We obtained informed consent as per the university's Research Ethics Board. Up to 6 participants were run at a time and sat at a computer with a barrier separating them from other participants' stations. All participants within a single session were run in the same condition. All participants watched a 33-minute video lecture on Hunger and the Chemical Senses drawn from the Introductory Psychology course. Before the start of the online lecture, participants in the reward condition were informed that they would be compensated $0.50 for each correct answer on the final comprehension quiz, earning up to $10.00 for demonstrating an understanding of the lecture. Six mind wandering probes were interleaved throughout the lecture and participants were instructed to report their mental state as being on-task, intentionally mind wandering, or unintentionally mind wandering (Wammes, Boucher, et al., 2016). The experimenter defined these possible responses prior to beginning the lecture as follows: Intentional mind wandering means you were not actively listening to the lecture and instead deliberately chose to think about something else. Unintentional mind wandering means that when the probe appeared, you realized you were spontaneously mind wandering without deliberately intending to think about something unrelated.

Participants responded to these prompts on a paper that was returned to the researcher upon completion of the lecture. It is important to note that participants were unaware of how many probes would appear during the lecture.

At the end of the lecture, all participants spent five minutes on arithmetic questions as a distractor task. Finally, they answered a short questionnaire about their academic background and familiarity with the lecture content before completing a 20-question multiple-choice quiz about the lecture material. Of the 20 questions, half were recall-based and half were application-based. These questions were drawn from the Introductory Psychology online quiz bank, so they represent an ecologically valid measure of learning (see Appendix A for sample questions). The experimenter then provided participants in the reward condition with the monetary compensation they had earned. All participants were debriefed and thanked for their participation. In all, the experiment took approximately one hour to complete.

Results

Participants were randomly assigned to either the reward (n=37) or control (n=40) condition. Mind wandering probe responses and proportion of correct responses on quiz questions were measured as dependent variables. An alpha level of 0.05 was used for all statistical comparisons.

Mind Wandering. Using a mixed factor ANOVA, with mind wandering type as a within subjects factor and condition as a between subjects factor, a significant interaction was noted between mind wandering and condition, $F(1,75)=4.464$, $p=.038$ (see Figure 1). To assess this interaction further, the simple main effects of condition were analyzed for each mind wandering type. Independent samples t-tests revealed a significant difference between reward and control conditions on intentional mind wandering reports ($t(1,75)=-2.432$, $p=0.017$), but not on unintentional mind wandering reports (t(1,75)=0.920, p=0.361). There were no significant main effects of condition or mind wandering type.

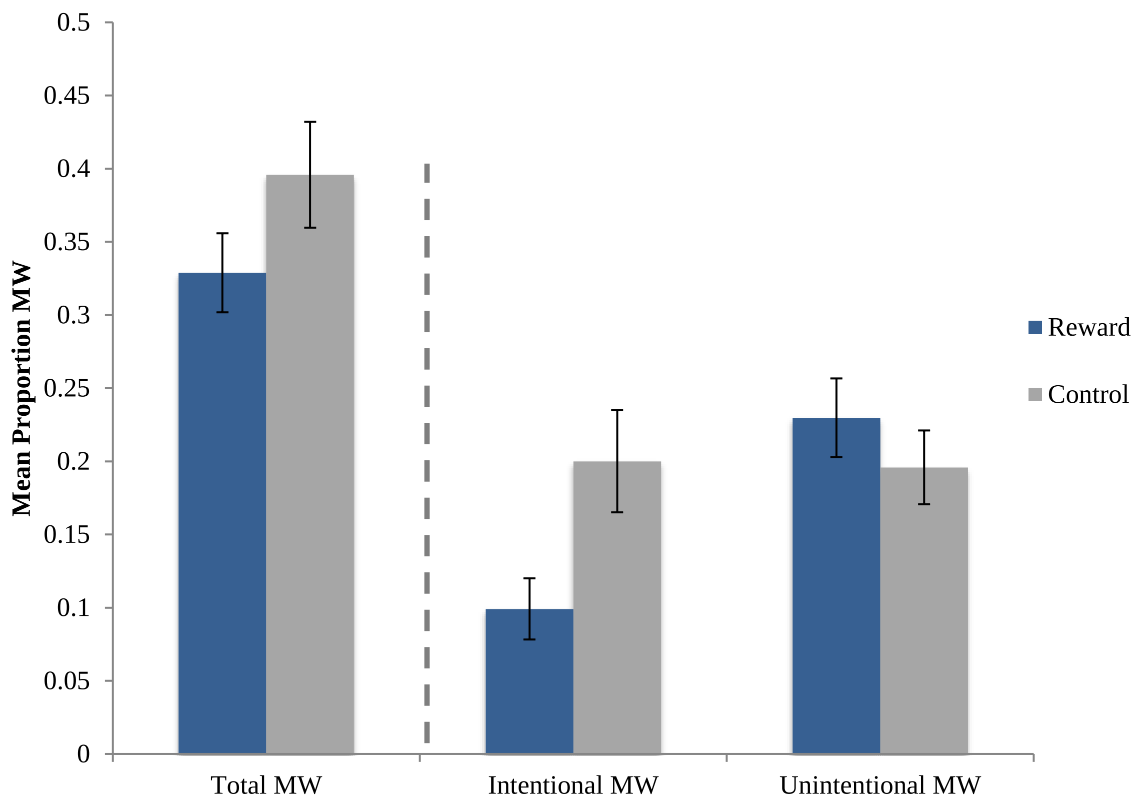

Figure 1. Mind wandering (MW) probe responses. Significantly less intentional mind wandering was reported in the reward condition than in the control condition (*t*(1,75)=-2.432, *p*=0.017). Error bars represent the standard error of the mean.

Comprehension Quiz. Participants from both the reward and control condition completed a comprehension quiz that contained recall- and application-type questions. A mixed factor ANOVA was conducted with question-type as a within-subjects factor and condition as a between-subjects factor. A summary of performance in the comprehension quiz is presented in Figure 2. This analysis revealed a main effect of question type. Participants performed better on recall questions (M=64%, SD=18.1) than they did on application questions (M=52%, SD=18.7;

F(1,75)=29.857, p<.001). Participants in the reward condition performed slightly higher (M=60%, SD=16.2) than participants in the control condition (M=56%, SD=15.1). However, these slight differences in total quiz performance were not statistically significant between conditions (t(1,75)=1.193, p=.569).

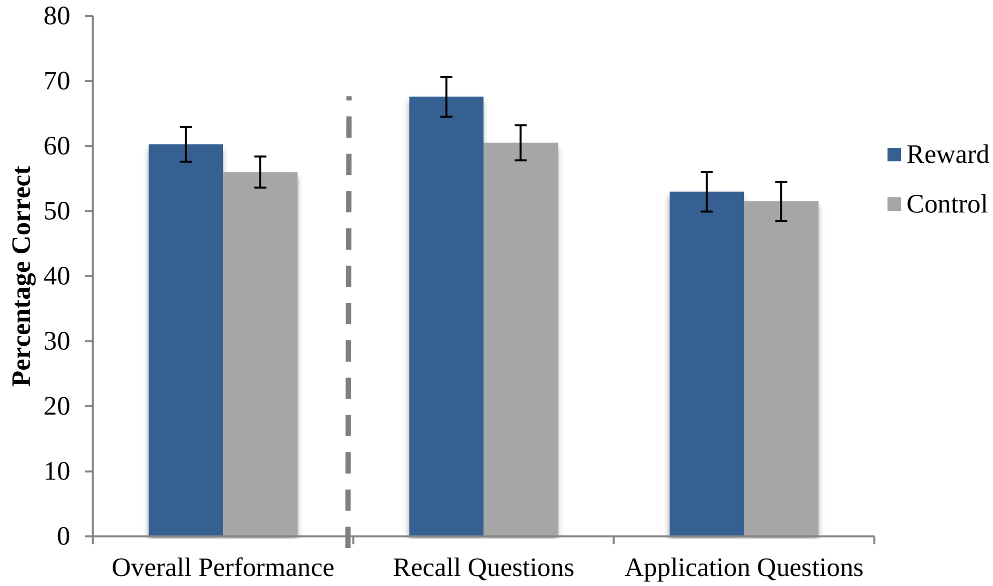

Figure 2. Comprehension quiz scores. Overall, participants performed better on recall questions than on application questions (*F*(1,75)=29.857, *p*<.001). Participants in the reward condition performed marginally better in overall comprehension than did control. Error bars represent the standard error of the mean.

Overall, mind wandering was negatively correlated with comprehension (r=-.402, p<.01), as seen in Figure 3. To examine whether this correlation differed depending on the type of mind wandering reported, we separately analyzed whether intentional and unintentional mind wandering reports were correlated with comprehension performance. Unintentional mind wandering reports were not significantly correlated with comprehension performance (r=-.207, p=.07). Intentional mind wandering reports, however, were significantly negatively correlated with comprehension performance (r=-.255, p<.01).

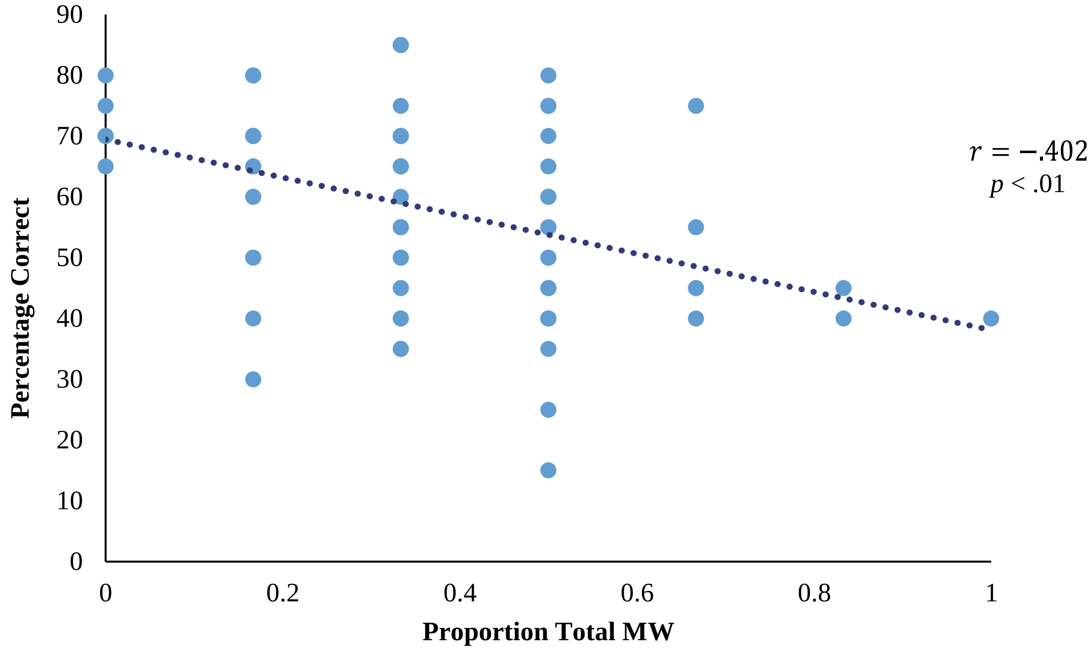

Figure 3. Comprehension quiz scores as a function of reported mind wandering levels. Mind wandering was significantly negatively correlated with comprehension scores (r=-.402, p<.01).

EXPERIMENT 2

Experiment 1 demonstrated that external rewards can influence reports of mind wandering during an online lecture in the laboratory. These mind wandering reports were in turn negatively correlated with comprehension of the lecture content. If rewards can reduce inattention during a learning situation, this may advocate for the use of external motivators in a broad range of contexts. However, if these rewards lead to reduced motivation at a later time when they are applied inconsistently, learning could be negatively impacted in the long run. Experiment 2 aimed to examine how the introduction of rewards affected later attention and learning when they were removed.

Method

Participants. Participants (N=59, Female=26) were recruited using the psychology undergraduate participant pool and were given partial course credit for their participation. To be eligible, participants could not have previously participated in Experiment 1.

Procedure. The procedure for Experiment 2 was the same as in Experiment 1, except that participants were asked to return for a second session 24–48 hours later, where they would engage in the same set of tasks as in Session 1 (reward: n=29, control: n=30). Participants watched one of two video lectures drawn from the McMaster University introductory psychology course (either Form Perception or Hunger and the Chemical Senses), with presentation order counterbalanced across participants. Otherwise, Session 1 was identical to Experiment 1.

In Session 2, participants returned to watch the second video lecture (i.e., Hunger and the Chemical Senses if they had started with Form Perception, or vice versa). All participants, regardless of whether they were in the control or reward condition, were told at the beginning of Session 2 that the only remuneration for this session would be course credit (i.e., nobody was given a monetary reward in Session 2). In all other areas, Session 2 resembled Session 1; participants watched their video lecture and answered mind wandering probes, completed a five-minute algebraic math distractor task, and then completed a twenty-question multiple choice comprehension test. Each session took approximately one hour to complete.

Results

Participants were randomly assigned to either the reward (n=29) or control (n=30) condition based on their condition in the first session of the experiment. Mind wandering probe responses and proportion of correct responses on quiz questions were measured as dependent variables in both Session 1 and Session 2. An alpha level of 0.05 was used for all statistical comparisons.

Mind Wandering. Mind wandering reports collected during Session 1 and Session 2 were analyzed separately using a mixed factor ANOVA, with mind wandering type as a within-subjects factor and condition as a between-subjects factor. There was a main effect of condition in Session 1 ($F(1,52)=4.489$, $p=.039$), such that participants in the reward condition reported mind wandering of either type on 35% of probes (SD=21.7), while participants in the control condition reported mind wandering on 48% of probes (SD=26.0) , as seen in Figure 4A. For Session 1, a significant effect of mind wandering type was also found ($F(1,52)=7.853$, $p<.01$). Overall, participants reported more unintentional (M=27%, SD=19.6) than intentional (M=15%, SD=37.7) mind wandering. There was no significant interaction between condition and mind wandering type ($F(1,52)=1.063$, $p=.307$), although the pattern of results was similar to that in Experiment 1.

In Session 2, a significant effect of mind wandering type was found ($F(1,52)=24.246$, $p<.001$). Overall, participants reported more unintentional (M=27%, SD=18.4) than intentional (15%, SD=14.6) mind wandering, as seen in Figure 4B. There was no main effect of condition in Session 2 ($F(1,52)=1.403$, $p=.242$). There was also no significant interaction between condition and mind wandering type ($F(1,52)=.776$, $p=.383$).

Comprehension Quiz. Participants from both the reward and control condition completed a comprehension quiz that contained recall- and application-type questions in both Session 1 and Session 2. A mixed factor ANOVA was conducted with question-type as a within-subjects factor and condition as a between-subjects factor. Summary of performance in the comprehension quiz for Sessions 1 and 2 are presented in Figures 5A and 5B, respectively.

For Session 1, the analysis revealed a main effect of question type, F(1,36)=20.494, p<.001. Participants performed better on recall questions (M=62%, SD=17.0) than they did on application questions (M=48%, SD=17.7). There was no significant main effect of condition (F(1,36)=.349, p=.559) or interaction between condition and question type (F(1,36)=.669, p=.419).

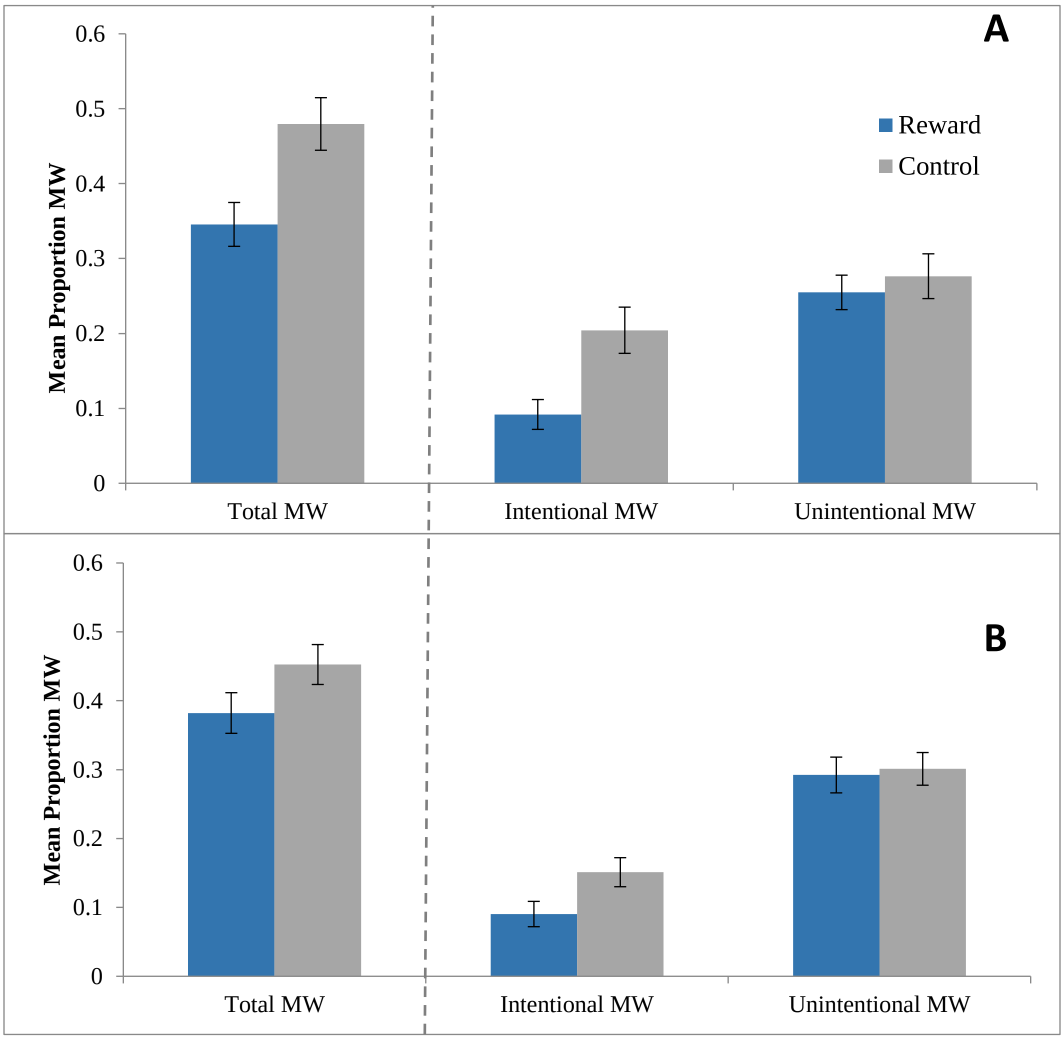

Figure 4. Mind wandering probe responses for Session 1 (panel A) and Session 2 (panel B). In Session 1, significantly more unintentional mind wandering was reported compared to intentional mind wandering (F(1,52)=7.853, p<.01). The reward condition reported significantly less mind wandering than the control condition (F(1,52)=4.489, p=.039). In Session 2, significantly more unintentional mind wandering was reported compared to intentional mind wandering (F(1,52)=24.246, p<.001). Error bars represent the standard error of the mean.

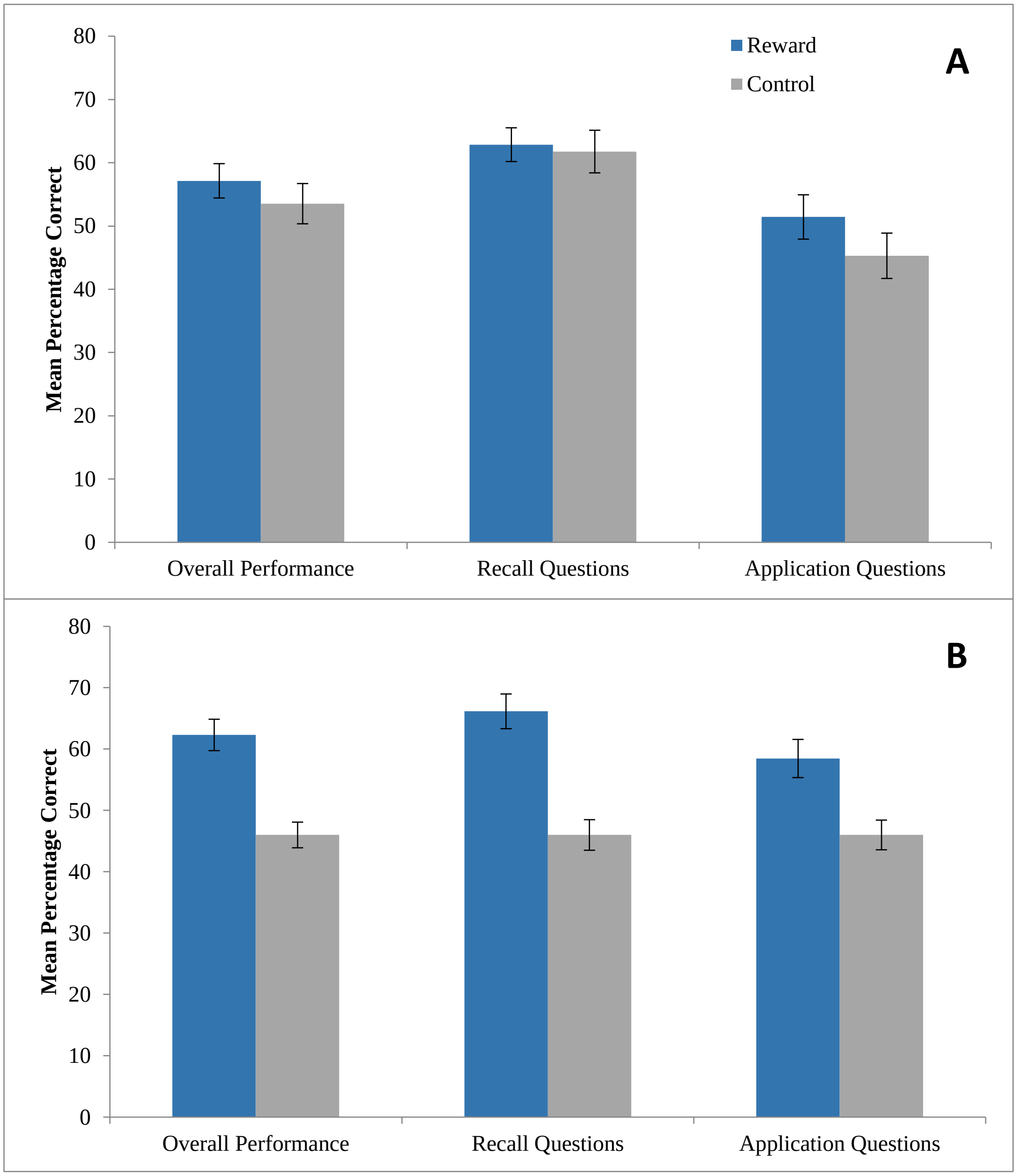

Figure 5. Comprehension test scores for Session 1 (panel A) and Session 2 (panel B). In Session 1, participants performed significantly better on recall compared to application questions ($F(1,36)=20.494$, $p<.001$). In Session 2, the reward condition significantly outperformed the control condition ($F(1,36)=10.699$, $p<.01$). Error bars represent the standard error of the mean.

For Session 2, there was no significant main effect of question type ($F(1,36)=1.655$, $p=.206$). There was, however, a significant main effect of condition ($F(1,36)=10.699$, $p<.01$). Participants in the reward condition (M=62%, SD=16.4) outperformed those in the control condition

($M=46\%$, $SD=13.4$). There was no significant interaction between question type and condition ($F(1,36)=1.655$, $p=.206$).

The correlations between mind wandering and comprehension quiz performance in Sessions 1 and 2 are presented in Figures 6A and 6B, respectively. For Session 1, mind wandering was significantly negatively correlated with comprehension performance ($r=-.452$, $p<.01$). For Session 2, however, mind wandering was not significantly correlated with comprehension performance ($r=-.202$, $p=.205$). Again, we separately analyzed whether intentional and unintentional mind wandering reports were differentially correlated with comprehension in each session. Unintentional mind wandering reports were not significantly correlated with comprehension performance in either session (Session 1: $r=-.207$, $p=.072$; Session 2: $r=.016$, $p=.893$). However, intentional mind wandering reports were significantly negatively correlated with comprehension performance in both sessions (Session 1: $r=-.339$, $p<.01$; Session 2: $r=-.408$, $p<.01$).

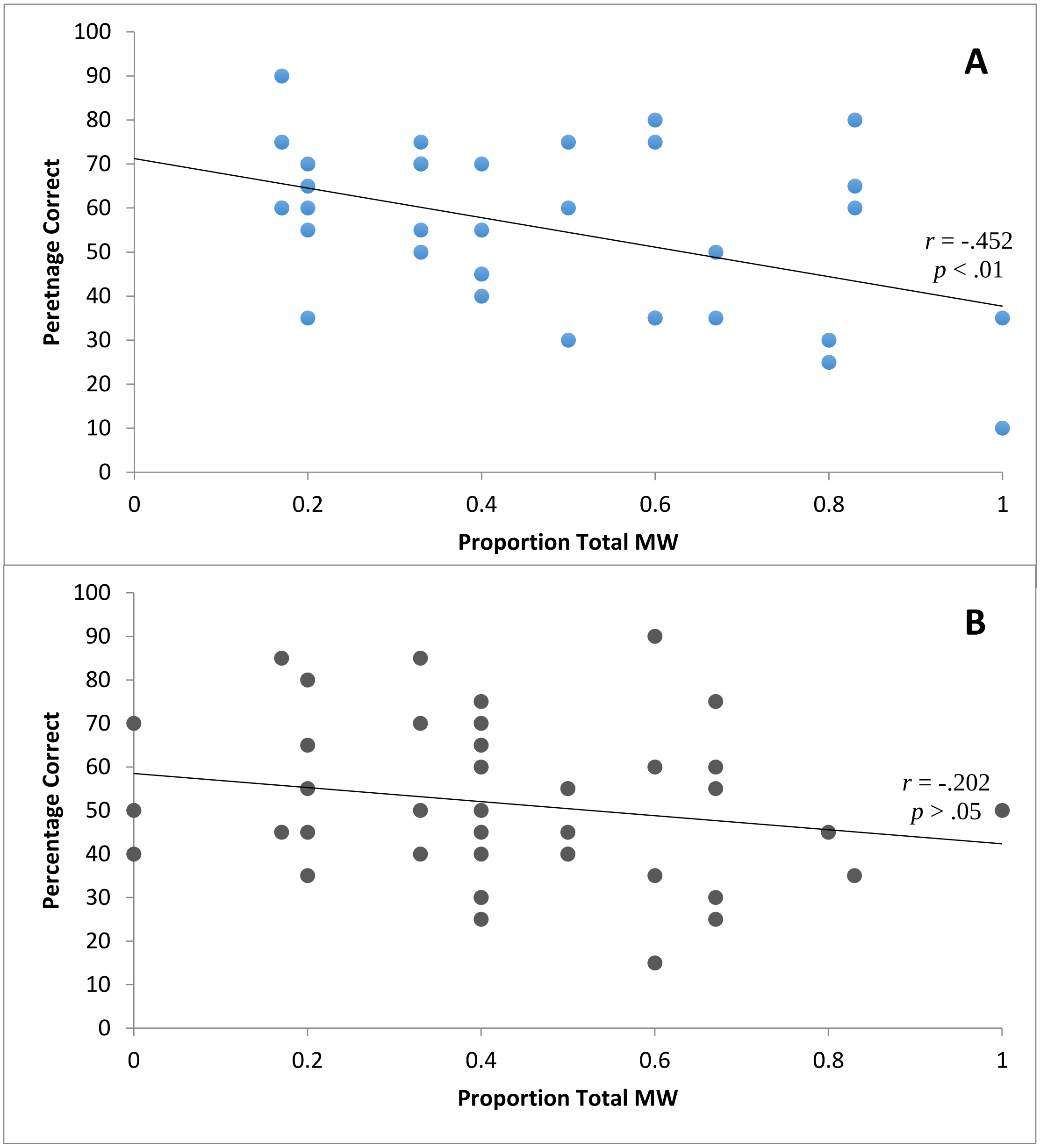

Figure 6. Comprehension quiz scores as a function of reported mind wandering (MW) levels for Session 1 (panel A) and Session 2 (panel B). Mind wandering was significantly negatively correlated with comprehension scores in Session 1 (r = -.452, p<.01), but not in Session 2 (r = -.202, p = .205).

GENERAL DISCUSSION

The current research aimed to determine whether learning in the laboratory could more closely approximate the motivational context of the classroom by introducing external rewards.

Experiment 1 demonstrated that monetary rewards reduced reports of intentional mind wandering, without affecting unintentional mind wandering reports. Although there was no effect of reward on comprehension, intentional mind wandering reports were significantly negatively correlated with overall comprehension performance. Experiment 2 examined whether monetary rewards would continue to affect mind wandering reports and lecture comprehension in a second session when those rewards were removed. In Session 1, the reward condition reported significantly less mind wandering than the control condition, particularly in the intentional mind wandering reports. Again, condition did not significantly affect comprehension performance but there was a significant negative correlation between intentional mind wandering reports and comprehension. The patterns of results in Session 2 closely matched those in Session 1, although the reward condition's reduction in mind wandering reports was not statistically significant in Session 2. Interestingly, Session 2 did demonstrate a significant benefit of initial reward on comprehension performance, while continuing to maintain the significant negative correlation between intentional mind wandering and overall comprehension performance.

The inconsistent effect of reward on comprehension performance requires a closer look—the reward condition only outperformed the control participants in Session 2 of Experiment 2, when rewards were actually no longer present. However, it appears that this effect is primarily driven by the reward condition maintaining their performance across the two sessions, while the control condition drops from Session 1 (M=54%) to Session 2 (M=46%). This may be interpreted as sustained motivation in the reward condition, despite the absence of continued reward, while participants in the control condition were unwilling to continue engaging effort in learning when they returned for a second session. This hypothesized sustained motivation in the reward condition is supported when considering the mind wandering reports in Session 2: despite the lack of a significant main effect of reward condition, the pattern of results is clearly replicated across the two sessions, indicating that rewarded participants were willing to increase attention to the lecture in both sessions compared to controls. This leaves us with the question of why removing the reward manipulation in Session 2 did not negatively impact attention or learning. External rewards that are contingent on a certain level of performance can be less detrimental to future motivation and performance than other types of external rewards because they include a feedback component (Deci et al., 1999). The rewards used here drew a participant's attention to their competency in the task, which can foster intrinsic motivation that may persist in Session 2 when the rewards are removed. It is also possible that participants still believed they would receive a reward for their performance since they were engaging in the same tasks in Session 2, despite being told otherwise.

There may be two factors that impact performance in Session 2: a lack of motivation to engage in these tasks for a second time, and a desire to possibly earn valuable rewards. The control condition is only subject to the former, which leaves them engaging little effort in learning the content presented in Session 2. However, participants in the reward condition may experience a lack of motivation to repeat these tasks, but counter this negative influence with the desire to earn rewards, including intrinsically rewarding knowledge, leaving them with similar performance across the two sessions.

Across all experimental sessions reported here (Experiment 1 and both sessions in Experiment 2), we observe a negative correlation between intentional mind wandering reports and comprehension performance. We might expect that intentional mind wandering has the potential to be more strategic or beneficial to learning. However, our findings are counter to what we would expect if these bouts of intentional mind wandering were content-related and productive. For example, in a study using randomly interpolated testing to motivate students, tested students were more likely to engage in lecture-related mind wandering than controls, and these students also outperformed the control group on comprehension measures (Jing, Szpunar, & Schacter, 2016). Since the intentional mind wandering reports given here are negatively correlated with learning, it seems unlikely that they are content-related and reflective of high levels of motivation. Those who report intentional mind wandering might encompass two distinctly different groups of participants: those who are strategically allocating their attention in an effort to integrate information, and those who are purposefully disengaging from a task due to a lack of motivation. Future research should explore the contents of intentional mind wandering in an effort to determine why participants choose to disengage from a task.

The research conducted here further validates the importance of separating intentional from unintentional mind wandering. In Experiment 1, if we had only considered total mind wandering, we would not have observed an effect of reward. Intentionality has been previously shown to be differentially related to multiple individual difference factors (Seli et al., 2015, 2017, 2013; Seli, Risko, & Smilek, 2016a), task difficulty manipulations (Seli, Risko, et al., 2016b), and academic consequences (Wammes, Seli, et al., 2016); we can now add reward manipulations to this list. Although intentionality appears to be a critical dimension on which we can define mind wandering, it remains unclear how intentionality intersects with other relevant dimensions like content-relatedness or emotional valence.

More broadly, the research conducted here has important implications on the ecological validity of mind wandering research. Introducing monetary rewards to a laboratory experiment brought mind wandering levels closer to those observed in a classroom setting (e.g., Wammes, Boucher, Seli, Cheyne, & Smilek, 2016). These monetary rewards also provided participants with knowledge of their own understanding, which may act as further motivation, even when rewards are no longer present. This context is consistent with an authentic classroom environment and may be able to provide data that are more readily generalizable to this setting. If our goal as researchers is to provide valuable recommendations to educators and students about how to promote attention and learning, we must conduct research in settings that mirror the classroom as much as possible.

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Appendix A

Sample Quiz Questions

Recall Questions

Which of the following correctly describes a distinguishing feature between smell and other senses?

a) Smell is the only sense that does not pass through the thalamus.
b) Smell is the only sense that combines with visual input.
c) Smell is the only sense that combines with auditory input.
d) Smell is the only sense that does not pass through the hypothalamus.

Which of the following hunger hormones is correctly matched with its source organ?

a) CCK - small intestine
b) Insulin - liver
c) NPY - pancreas
d) Leptin - hypothalamus

Application Questions

Jane is late for work and decides to skip breakfast. At lunchtime, she eats double the portion she normally would. Which of the following is a plausible reason for why Jane may have overeaten?

a) Her glycogen stores in the liver were high.
b) Her levels of CCK were lower than normal.
c) Her levels of NPY were lower than normal.
d) Her blood glucose concentration was high.

After a fall, when a taste-tester for a Frozen Yogurt Company is asked to compare the sour "Tangy Lemon" with the sweet "Velvety Chocolate", he correctly claims that both flavours are delicious and creamy, but he incorrectly states that they taste identical. Based on this information, which brain area is most likely to be implicated in his injury?

a) Primary somatosensory cortex
b) Orbital cortex
c) Olfactory cortex
d) Gustatory cortex

CHAPTER 4

EXPLORING THE BOUNDARIES OF MOTIVATIONAL MANIPULATIONS DURING LECTURES

Amy A. Pachai, Jack Lawrence, Jhanahan Sriranjan, David I. Shore, & Joseph A. Kim

Abstract

Grades motivate students' learning, whereas mind wandering hinders it. Measuring mind wandering in the lab lacks the motivating presence of grades. Pachai, Yaseen, Lawrence, and Kim (in prep) approximated classroom learning by motivating participants with monetary rewards. Participants offered a monetary reward for correct responses on a post-lecture test reported less intentional mind wandering, but similar levels of unintentional mind wandering. To test the generalizability of Pachai et al.'s (in prep) effect, Experiment 1 used a time-based reward: participants correctly completing 70% of the comprehension questions were allowed to leave early. This reward had the opposite effect on mind wandering, with the control condition reporting less mind wandering overall. We hypothesize that this effect was due to increased anxiety or negative affect caused by the reward instructions. Experiment 2 measured participants' trait anxiety and negative affect to determine whether anticipated monetary reward maintains its benefit in reducing mind wandering in these high-risk groups. Participants with high trait anxiety reported higher levels of unintentional mind wandering, but these reports were not affected by the reward. High negative affect was associated with more mind wandering reports in the control group only, indicating a protective effect of reward, but this pattern as not observed in those with low negative affect. These findings demonstrate a protective effect of reward in those with high negative affect but not those with high anxiety. Together, these

experiments clarify the role of motivation in reducing unwanted mind wandering in the classroom.

Introduction

Mind wandering pulls our attention away from task completion (Smallwood & Schooler, 2006). Task performance suffers when attention shifts towards internally-oriented, non-task relevant thoughts (Pachai, Acai, LoGiudice, & Kim, 2016; Smallwood, 2013; Smallwood & Schooler, 2006). Therefore, bouts of mind wandering have a negative impact on learning (e.g., Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Szpunar, Khan, & Schacter, 2013). Given the goal of maximizing the learning experience, students and teachers should be invested in learning how to control, and possibly eliminate, unproductive mind wandering episodes. To achieve this goal, it is paramount to understand which students are most at risk for mind wandering and why. The present research explores the impact of motivation and anxiety on the number and type of bouts of mind wandering.

Most people will confidently report that they mind wander, and can identify their mind wandering episodes. In their seminal paper on mind wandering, Smallwood and Schooler (2006) defined mind wandering as the cognitive shift away from primary tasks towards non-goal-directed personal thoughts. This definition is initially attractive because its simplicity lends well to empirical research (i.e., identifying a 'mind wandering episode' can be as easy as identifying an 'off-task' participant). However, the definition is limited by its simplicity. It has been argued that mind wandering bouts can be defined on a number of dimensions (e.g., task relevance, guidedness, future-orientedness; Seli et al., 2018; Seli, Ralph, Konishi, Smilek, & Schacter, 2017).

Intentionality provides one dimension that has proven important. Unintentional mind wandering occurs despite the best intentions of the participants to stay focused, whereas intentional mind wandering occurs when participants purposely thinking about task-unrelated ideas (Seli, Risko, Smilek, & Schacter, 2016). These two categories of mind wandering are empirically dissociable (Seli et al., 2014; Seli, Smallwood, & Cheyne, 2013; Seli, Risko, Purdon, & Smilek, 2017; Seli, Risko, & Smilek, 2016a). For example, difficult tasks produce more unintentional mind wandering, whereas easy tasks produce more intentional mind wandering (Seli, Risko, & Smilek, 2016b). Allowing participants to specify whether their mind wandering was 'intentional' or 'unintentional' provides a more accurate and meaningful depiction of the mind wandering experience (Seli, Risko, & Smilek, 2016b). For these reasons, the current research separately examines reports of intentional and unintentional mind wandering during a learning task. One factor known to influence the proportion of intentional and unintentional mind wandering is motivation (Seli, Wammes, Risko, & Smilek, 2016). The factor of motivation becomes even more relevant since the vast majority of the research examining mind wandering and its dimensions has been conducted in a laboratory setting (for notable exceptions, see Wammes, Boucher, Seli, Cheyne, & Smilek, 2016; Pachai, Ogrodnik, & Kim, in prep). This may compromise the validity of the conclusions drawn because, in the classroom, people are driven to stay on-task by extrinsic rewards like praise or grades (Deci, Koestner, & Ryan, 1999). Conversely, participants in a laboratory traditionally do not face consequences for being off-task, with many of them receiving their course credit just for showing up.

This motivational difference changes the mind wandering experience. For example, contrary to many laboratory-based findings, classroom mind wandering does not seem to consistently increase with time on task (Risko, et al., 2012; Wammes, Seli, et al., 2016). Indeed, classroom mind wandering occurs less than originally thought, and when it does occur, it is more likely to reflect intentional strategy than accidental attention failure (Wammes, Seli, et al., 2016). Pachai, Lawrence, Yaseen, & Kim (in prep) established a methodological paradigm using money as an extrinsic reward in an attempt to make mind wandering research more ecologically valid. In this case, monetary rewards, contingent on comprehension performance, were used to approximate increasingly positive grade outcomes that students might experience in a classroom. They demonstrated that participants expecting monetary rewards reported less intentional mind wandering than did participants in a control condition. This finding validates the importance of considering motivational context in mind wandering research.

EXPERIMENT 1

Rationale

Pachai et al. (in prep) approximated grade-based classroom learning with monetary rewards. It is possible, however, that alternative extrinsic motivators could serve equally well, such as positive feedback, time spent engaging in an enjoyable task (e.g., video games), or gifting other tangible rewards (e.g., food). In Experiment 1, we examined the effects of using a time-based reward as an extrinsic motivator to mimic the limited time in which students have to allot to academic, personal, and work commitments. The more quickly a student can effectively learn the material, the more time they have for other activities. We predicted that the time-based reward would produce similar results to a monetary reward, in that it would specifically reduce reports of intentional mind wandering.

This experiment also explored the specific content of participants' mind wandering episodes since intentional mind wandering might reflect a strategic attentional shift away from the immediate task that may still benefit complex learning (Wammes, Seli, et al., 2016). Intentional mind wandering appears more future-oriented and specific than unintentional mind wandering (Seli, Ralph, et al., 2017). However, the amount of intentional, but not unintentional, mind wandering, negatively correlates with comprehension performance (Pachai et al., in prep).

In Experiment 1, we used a two-step content-based probe to assess the content-relatedness of participants' mind wandering episodes to determine whether intentional reports were more likely to be described as content-related. This probe first categorized mind wandering as intentional versus unintentional; then, the second step categorized mental activity from completely related to the lecture material to completely unrelated. If intentional mind wandering represents a strategic shift of attention to benefit complex learning, then we should observe that intentional mind wandering is more often reported as being content-related.

Method

Participants. Participants (N = 43) were recruited using the psychology undergraduate participant pool and were given partial course credit for their participation. To be eligible, participants must not have previously completed the course from which the lecture materials were drawn, nor could they have participated in previous studies using similar protocols. Prior to beginning the experiment, participants provided informed consent. The university's research ethics board approved this study.

Procedure. All participants began by watching an approximately 25-minute *Form Perception* video lecture drawn from the introductory psychology course. Mind wandering probes were approximately evenly interpolated throughout the lecture, prompting participants to note their current attentional state as 'On-Task', 'Intentionally Mind Wandering', or 'Unintentionally Mind Wandering' (Wammes, Boucher, et al., 2016). This probe question was immediately followed by a second question, prompting participants to describe the content of the mind wandering they reported. Their responses were forced choice: 'I wasn't mind wandering', 'I was thinking about something presented earlier in the lecture', 'I was thinking about something related to the ideas in this lecture', or 'I was thinking about something completely unrelated to the lecture.' The responses to both questions were recorded using pencil and paper.

Upon completing the module, participants worked for five minutes on an algebraic math distractor task. Then, participants completed a twenty-question multiple-choice comprehension test, consisting of half recall-based and half application-based questions taken directly from the course test bank to represent an ecologically valid measure of learning (see Appendix A for sample questions). Critically, prior to beginning the video lecture, half of the participants were told that there were forty multiple-choice questions, but they could leave after the first twenty if they answered at least fourteen correctly (70%). The other half of the participants did not receive this instruction, and all participants only completed twenty questions regardless of their performance. Whether participants received the time-based reward or control condition was determined by random assignment.

Results

This experiment used a factorial design, analyzed using a mixed model ANOVA. Reward condition (i.e., 'Time-Based Reward' or 'Control') was a between-subjects independent factor. Mind wandering type (i.e., 'Intentionally Mind-Wandering' or 'Unintentionally Mind-Wandering') and comprehension question type (i.e., 'Recall' or 'Application') were within-subject dependent factors in their respective analyses. The relative proportions of mind wandering probe responses and correct answers on comprehension test questions were dependent measures. The content-based mind wandering probes were additional dependent measures, but we found no significant effect of reward condition or mind wandering type on reported content relatedness so those data are not reported here. All statistical comparisons used an alpha level of .05.

Mind Wandering Data. Participants reported more unintentional mind wandering (M = .31, SD = .22) relative to intentional mind wandering (M = .17, SD = .20; $F(1,42) = 6.9$, $p = .012$) (see Figure 1). Participants who received the time-based reward reported more mind wandering (M = .53, SD = .21) than participants in the control condition (M = .41, SD = .22), which was approaching significance ($F(1,42) = 3.5$, $p = .067$). The interaction between mind wandering type and reward condition was not significant (F(1,42) = .049, p > .1).

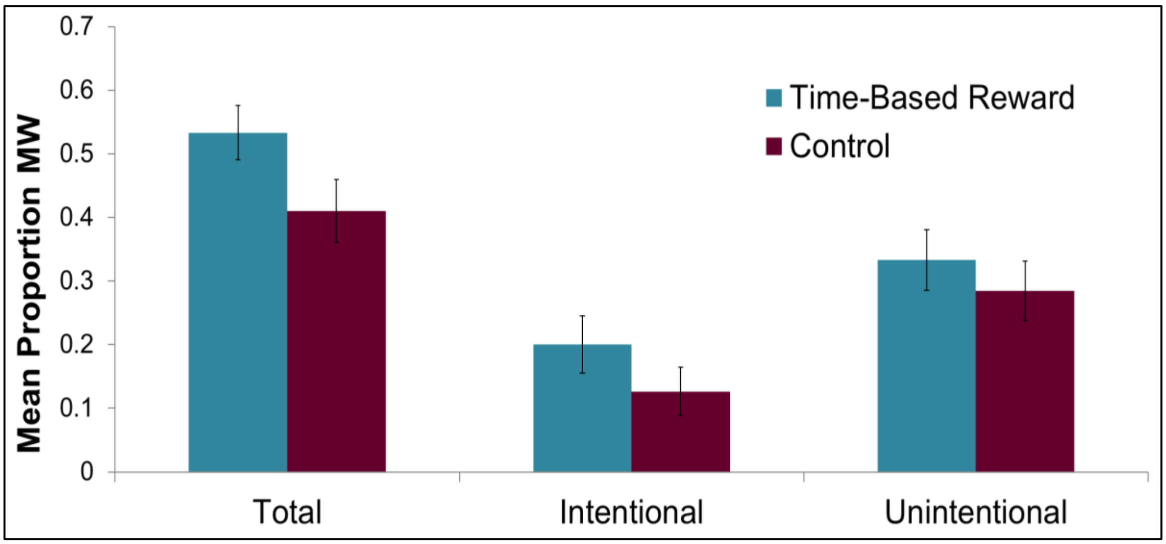

Figure 1. Proportion of time spent mind wandering (MW) versus reward condition. More total mind wandering was reported by 'Time-Based Reward' participants than 'Control' participants ($F(1,42) = 3.5$, $p = .067$), and significantly more unintentional mind wandering was reported relative to intentional mind wandering ($F(1,42) = 6.9$, $p = .012$). Error bars represent the standard error of the mean.

Comprehension Data. Comprehension performance was similarly analyzed using a 2x2 mixed factorial ANOVA, with reward condition as a between-subjects factor and question type (recall vs. application) as a within-subjects factor. There was no significant effect of reward condition on comprehension test performance ($F(1,27) = .32$, $p > .1$), nor was there a significant effect of question type or an interaction.

Mind Wandering vs. Comprehension. Comprehension test scores did not correlate with related ($r = -.031$, $p > .1$), unrelated ($r = -.20$, $p > .1$), and unintentional mind wandering ($r = .23$,

$p > .1$). However, there was a marginally significant correlation between comprehension test scores and intentional mind wandering ($r = -.34$, $p = .078$), such that participants eventually performed worse if they reported spending more time intentionally mind wandering.

Discussion

In Experiment 1, reports of intentional mind wandering were not more likely to be classified as content-related. This finding demonstrates a failure to support the hypotheses of researchers such as Wammes, Seli, et al. (2016) who have proposed that intentional mind wandering may reflect a *strategic* attentional shift away from the primary task, which we may expect to be more often content-related. However, Pachai et al. (in prep) and the current experiment have demonstrated a negative correlation between intentional mind wandering reports and subsequent comprehension performance, which one would suspect is indicative of content-unrelated mind wandering. In fact, reports of intentional mind wandering were not significantly correlated to reports of related ($r = .11$, $p > .1$) or unrelated ($r = .01$, $p > .1$) mind wandering.

The null correlations between intention mind wandering reports and related or unrelated mind wandering reports might be the result of two qualitatively different groups that pull the correlation in opposite directions: those who intentionally mind wander as a means to think strategically about their learning and those who intentionally mind wander because they are disinterested. Strategic intentional mind wandering should be more content-related and, thus, benefit comprehension, while disinterested intentional mind wandering should be less content-related and hinder comprehension. If both reasons are present in the group of participants, this may explain the observed null results.

The other primary finding of Experiment 1 was that a time-based reward resulted in more reported mind wandering, whereas we had expected a reduction in mind wandering (e.g., Pachai et al., in prep). The time-based reward was characterized by instructions that the comprehension test consisted of 40-questions, but achieving a minimum standard (70%) on the first 20 questions would allow participants to leave early. This instruction is juxtaposed with the control condition instruction, which outlined that they would be completing a 20-question multiple choice test. This time-based reward negatively affected participants, leading to poorer attention during the lecture. The perceived difficulty may have been too high, pushing people to a non-beneficial level of stress. Consider the Yerkes-Dodson curve (Yerkes & Dodson, 2005), where an intermediate level of arousal maximizes learning; tasks that elicit too little or too much anxiety produce poorer performance. The time-based reward instructions used here may have created undue anxiety, which produced negative affect and increased the amount of mind wandering. Experiment 2 was designed to shed light on this possibility.

EXPERIMENT 2

Rationale

We hypothesize that the time-based reward instructions in Experiment 1 increased stress and negative affect, which, in turn, increased the amount of mind wandering. Some evidence exists supporting the relation between mind wandering and negative mood. For example, depressive symptoms positively correlate with the amount of time an individual mind wanders (Killingsworth & Gilbert, 2010; Smallwood & O’Connor, 2011). Non-depressed individuals reporting negative mood also mind wander more when under stress (Vinski & Watter, 2013). Furthermore, individuals with specific anxiety symptoms, such as obsessive-compulsive disorder

(OCD) symptomology, reported higher rates of unintentional mind wandering, in particular (Seli, Risko, et al., 2017). Together, these data support a link between stress and mind wandering.

In Experiment 2, we examined whether an individual difference could interact with, and thus potentially confound, the effect of reward. To examine this relation, we combined the monetary reward instructions previously used (Pachai et al., in prep) with trait measures of anxiety and negative affect. We returned to the monetary reward because it appears to produce intermediate levels of stress, but should differentially affect individuals with high anxiety or negative affect. Specifically, we predicted that the potential for reward might be particularly important as a protective measure in these participants since they will generally spend more time mind wandering. This effect may be particularly obvious in the unintentional mind wandering reports (Seli, Risko, et al., 2017).

Method

Participants. Participants (N = 95) were recruited using the same psychology undergraduate participant pool and eligibility criteria as Experiment 1. Experiment 2 recruited double the number of participants to accommodate the additional between-subjects factors of anxiety and negative affect. Prior to beginning the experiment, participants provided informed consent. The university's research ethics board approved this study.

Procedure. All participants began by watching the same *Form Perception* video lecture as in Experiment 1. The mind-wandering probes prompted participants to note their current attentional state as 'On-Task', 'Intentionally Mind Wandering', or 'Unintentionally Mind Wandering' with pencil and paper (Wammes, Boucher, et al., 2016). Because the content-related probes did not produce any significant relations with intentionality or comprehension performance, they were not included here.

Upon completing the lecture, participants answered the State Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree, French, MacLeod, & Locke, 2008) and the Positive and Negative Affect Schedule (PANAS; Watson & Clark, 1988). Participants then completed a twenty-question multiple-choice comprehension test consisting of half application and half recall questions. Prior to beginning the video lecture, half of the participants were told that they would earn $0.50 for every multiple-choice question they answered correctly on the post-lecture comprehension test. The other half of the participants received neither this instruction nor the monetary reward. Whether participants received the monetary reward or control condition was determined by random assignment.

Results

This experiment used a factorial design, analyzed using a mixed factor ANOVA. Reward condition (i.e., 'Monetary Reward' or 'Control') was a between-subjects independent factor, such that every participant received only one level of reward. Mind wandering type (i.e., 'Intentional Mind-Wandering' or 'Unintentional Mind-Wandering') was a within-subject dependent factor, such that one participant could report both intentional and unintentional mind wandering. Similarly, comprehension question type was a within-subjects independent factor, such that each participant answered both 'Recall' and 'Application' questions.

Our analyses also included anxiety level (i.e., 'High Anxiety' or 'Low Anxiety') and negative affect (i.e., 'High Negative Affect' or 'Low Negative Affect') as between-subjects factors. To analyze anxiety and negative affect, we ordered participants' responses on the STICSA or PANAS, respectively, from highest to lowest and divided these data into thirds. We labeled participants scoring in the top third as 'High' and those scoring in the bottom third as 'Low'. Thus, anxiety and negative affect levels were a quasi-independent (i.e., non-randomly assigned) variable (see Morgan, Gliner, & Harmon, 2000 for a discussion on quasi-experimental research designs). The relative proportions of mind wandering probe responses and correct answers on comprehension test questions were dependent measures. All statistical comparisons used an alpha level of .05.

Mind Wandering Data. Unintentional mind wandering (M = .25, SD = .19) was reported significantly more often than intentional mind wandering (M = .11, SD = .17; $F(1,69) = 16.89$, $p < .001$). Mind wandering reports were not significantly affected by reward condition ($F(1,69) = .79$, $p > .05$). At this level of analysis, this finding represents a failure to replicate.

Negative Affect. Condition and negative affect level significantly interacted ($F(1, 69) = 5.89$, $p = .018$; see Figure 2). For those with high negative affect, the control condition (M = .54, SD = .22) reported significantly more mind wandering than the reward condition (M = .36, SD = .28) ($t(1,31) = -2.04$, $p = .05$). For those with low negative affect, the reward (M = .35, SD = .21) and control (M=.27, SD = .20) conditions were similar ($t(1,38) = 1.25$, $p > .1$). This finding indicates a protective effect of reward specifically for those with high negative affect.

There was also a significant three-way interaction between condition, mind wandering type, and negative affect level ($F(1,69) = 9.75$, $p = .003$). To examine this effect, we separately analyzed intentional and unintentional mind wandering reports. There was a significant interaction between condition and negative affect level on unintentional mind wandering reports ($F(1,72) = 16.73$, $p < .001$), which we then explored further.

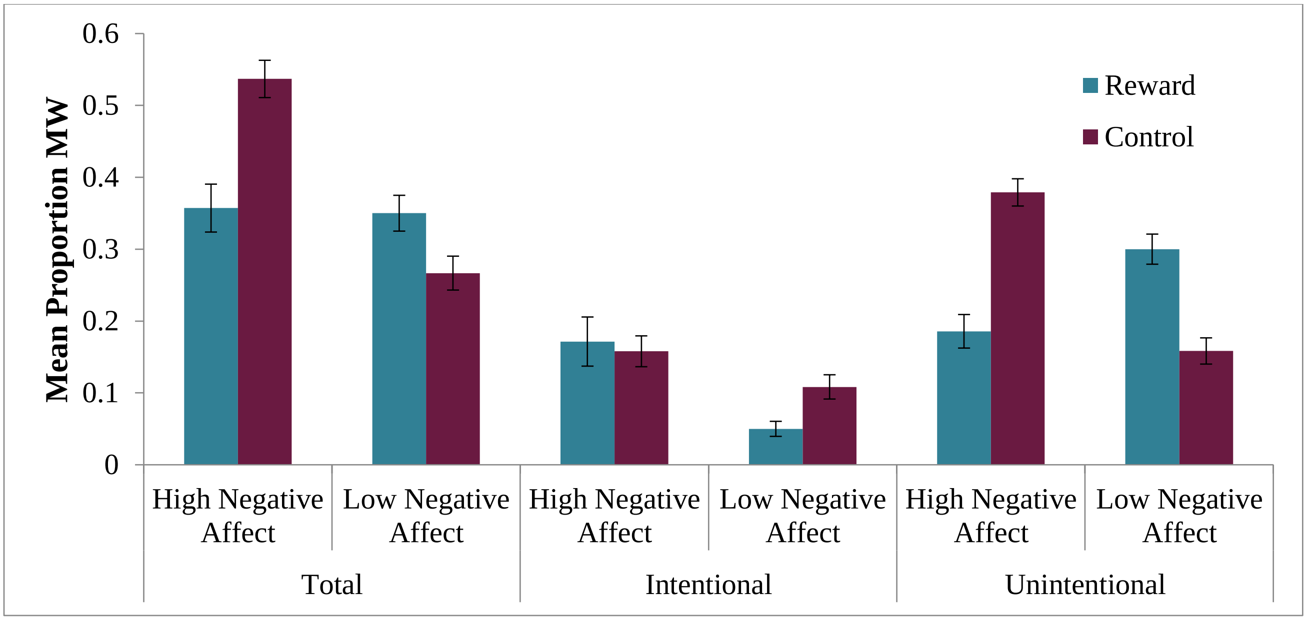

Figure 2. Mean proportion of mind wandering (MW) reports as a function of reward condition and negative affect level (as measured by the PANAS). There was a significant three-way interaction between condition, mind wandering type, and negative affect level (F(1,69) = 9.75, p = .003). Error bars represent the standard error of the mean.

For high negative affect, the control condition reported significantly more unintentional mind wandering (M = .38, SD = .16) than the reward condition (M = .19, SD = .20) (t(1,31) = 3.01, p = .004). For low negative affect, on the other hand, the reward condition reported significantly more unintentional mind wandering (M = .30, SD = .18) than the control condition (M = .16, SD = .16) (t(1,38) = 2.66, p = .012). By contrast, there were no significant main effects of condition or negative affect level on intentional reports, nor a significant interaction.

Anxiety. The interaction between mind wandering type and anxiety level (as measured by the STICSA) approached significance (F(1,61) = 3.33, p = .07; see Figure 3). Because of the *a priori* hypothesis that these factors should interact (Seli, Risko, et al., 2017), we examined this interaction by separating the intentional and unintentional mind wandering reports. The high anxiety group reported more unintentional mind wandering (M = .30, SD = .21) than the low anxiety group (M = .21, SD = .19) (t(1,63) = -1.83, p = .072). However, the low anxiety group reported similar levels of intentional mind wandering (M = .13, SD = .22) to those of the high anxiety group (M = .08, SD = .21) ($t(1,63) = .91$, $p > .1$). This finding is similar to that of Seli, Risko, et al., 2017 wherein a high anxiety group (i.e., people with OCD) reported significantly more unintentional mind wandering than controls. Anxiety level did not exhibit any other significant 2-way or 3-way interactions with condition or mind wandering type.

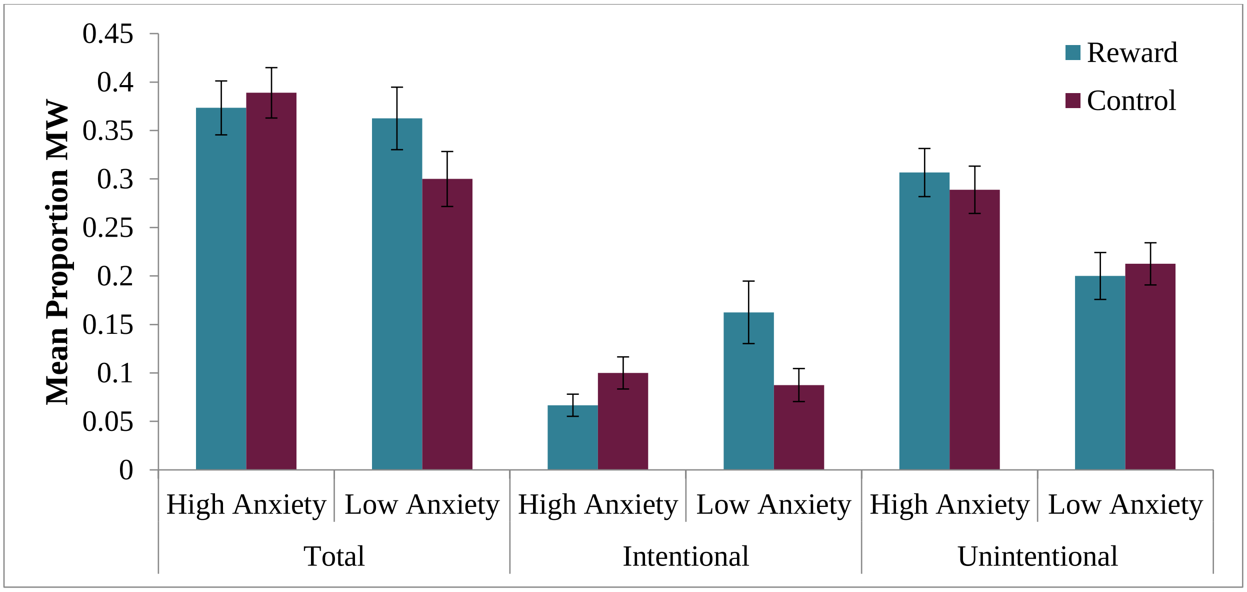

Figure 3. Mean proportion of mind wandering (MW) reports as a function of reward condition and anxiety level (as measured by the STICSA). There was a significant interaction between mind wandering type and anxiety level approached significance ($F(1,61) = 3.33$, $p = .07$). Error bars represent the standard error of the mean.

Comprehension Data. Comprehension performance was similarly analyzed using two 2x2x2 mixed factorial ANOVAs, with reward condition as a between subjects factor, question type (recall vs. application) as a within subjects factor, and either negative affect level or anxiety level (high vs. low) as the final between subjects factor. There were no significant main effects or interactions (all $p > .1$).

Mind Wandering vs. Comprehension. To assess the degree to which mind wandering reports during the lecture were directly related to performance on the subsequent comprehension test, we measured the Pearson's correlation between these factors. Mean proportion of reported mind wandering was negatively correlated with mean comprehension test score (r = -.225, p = .028). This relation was driven by intentional mind wandering (r = -.243, p = .018), but not unintentional mind wandering reports (r = -.067, p > .1). To summarize, participants performed worse when they reported more intentional mind wandering while watching the lecture.

Discussion

In Experiment 2, we divided participants into high and low anxiety, and high and low negative affect to examine how the original monetary reward used in Pachai et al. (in prep) affected mind wandering reports and comprehension performance. Consistent with our hypotheses, those with high negative affect reported more mind wandering overall, while those with high anxiety specifically reported higher levels of unintentional mind wandering. Interestingly, in those with high negative affect, reward protected them from this trend: the rewarded group reported fewer mind wandering bouts than the non-rewarded group. However, reward did not elicit the characteristically lower levels of intentional mind wandering found in previous experiments, which represents a failure to replicate. Because negative affect tends to be associated with more mind wandering overall, the reward instructions appears to have affected both types of mind wandering.

General Discussion

The current experiments aimed to further examine how motivation affects mind wandering during laboratory studies of learning. We targeted two potentially critical factors: type of reward and individual differences. Although Experiment 1 attempted to increase motivation using an alternative reward, it produced an unexpected increase in mind wandering reports. Not all rewards are created equally—labelling a manipulation as a "reward" does not make it so.

Rewards necessarily are defined by their result on behaviour, despite the intention of the time-based manipulation introduced in Experiment 1. Increased anxiety, depressive thinking, and negative affect are demonstrably related to increased reports of mind wandering, so “rewards” that increase stress may have an undesired outcome.

The results of Experiment 2 are consistent with the hypothesis that the increased mind wandering reports in Experiment 1 were due to a shift in the perceived demands of the task that increased stress beyond the optimal range. Experiment 2 demonstrated that participants with high levels of negative affect mind wander more, while those with high levels of anxiety specifically report more unintentional mind wandering. Monetary reward protected those with high negative affect against the large increase in overall mind wandering reports. These data are consistent with the hypothesis that negative affect and anxiety are related to poorer attention. Experiment 2 provides initial evidence for monetary rewards as effective motivators to reduce inattention; however, more research is needed to determine the most effective motivational strategies for these groups. In general, motivators may be particularly important for those at high risk for inattention, such as those with depression or anxiety.

The results of Experiment 1 are not to say that time-based rewards are necessarily ineffective at improving attention in either the general population or high risk groups. The protocol in Experiment 1 may be refined to match better the time-based reward instructions to the control instructions by informing the control condition that their test is also 40 questions in length, but unexpectedly allowing all participants to leave after 20 questions. This may increase the overall levels of mind wandering in both groups due to the increase in perceived task demands and subsequent stress levels, but should not introduce a selective detriment to the reward condition.

Future research may also wish to explore the effect of purposefully inducing negative affect or anxiety rather than using self-report to create quasi-independent factors for analysis. Negative affect can be induced using protocols such as the Velten Mood Induction Procedure, in which participants read either neutral or increasingly negative self-referential statements (Velten, 1968). If these results mirror those found in Experiment 1, it would support the hypothesis that we unintentionally increased anxiety or negative affect in these participants with the time-based reward instructions.

Using probes that explore the contents of mind wandering bouts may further elucidate the relation between task-induced stress and mind wandering. The two-stage probe used in Experiment 1 did not demonstrate a relation between content-related mind wandering and intentional mind wandering or comprehension performance. Previous research has shown some success in examining the contents of mind wandering bouts, however. For example, participants have rated intentional mind wandering as more future-oriented and specific than unintentional mind wandering (Seli, Ralph, et al., 2017). Future research should explore whether mind wandering following the induction of high anxiety or negative affect tends to be related to the anxiety-inducing manipulation.

Broadly speaking, the research conducted here has implications for both research and educational practice. Researchers must strive to bridge the gap between the laboratory and the classroom by introducing ecologically valid materials, such as the lecture and test used here, and creating a motivational context that mirrors an authentic learning environment. This attempt at ecological validity also includes the exploration of anxiety and negative affect, which represent an increasingly prevalent characteristic among students enrolled in higher education (American College Health Association, 2016). To ignore the cognitive and motivational experience of students with high anxiety and negative affect is to ignore a large portion of the student population whom educational research seeks to support.

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Appendix A

Sample Comprehension Questions

Recall Questions

Which of the following is true of visual illusions?

a) The Muller-Lyer Illusion misapplies location constancy, which leads to inaccurate judgments in length.
b) The Ames Room Illusion misapplies shape constancy, as people who are of similar heights appear to be of different shapes and sizes.
c) The Muller-Lyer Illusion misapplies size constancy, which leads to inaccurate judgments in length.
d) The Ames Room Illusion misapplies location constancy, as people are perceived to be stationary when, in fact, they are moving.

How can different types of processing influence perception?

a) Using top-down processing, specific characteristics of a stimulus guide perception.
b) Using top-down processing, our own expectations hinder perception.
c) Using bottom-up processing, the entire stimulus is analyzed instead of specific features.
d) Using bottom-up processing, features from the stimulus are compared to features in memory when processing objects.

Application Questions

Which of the following situations is most likely utilizing the Gestalt principle of proximity?

a) A white wire crossing behind and in front of other wires is likely to be grouped together as being one.
b) One group of Canadian geese flying south is likely to be grouped together as it passes by another group headed north.
c) A group of flowers set beside other flowers is likely to be grouped together.
d) A field of evenly spaced corn stalks is likely to have the row closest to the viewer grouped together.

What perceptual constancy would explain why, when a ball was coming closer to Alisa while playing catch, she did not turn around and run away thinking the ball was getting bigger as it approached her?

a) Location Constancy
b) Shape Constancy
c) Size Constancy
d) Brightness Constancy

CHAPTER 5

GENERAL DISCUSSION

The current thesis explored the impact of motivation and mind wandering on learning. This research specifically focused on the question of which interventions increase motivation to reduce mind wandering and promote learning. We examined three motivational manipulations: quizzing, monetary rewards, and time-based rewards.

Summary of Data Chapters

To assess classroom learning, Chapter 2 introduced quizzing as a motivational intervention in a large introductory psychology course. Quizzing reduced mind wandering reports regardless of whether questions were interpolated throughout the lecture or presented together at the end. Reports of both intentional and unintentional mind wandering predicted performance on quiz questions; intentional mind wandering also maintained a significant effect on weekly test performance that followed the lecture. Instructional interventions like quizzing can increase motivation, and support classroom learning in the short- and medium-term. There was no evidence of a significant effect on long-term learning as measured by final exam performance. This chapter served as a foundation for the laboratory research conducted in Chapters 3 and 4.

Chapter 3 described two experiments that addressed whether performance-contingent monetary rewards reduce intentional and unintentional mind wandering to promote learning, and if these effects remain when the contingency between performance and reward is no longer valid. The goal of this chapter was to bridge the gap between the motivation of grades naturally present in a classroom setting and the lack of motivators used in a typical laboratory setting. The key findings of this chapter were that performance-contingent monetary rewards specifically reduced intentional mind wandering, but yielded no direct effect on comprehension performance. However, mind wandering reports were negatively correlated with comprehension performance—an effect specifically driven by reports of intentional mind wandering. In a second session, as part of Experiment 2 in Chapter 3, when participants were asked to view a new video lecture and complete a comprehension test, but were informed that there would be no performance-contingent monetary rewards, intentional mind wandering remained lower than the reports of control participants. Performance-contingent monetary rewards specifically reduced intentional mind wandering, which was negatively correlated with comprehension. Based on the results of Experiment 2 of this chapter, this effect is durable in the short-term even when the rewards are removed, which has important implications for the use of rewards in classroom settings.

Chapter 4 examined performance-contingent time-based rewards as a substitute for monetary rewards. For the time-based reward instructions, participants were told they could leave early if they achieved a certain level of performance on the first half of their comprehension test. Experiment 1 of this chapter further explored whether intentional and unintentional mind wandering reports differed in whether their contents were related to the presented lecture. We observed no clear relation between intentionality and content-relatedness. In fact, we observed a negative correlation between intentional mind wandering reports and comprehension performance, indicating that intentional mind wandering, in particular, was detrimental to learning. Although we predicted that the time-based rewards would produce a similar reduction in intentional mind wandering as monetary rewards, these rewards actually *increased* mind wandering reports overall. These results may have been driven by reward increased stress or negative affect, which resulted in increased mind wandering.

Experiment 2 of this chapter directly examined the impact of anxiety on performance. We reinstated the performance-contingent monetary rewards used in experiments in Chapter 3 and examined individual differences in anxiety and negative affect. Participants with high negative affect reported more mind wandering overall, which was consistent with our hypotheses; depression and negative mood are associated with more mind wandering (see also Killingsworth & Gilbert, 2010; Smallwood & O'Connor, 2011; Vinski & Watter, 2013). Reward appears to have protected those with high negative affect from the large increase in mind wandering seen without reward. Additionally, those with high anxiety reported higher levels of unintentional mind wandering, which is consistent with the finding that individuals with Obsessive-Compulsive Disorder (OCD) symptomology—a specific anxiety disorder—report more unintentional mind wandering (Seli, Risko, Purdon, & Smilek, 2017). These participants did not exhibit any benefit of reward, however. Increasing anxiety or negative affect—as may have happened with the time-based reward instructions in Experiment 1—increased mind wandering.

There are three primary contributions of this thesis. First, we implemented interpolated testing in a large-scale classroom setting and found that the reduction in mind wandering resulting from quizzing had short- and medium-term effects on learning. Second, we further validated intentionality as important dimension on which to measure mind wandering. Third, we developed a paradigm for more closely matching the motivational contexts of the laboratory and the classroom.

Implications for Mind Wandering

When considering mind wandering reports across all three data chapters, it is notable that the total mind wandering reported in Chapter 2, which took place during course lectures, is approximately 31%. In Chapters 3 and 4, which took place in a laboratory setting, mind wandering was reported on 33% to 54% of all probes, depending on the experimental conditions. The conditions most closely resembling the classroom data were the monetary reward conditions, particularly those with low negative affect and anxiety. This is further evidence for the claim that laboratory experiments require motivators if they are to mimic classroom learning.

Video recorded lectures, like those used in Chapters 3 and 4, have been shown to induce more mind wandering over time than live, in-person lectures (Wammes & Smilek, 2017). This is particularly concerning given the increase in online and blended learning in higher education (Canadian Digital Learning Research Association, 2019). Methods for increasing motivation may be necessary to maintain the integrity of the learning in online courses.

The current thesis validates the importance of intentionality as a dimension on which to define a mind wandering experience (Seli, Risko, Smilek, & Schacter, 2016). Throughout the experiments presented here, intentional and unintentional mind wandering were distinguishable—participants tended to report more unintentional than intentional mind wandering. Had we not separated intentional and unintentional reports, we may not have observed an effect of our motivational manipulations, which often only impacted reports of intentional mind wandering.

Consistently across this thesis, intentional, but not unintentional mind wandering negatively correlated with comprehension performance. Extensive evidence exists that mind wandering interferes with task performance (e.g., Kane & McVay, 2012; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Szpunar, Khan, & Schacter, 2013; Thomson, Seli, Besner, & Smilek, 2014), but most previous research has assumed that the reported mind wandering is unintentional and task-unrelated. The current data suggest that an intentional redirection of attention, possibly due to a lack of interest or engagement, yields a much larger negative effect on learning.

A logical prediction following from this negative correlation might be that intentional mind wandering is often task-unrelated. However, we observed no clear relation between intentionality and content-relatedness in either direction. This may be because some intentional mind wandering is content-related—thinking about previously presented concepts or how these concepts integrate with a larger knowledge base—but other intentional mind wandering bouts are entirely unrelated to the current task. Regardless of the content-relatedness, not attending to the information currently being presented in the lecture was a detriment to participants' comprehension.

Implications for Motivation

The three motivational manipulations used in this thesis represent varying degrees of educational relevance and help bridge the divide between classroom and laboratory research. Chapters 3 and 4 describe a replicable laboratory procedure to mimic classroom motivation more closely. This procedure can be used to further explore how instructional manipulations and students' individual differences affect mind wandering and learning. Chapter 4 began this work by assessing how pre-existing levels of negative mood and anxiety interacted with reward to affect attention and learning. These individual differences are highly prevalent in the university student population, making them an important starting point for this research.

Depression and anxiety are associated with higher levels of reported mind wandering, as demonstrated in Chapter 4 and in previous research (e.g., Seli, Risko, et al., 2017; Smallwood, Fitzgerald, Miles, & Phillips, 2009; Vinski & Watter, 2013). A pathway through which depression and anxiety may affect mind wandering is through motivation. One of the fundamental needs that underlies motivation is competence (Deci, Vallerand, Pelletier, & Ryan, 1991), which will differ between people depending on their perceived or actual ability. Depression and anxiety symptoms often include executive dysfunction, which is characterized by a diminished ability to think, concentrate, or make decisions (American Psychiatric Association, 2013). Executive dysfunction may impact perceived competence, reducing motivation and, consequently, increasing mind wandering. Working memory capacity is another such factor that has been shown to affect "ability", as it affects learning, problem solving, error proneness, and mind wandering (Kane & McVay, 2012). Those students with low working memory capacity may be less able to keep up with the demands of a learning situation, which may reduce their motivation as they are unable to satisfy the competence need outlined by Self-Determination Theory (SDT; Deci & Ryan, 2008). This may exacerbate the already elevated levels of mind wandering that individuals with low working memory capacity report. Perceived competence appears to drive motivation and thus mind wandering, which may be used to explain the findings in Chapter 4 of this thesis.

Motivational theories have also indicated that external rewards undermine intrinsic motivation (Deci, Koestner, & Ryan, 1999); however, Experiment 2 of Chapter 3 provides evidence that this may not apply in all contexts. After being rewarded in session 1, intentional mind wandering reports in session 2 remained lower than the control condition, which indicates that rewards may serve an important role in maintaining attention in the classroom. Considering the extensive demands for time and attention that may students face, explicit rewards are likely a crucial cue about where to focus mental energy.

Implications for Educational Practice

Throughout the current thesis, introducing motivators reduced inattention, which may affect comprehension and learning. Although the monetary and time-based rewards used here did not directly affect comprehension in Chapters 3 and 4, there was a consistent negative correlation between intentional mind wandering and comprehension. This indicates that reducing mind wandering should improve comprehension in general.

Quizzing in lectures, such as the manipulation used in Chapter 2, is one example of a pedagogical change that can improve attention in class across diverse groups of students and topics. Low-stakes testing has been shown to improve learning through reducing mind wandering (Szpunar, Khan, & Schacter, 2013), providing regular feedback (Butler & Marsh, 2013), and increasing cognitive encoding benefits (Agarwal, Bain, & Chamberlain, 2012; Karpicke & Roediger, 2008). Quizzing can be conducted in class using many low-cost tools, making it a powerful pedagogical strategy. Active learning manipulations in general, which can include quizzing, improve engagement and attention (Freeman et al., 2014).

Limitations and Future Directions for Mind Wandering Research

Mind wandering research relies on self-report to quantify these complex dimensions of the mind wandering experience. Caution must always be exercised when exclusively relying on self-report data. In the context of mind wandering, the complexity of the question asked in the probe may affect the validity of the responses. For example, participants may be able to respond confidently to the question, “Were you just mind wandering?” because this “yes” or “no” response relies on the relatively simple judgment of whether they can remember engaging in the external task immediately prior. However, when the mind wandering probe asks participants to introspect on the content of these thoughts or *why* they were mind wandering—through deliberate intention or automatically—participants may be unable to accurately do so. The history of introspective research has shown that participants will often confidently respond to all introspective questions, even if they are unlikely to be basing these reports on their actual mental processes (Kellogg, 1982; Nisbett & Wilson, 1977). To validate reports of mind wandering, we may need alternative methods.

Physiological and behavioural indicators of mind wandering are valuable, alternative tools to measure mind wandering. A number of different markers have been correlated with off-task thought, including alpha power (Braboszcz & Delorme, 2011), default mode network activation (Gruberger, Ben-Simon, Levkovitz, Zangen, & Hendler, 2011), pupil dilation (Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013), and fidgeting (Seli et al., 2014). So far, there is no standard measure that can be used to reliably and validly identify mind wandering episodes as they occur. This will continue to be an important and active area of research, however, as much of the field of mind wandering research, including the current thesis, relies on self-reports of mind wandering.

This thesis only considered self-reports of intentionality and content-relatedness; however, many dimensions have been used to characterize mind wandering that may be equally fruitful to explore in a lecture context. For example, the perceived intrusiveness of mind wandering thoughts (Seli, Ralph, Konishi, Smilek, & Schacter, 2017) may be higher in contexts where performance is highly motivated—any disruption could be seen as more costly. A potentially related dimension is positive/negative valence of the thoughts, such that negative thoughts may be perceived as being more intrusive. Exploring intentionality has served a valuable starting point for understanding the complex human experience of mind wandering, but little is known about how other dimensions interact with intentionality to alter the consequences of mind wandering on performance.

Limitations and Future Directions for Motivation Research

Students derive motivation from their instructor, peers, course structure, interest in the content, personal values, and innumerable other factors. The current research examined three methods of increasing motivation, but each of these relied on extrinsic rewards to varying degrees. The quizzing manipulation in Chapter 2 used bonus points that would eventually count towards grades to create accountability in students, while the monetary and time-based rewards in Chapters 3 and 4 were externally allocated and reinforced. Extrinsic rewards, particularly tangible rewards such as money, undermine intrinsic motivation (Deci, Koestner, & Ryan, 1999). Although the rewards used are consistent with those used in an educational setting, numerous other possible motivators may be more effective and sustainable. For example, manipulations of the course content or lecture structure may tap into intrinsic or internalized motivation, which could improve learning outcomes in the long-term.

One such way to alter the educational setting that should be an avenue for further research is to provide students with the opportunity to self-determine their learning activities, topics of study, or process of tackling a problem. One such example is the increased use of recorded lectures, which allows students to engage in the learning process at their own pace and timing. Not only can students tailor their learning environment to maximize their perceived competence, the act of decision making taps into another SDT basic need: autonomy (Deci et al., 1991). Providing students, particularly those with high anxiety or depression, with the autonomy to make decisions about their learning should increase motivation, which in turn will reduce mind wandering and promote durable learning.

Limitations and Future Directions for Educational Research

The current findings are within the context of undergraduate introductory psychology lecture content, in the classroom and laboratory, but it remains unclear how applicable these manipulations are within other domains: K–12 classrooms, physical education, mathematics, English literature, and more.

More broadly, the structure of our current education system may be detrimental to motivation for lifelong learning and curiosity. The paradigm used in Chapters 3 and 4 show that mimicking the external rewards of grades can improve engagement in the short-term, but the long-term impact remains unclear. Consistently relying on external motivators harms intrinsic motivation (Deci et al., 1999), so it is crucial for the education system to tap into means of increasing students' interest if we are to foster a continued excitement to learn beyond formal education.

Concluding Remarks

Motivation affects attention and, consequently, learning. This framework was the primary focus of the current thesis. We sought to capitalize on this framework by examining which interventions increase motivation to reduce mind wandering and, ultimately, promote learning. The work in this thesis consistently demonstrated an effect of motivation on mind wandering. We observed a negative correlation between mind wandering reports and comprehension performance, but the reductions in mind wandering as a consequence of the motivational manipulations did not translate to statistically significant improvements in learning. In other words, the motivational manipulations used here did not, however, improve learning outcomes.

However, each of the factors manipulated and measured in this thesis—motivation, mind wandering, and learning—is complex in and of itself. Examining their interaction in this thesis required simplification while trying to maintain the integrity of the educational environment. We successfully reduced mind wandering by introducing quizzing in the classroom and performance-contingent monetary rewards in the laboratory as motivators. The time-based reward, in contrast, had the opposite effect on motivation and mind wandering.

The current thesis has applications to educational settings—manipulations to increase motivation, such as retrieval practice or associating rewards with learning activities, can be used to promote learning. However, there is much work remaining to understand how motivation affects mind wandering to promote or impede learning in the long-term, in diverse contexts, with diverse students, or with nuanced definitions of mind wandering. This framework, and the current thesis, provide a foundation for advancing our ability to support student learning.

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