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Mind Wandering and Academic Success: Insight into Student Learning and Engagement

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Mind Wandering and Academic Success: Insight into Student Learning and Engagement

By

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Mind Wandering and Academic Success: Insight into Student Learning and Engagement

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ABSTRACT

Mind wandering may be detrimental to learning and memory. This is especially true for university students, who are often identified as at greater risk for distraction by readily available technology (e.g., laptops, cell phones, smart watches) in learning environments. As mind wandering is a complex construct, it is difficult to capture and quantify. Behavioural and subjective measures used in the past have been criticized for the lack of generalizability from research environments to other settings. The current study investigated mind wandering within the context of learning engagement in university students using functional near-infrared spectroscopy (fNIRS). Mind wandering episodes were inferred from errors made during a measure of sustained attention (SART task) and a real-life analog task (video lecture) with follow-up comprehension questions. fNIRS was used to investigate patterns of brain activation during mind wandering and non-mind wandering episodes. The current study replicated previous findings that default mode network activation increases prior to errors in the SART task. There was no significant difference in brain activation for the video analog task. Finding an objective, reliable measure of mind wandering, particularly one that relates to real-life applications, has relevance for student learning and success. Results from this study may contribute to the development of interventions to reduce mind wandering in learning settings, particularly in large-format lecture classes where one-on-one interactions are less common.

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LIST OF ABBREVIATIONS/SYMBOLS

ARCES = Attention Related Cognitive Errors Scale

BAARS-IV-SCT = Sluggish Cognitive Tempo Measure

dlPFC = dorsal lateral prefrontal cortex

DMN = default mode network

fNIRS = functional near-infrared spectroscopy

fMRI = functional magnetic resonance imaging

GLM = general linear model

HbO = Oxygenated hemoglobin

HbR = deoxygenated hemoglobin

HRF = hemodynamic response function

Trait-MAAS = Mindful Awareness Attention Scale-Trait measure

State-MAAS = Mindful Awareness Attention Scale-State measure

mPFC = medial prefrontal cortex

MW-D = Mind Wandering Deliberate Scale

MW-S = Mind Wandering Spontaneous Scale

PALS = Patterns of Achievement Learning Scale

PSS = Perceived Stress Scale

SART = sustained attention to response task

SCT = sluggish cognitive tempo

CHAPTER 1

INTRODUCTION

1.1 Mind Wandering as a Construct

Mind wandering is extremely common, occurring roughly half of the time spent awake (Christoff et al., 2016). It is generally characterized as a shift in attention from a point of focus to transient thoughts (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012). Shifts in focus may be intentional, may result from an overtaxed cognitive system, or might happen when engaged in a familiar, automatic, or low engagement task (Carriere, Seli, & Smilek, 2013). Carriere and colleagues (2013) describe deliberate mind wandering as purposely allowing thoughts to drift and disengage from the task at hand, analogous to daydreaming.

Much of the extant literature frames mind wandering as a transitional off-focus state, typically considered to be the opposite of focused attention. However, mind wandering is a complex construct that represents various states of consciousness and can manifest in multiple ways (Mittner, Hawkins, Boekel, & Forstmann, 2016). Consequently, the comprehensive measurement of mind wandering is difficult to measure accurately. Thus, one limitation of previous research involves the reduction of mind wandering to a singular process, resulting in investigating only one aspect and often missing other aspects of the complex construct.

Mind wandering may be better represented by the hierarchical model proposed by Mittner and colleagues (2016), whereby episodes occur at varying levels of detachment. This model fits conceptually with the perceptual decoupling hypothesis (discussed further in Section 1.2), with greater detachment (i.e., deeper levels of mind wandering) leading to greater impairments in performance. According to Mittner and colleagues' (2016) model, the levels of mind wandering can be characterized as (1) 'tuning out': partial detachment, which still allows task engagement with little disruption to task performance; (2) 'zoning out': passive engagement in a task, while actively participating in internal thought unrelated to the task; and (3) 'complete detachment', wherein the participant is unresponsive to task-related/external stimuli.

Christoff and colleagues (2016) propose a dynamic framework, whereby mind wandering is characterized as spontaneous thought within a continuum of cognitive constraints. They theorize that thoughts vary by automatic and deliberate constraints which influence the contents of thoughts and how they fluctuate over time. Within this model, spontaneous thought includes dreaming, creative thinking, and mind wandering. At the highest level of deliberate constraint, thoughts are goal oriented. In contrast, thoughts at the highest level of automatic constraint are obsessive or ruminative. According to this framework, mind wandering is defined as free-moving thought attributable to reduced deliberate control.

1.2 The Effects of Mind Wandering

Mind wandering is a normative cognitive experience and has been described as representing both positive (adaptive) and negative (i.e., a failure in self-monitoring of attention) performance. It has been linked to creativity, imagination, and future planning (Schooler et al., 2014). However, research shows that mind wandering has many costs for many people (Mooneyham & Schooler, 2013). For instance, several studies indicate that mind wandering can be detrimental to reading comprehension, sustained attention, and working memory (Mooneyham & Schooler, 2013; Smallwood, Fishman, & Schooler, 2007; Risko et al., 2012; Schad, Nuthmann, & Engbert, 2012). In some circumstances, lapses in attention can have even greater deleterious effects (e.g., for pilots flying a plane or for doctors performing surgery).

The perceptual decoupling hypothesis posits that mind wandering is disruptive because it disconnects individuals from their external environments and redirects their attention toward unrelated thoughts or concerns (Mooneyham & Schooler, 2013). Smallwood, Fishman, and Schooler (2007) explain that learning involves the integration of information from the surrounding environment with our own internal representations of the world. Mind wandering hinders this integration, impairing information encoding and the development of a deep understanding of learned material (Smallwood et al., 2007).

Likewise, chronic stress has been shown to impair attentional control (Liston, McEwen, & Casey, 2009). A study by Liston and colleagues (2009) demonstrated that students showed impaired performance on attentional tasks when tested at times when they experienced higher stress. When tested again at times of reduced stress, the same students did not show the same attentional impairments. Another study found that students reported more frequent mind wandering when they were fatigued, anxious, or engaged in unpleasant or boring activities (Szupunar et al., 2013). Together, these findings suggest cyclical effects between inattention and chronic stress. This effect is further supported by evidence linking anxiety and hyperactivation in brain areas associated with mind wandering (i.e., the default mode network; Sood & Jones, 2013).

The literature notes two populations that experience greater instances of mind wandering and are most at risk of experiencing its associated negative effects: individuals diagnosed with attention-deficit/hyperactive disorder (ADHD), and individuals who report higher levels of dysphoria and/or depression (Smallwood et al., 2007). Symptoms of ADHD include hyperactivity, impulsivity, and inattention, all of which are highly correlated with mind wandering (Franklin et al., 2014). Specifically, research shows that individuals with ADHD are more likely to experience spontaneous mind wandering in contrast to deliberate mind wandering (Smallwood et al., 2007).

In this context, deliberate and spontaneous mind wandering are not to be confused with Christoff et al.'s (2016) concepts of spontaneous thought and deliberate constraint. Deliberate mind wandering is considered to be more benign than spontaneous mind wandering, as it is controlled and related to motivation (Seli, Risko, Smilek, & Schacter, 2016). Seli and colleagues (2016) explain that low motivation and high boredom can elicit intentional shifts in attention, whereas spontaneous mind wandering occurs outside of conscious awareness. Thus, the unintentional mind wanderer may not be aware of when the shift in attention began, potentially leading to feelings of frustration and a perceived lack of agency (Seli et al., 2016). Individuals with ADHD frequently experience impairments in academic performance as well as day-to-day activities (Smallwood et al., 2007). It could be that these impairments are a consequence of frequent, spontaneous mind wandering (amongst other factors).

Impairments in functioning relating to inattention are not exclusive to ADHD. Sluggish cognitive tempo (SCT) is a collection of symptoms typically associated with—but usually described as distinct from—ADHD (Becker, Langberg, Luebbe, Dvorsky, & Flannery, 2014). Symptoms are characterized by mental 'fogginess', day-dreaming, slow information processing, and low energy and activity levels (Becker et al., 2014). SCT is of interest because it is associated with inattention and internalizing symptomology, and it contributes to problems in academic functioning regardless of ADHD diagnosis (Becker et al., 2014). Specifically, one study by Becker and colleagues (2014) found that SCT positively predicted anxiety, depression, and academic impairment in students with and without ADHD.

Individuals who exhibit higher levels of depression, dysphoria, and/or negative affect also tend to have more difficulty concentrating and staying on-task (Smallwood et al., 2007). Researchers propose that the causal relation between mood and attention is bi-directional; depressed mood leads to more mind wandering and vice versa (Risko et al., 2012). For instance, rumination is a type of thought that is fixed and negatively valanced–often considered a core feature of depression (Smallwood & Hanna, 2013). It is sometimes thought of as the negative extreme of mind wandering (Christoff et al., 2016). Christoff and colleagues' (2016) proposed that mind wandering is a separate process from rumination because the focus of a ruminative thought is fixed, whereas mind wandering implies that thoughts are free moving. In either case, there appears to be an association between attention and mood. In a study by Brown and Ryan (2003), results demonstrated a relation between mindfulness (present attentiveness) and emotional well-being. Thus, as illustrated, mind wandering has important implications for academic success, particularly in the context of ADHD, anxiety, and depression.

1.3 Measuring Mind Wandering in Previous Research

Previous researchers have measured mind wandering from a number of perspectives, including observations during learning or in the context of research, experience sampling, and self-reports/ratings. Earlier projects have measured mind wandering with a focus on the observable signs of inattention, such as averting gaze, fidgeting, performance, retention, and note taking (Szupunar, Moulton, & Schacter, 2013). Szupunar and colleagues (2013) warned against the use of observational measures, noting that diverting one's gaze away from the speaker does not necessarily indicate inattention. Likewise, a fixed gaze does not necessarily reflect focused attention. In addition, the evidence for note taking as a valid measure of inattention is inconclusive, as taking notes is not necessarily reflective of comprehension or attentiveness. Rather, note taking could reflect automatized behaviour that falls into the first two levels of Mittner and colleague’s (2016) model.

Other studies have attempted to address the shortcomings of observable measures by employing subjective measures of mind wandering. For example, in experience sampling paradigms, participants are instructed to record when mind wandering or inattentional failures occur throughout the day (Szupunar et al., 2013). However, self-report measures of mind wandering may not provide a clear picture of inattentional episodes. Because mind wandering occurs outside of conscious awareness, individuals may not always be aware of when lapses in attention happen (Szupunar et al., 2013). One way in which researchers have side-stepped this limitation is by implementing thought probes. Thought probes are presented to participants incrementally within a period of time (usually during a lecture or via text message). When probed, participants are instructed to rate their attention at that time. Thought probes cannot be administered too often within a particular time-frame, otherwise they would disturb the flow of the lecture or activity (Risko et al., 2012). They may also fail to capture every instance of mind wandering, providing only a general idea of when episodes occur. Thought probes and experience sampling paradigms are examples of measures that reduce mind wandering to the singular construct.

The subjective and observational methods discussed above focus on attention at the state-level. This means that changes in attentional state are evaluated over time (Brown & Ryan, 2003). In addition to state measures of mind wandering, researchers have also investigated trait measures. Trait measures assess an individual’s dispositional characteristics that remain relatively stable throughout the lifespan (Brown & Ryan, 2003). The Mindful Attention Awareness Scale (MAAS), constructed and tested by Brown and Ryan (2003), measures state and trait mindfulness. The State-MAAS assesses perceived awareness in any given moment, whereas the Trait-MAAS evaluates one’s perceived general tendency to be consciously aware or mindful in everyday life. Higher scores on the state scale represent a greater frequency of mind wandering and difficulties staying on task. In contrast, lower scores on the trait scale represent reduced cognizance and a greater propensity to become lost in thought. These scales verify state and trait effects as related, but conceptually distinct—further highlighting each measure's relevance in research.

Neuroimaging has also previously been used to measure off-task states. The locus coeruleus/norepinephrine system may offer a neural correlate to mind wandering, as it is implicated in arousal and vigilance (Mittner et al., 2016). However, measuring locus coeruleus activation using functional magnetic resonance imaging (fMRI) is exceedingly difficult due to its size and location in the pons of the brainstem (Mittner et al., 2016). Evidence indicates a link between pupil dilation and locus coeruleus-norepinephrine activation, with some studies showing an increase in baseline pupil size immediately prior to task errors during mind wandering episodes (Mittner et al., 2016). Thus, pupillometry may provide a viable alternative to research methods implementing fMRI. Although pupillometry may offer an indirect measure of mind wandering because it is related to locus coeruleus activation, it is sensitive to stress and fatigue, which are potential confounds in mind wandering research (Laeng, Sirois, & Gredeback, 2012). Pupillometry is also sensitive to environmental influences and physiological differences, such as ambient light, level of arousal (awake or sleepy), medication, caffeine, nicotine, age, and pregnancy (Köles, 2017).

1.4 Problems with Previous Research

Even with the plethora of measures created to investigate mind wandering, observational and performance-based measures have limited construct validity. In other words, these assessments may not always capture what was intended. Due to contextual and individual differences, observable measures such as averted gaze, fidgeting, and note taking are not definitive signs of mind wandering (Szupunar et al., 2013). These behaviours could be representative of multiple underlying functions. For example, averted gaze could signify social anxiety, information processing/visualization, or cultural practices/norms. There is no way to validate these measures in isolation. A more robust practice would employ multiple methods of data collection (e.g., neuroimaging, self-report measures) in lieu of just one.

Performance and memory are also used as correlates of mind wandering. It is thought that if an individual is paying attention to the information being presented, they would be able to retain and recognize the information (Szupunar et al., 2013). Once again, however, findings are equivocal for the use of retention as a valid measure of mind wandering (Szupunar et al., 2013; Scerbo et al., 1992; Burns, 1985; Thomas, 1972). Poor performance, while not necessarily reflective of attentional failures, can be accounted for by cognitive failures. If a task is too challenging, poor performance may be indicative of difficulties in specific areas of functioning, such as processing speed or working memory. Furthermore, there are many confounds that would interfere with the validity of the above measures. For instance, primacy and recency effects, motivation, and context can muddy the interpretation of performance and retention-related results (Risko et al., 2012; Szupunar et al., 2013). Therefore, caution is warranted when using observable measures to capture mind wandering.

1.5 Attention and Effort

Mind wandering is typically studied in relation to attention, which is defined as the ability to orient oneself towards and focus one's awareness on specific stimuli in the environment (Glass, 2016). This process can be conscious or unconscious, meaning that it is within or outside of our awareness. Unconscious processes are thought to be behaviours that are automatic and effortless, requiring little to no focused attention (Kolb & Whishaw, 2015). Saling and Phillips (2007) note that unconscious processes can occur following practice or training, whereby actions become automatized. This concept fits with Mittner and colleagues's (2016) first and second levels of mind wandering. When a task requires little cognitive effort and is easy or practiced, the task becomes automatic, allowing one to 'tune out'. The greater the cognitive resources available, the more an individual can daydream or 'zone out' (Risko et al., 2012; Forster & Lavie, 2009).

Automatization can refer to one of two definitions depending on the context. The first definition refers to behaviour that becomes automatic when a task is practiced. In this context, cognitive resources are freed up, reducing cognitive demand, thereby allowing mind wandering to occur. For instance, an experienced driver may 'zone out' when driving from one location to the next because the task requires little to no mental effort. This also fits with perceptual load theory, which posits that distraction is more likely when attentional capacity (i.e., how much information one can processed at any given time) is greater than the cognitive effort required to accomplish a task (Forster & Lavie, 2009). As a result, more cognitive resources are free to process unessential information or allow one's thoughts to wander.

The second definition refers to behaviour that is automatized as a result of mind wandering. In this case, the driver may accidentally drive past their intended destination because they are lost in thought. The latter definition is thought to have more of a negative impact on performance than the former definition (Risko et al., 2012). Automatization in the context of practice effects (the first definition) occurs due to repetitive and consistent stimuli presentation and response mapping (Risko et al., 2012). The individual can still complete the task because it requires less cognitive effort. In the case of the second definition, the individual may have difficulty completing the task because automatization is incompatible with the task goal or the amount of effort required.

Certain tasks, such as taking notes in a lecture or studying, require greater amounts of attention than others, and thus, are not automatic. These conscious processes are effortful and can require prolonged, unwavering attention. Sustaining one's attention for too long can lead to fatigue and cause an individual to 'tune out'. Attention is resource-dependent (Risko et al., 2012). The more difficult a task, the more cognitive resources are needed to process information (Forster & Lavie, 2009). When a task is too difficult, an individual may deliberately mind wander to cope with frustration or boredom. Risko and colleagues (2012) reason that if sustained attention during a task drains cognitive resources, the probability that attentional control will fail also increases. Likewise, if motivation is high, the individual may try to engage in the task, but consistently experience spontaneous mind wandering if the task is too long or demanding. The vigilance decrement, described by Mackworth (1948), exemplifies this—performance declines over time when prolonged attention is required. The relation between effortful attention and mind wandering is clear, further demonstrating the relevance of this research in the context of education.

1.6 Neural Correlates of Mind Wandering and Attention

The default mode network (DMN) is a neural network associated with autobiographical planning, introspective thought, and mind wandering (Mittner, Hawkins, Boekel, & Forstmann, 2016). This network is known as the 'default' because it is what the brain defaults to when not otherwise engaged in a task (Sood & Jones, 2013). The DMN is comprised of the medial prefrontal cortex (mPFC), posterior cingulate cortex, the precuneus, and the angular gyri. Several researchers have replicated previous findings that DMN activation is greater during mind wandering episodes and corresponds to attention-related errors (Durantin et al., 2015; Harrivel, Weissman, Noll, & Peltier, 2013). Studies involving fNIRS and fMRI have revealed that increases in DMN activation occur shortly prior to errors associated with lapses in attention (Durantin et al., 2015; Harrivel et al., 2013; Weissman, Roberts, Visscher, & Woldorff, 2006).

Activation of the DMN has been demonstrated to be inversely related to activation in attentional and task-related neural networks (Zhou et al., 2018). In other words, increased activity in either network (attentional or DMN) attenuates activity in the other network. Attentional networks include the dorsal attentional network and the salience network. The dorsal attentional network includes the middle frontal gyrus, frontal eye field, and superior parietal lobule (Mittner et al., 2016). These regions are associated with working memory and directed attention. The salience network comprises the anterior cingulate cortex, supplementary motor cortex, and anterior insular cortex, and is also implicated in attentional processes (Kolb & Whishaw, 2015). Zhou and colleagues (2018) suggested that the salience network plays a role in task-switching, and consequently the shifting between neural networks. The dorsal lateral prefrontal cortex (dlPFC) has been implicated in various processes related to cognitive control and goal-directed behaviour (Christoff et al., 2016; Spechler et al., 2016; Brosnan & Wiegand, 2017). The dlPFC is part of a larger neural network (the frontoparietal control network) that is connected to the dorsal attentional, salience, and default mode networks (Christoff et al., 2016; Dixon et al., 2018). Using fMRI, Dixon and colleagues (2018) have demonstrated that the frontoparietal control network is involved with regulating attentional processes—by directing attention inwards or outwards. In addition, the dlPFC is located in the neocortex, making it an accessible brain region for study using functional infrared spectroscopy (see Section 1.7 for more details on spatial resolution).

1.7 Functional Near-Infrared Spectroscopy (fNIRS) Overview

Functional near-infrared spectroscopy (fNIRS) may offer a viable solution to the limitations inherent in previously used measures of mind wandering. fNIRS is a safe, non-invasive, and relatively inexpensive imaging device. The device uses the same theoretical framework of fMRI in that inferences about neural activation can be made by measuring the hemodynamic response (Bakker, Smith, Ainslie, & Smith, 2012). Specifically, the fNIRS uses near-infrared light to detect in-vivo changes in oxygen in blood cells (oxygenated hemoglobin) in the brain. One advantage of fNIRS is that the device can measure both oxygenated (oxygen saturated) and deoxygenated (no oxygen bound to the molecule) hemoglobin, whereas fMRI is limited to paramagnetic deoxygenated hemoglobin (Fantini, 2014). The added dimension of oxygenated hemoglobin provides a clearer picture of the mechanisms behind the hemodynamic response (Cui, Bray, Bryant, Glover, & Reiss, 2011).

Heeger and Ress (2002) explained that the hemodynamic model proposes that increased brain activation requires more glucose to function, thus drawing more oxygen to a brain region in order to satisfy metabolic demands. This triggers an increase in cerebral blood flow, which brings oxygenated hemoglobin (HbO) to the area. As the HbO is consumed to sustain neural activation, deoxygenated hemoglobin (HbR) concentration initially increases, while oxygenated hemoglobin decreases. The increased cerebral blood flow is proportionate to the glucose consumption. However, it overcompensates for the oxygen supply by drawing more oxygenated hemoglobin than can be metabolized. At the same time, the increased blood flow causes vasodilation of veins, resulting in greater deoxygenated blood volume. This process, known as the hemodynamic response, evolves over a 20-30 second period (Gratton, 2017). The response features a 6-11 second delay after stimulus onset (Boecker, Buecheler, Schroeter, & Gauggel, 2007).

fMRI is considered to be the gold standard of functional neuroimaging. However, it is expensive, and incompatible with biomedical implants that contain conductive metals (e.g., metal pins or screws in bones, pacemakers, cochlear implants; Sammet, 2016). Sammet (2016) outlined the potential health risks associated with fMRI, which include hearing loss due to the loud volume of the machine (from repeated exposure), tissue and implant heating due to radiofrequency field and magnetic field gradients, and damage due to ferromagnetic projectiles being pulled towards the scanner. fNIRS is safe to use repeatedly on the same individual. Fibre optic cables allow near-infrared light to penetrate through skin and skull into cerebral tissue (Bakker et al., 2012). Depending on the properties of the light and the chromophores (i.e., the light-absorbing molecules; Bakker et al., 2012) in the tissue, light is scattered, reflected, or absorbed. Oxygenated and deoxygenated hemoglobin optimally absorb light at specific wavelengths unique to each chromophore. Wavelengths of light between 650 and 905 nanometers (nm) are most optimally absorbed by HbO and HbR, producing an optical window (ISS Medical, 2016). Any remaining light not absorbed or scattered is reflected into and recorded by the detectors. Using the light data with the Beer-Lambert Law (a mathematical equation), it is possible to calculate the concentration changes of a chromophore within tissue (see Bakker et al., 2012, for an in-depth explanation of the Beer-Lambert Law).

Each light source is paired with a detector. The light-detector pair is called an optode. The depth of optical signal depends on the distance between the source and detector (Bakker et al., 2012). The path length between source and detector is typically between 3-5 cm, allowing for a spatial resolution of approximately 1-1.5 cm deep. Of course, this limits data collection to the neocortex or outer layer of the cerebral cortex (Quaresima et al., 2011). In addition, fNIRS signals feature a smaller signal-to-noise ratio than fMRI, meaning that there is more noise in the signal relative to fMRI (Cui et al., 2011).

Despite its limitations, fNIRS offers many advantages. It is relatively robust to movement artifacts, unlike electroencephalography and fMRI (Bakker et al., 2012). It is also robust to electromagnetic interference and has better temporal resolution than fMRI (Bakker et al., 2012). Cui and colleagues (2011) replicated findings that fNIRS signals were highly correlated with fMRI data. This further supports the use of fNIRS as a valuable neuroimaging device.

CHAPTER 2

RATIONALE

As evidenced by the limitations of subjective, behavioural, and imaging measures, mind wandering is difficult to quantify and assess. Therefore, there is a need for an objective measure of task-unrelated thought. fNIRS may offer such an option, and a plethora of research has used the device to investigate attentional states. A study by Durantin and colleagues (2015) attempted to measure mind wandering specifically; however, a major limitation of that study was the omission of neural correlates of attentional networks due to technical difficulties. Thus, crucial information was missing from their analysis.

There is empirical support to suggest that mind wandering is of particular concern in educational and academic settings (Szupunar et al., 2013). Attention is crucial to learning. Students must engage with the demands of the academic environment in order to encode, retain, and recall information. Yet, measurement of mind wandering in a typical learning environment would likely disrupt the learning process. Therefore, a video lecture may replicate the demands of the educational setting within a lab environment (Szupunar et al., 2013). Similar to the course context, participants would complete a quiz based on the video lecture. Incorrect answers could then be compared to neural activation at the corresponding time point in the video to identify whether task errors are proceeded by DMN activation (Weissman et al., 2006). Comparison between brain activation and task responses could be used to classify attentional states (see Figure 1). A computerized go/no-go task could also be used to facilitate attention-related errors. The video lecture task and the computerized go/no-go tasks could be used to capture different manifestations of mind wandering and in conjunction with the fNIRS to compare brain activation during task errors. A self-evaluation measure could be used to capture participants' perception of their ability to attend to the lecture. This would assess meta-awareness of off-focus states, which is a skill that Smallwood, Fishman, and Schooler (2007) purport is integral to learning success. The self-evaluation measure could also be used to help rule out potential confounds that might influence quiz responses.

In addition to the two attention tasks, participants completed several self-report measures. These measures included demographic information, measures of state and trait mindful attention awareness, the frequency of deliberate and spontaneous mind wandering, a measure of sluggish cognitive tempo, frequency of attention-related cognitive errors, a measure of learning orientation, and ratings of perceived stress in daily life. These measures were used for correlational and prediction purposes. A task feedback questionnaire was used to control for confounds such as discomfort from the fNIRS headband or fatigue during the task.

Figure 1. Experimental Research Design

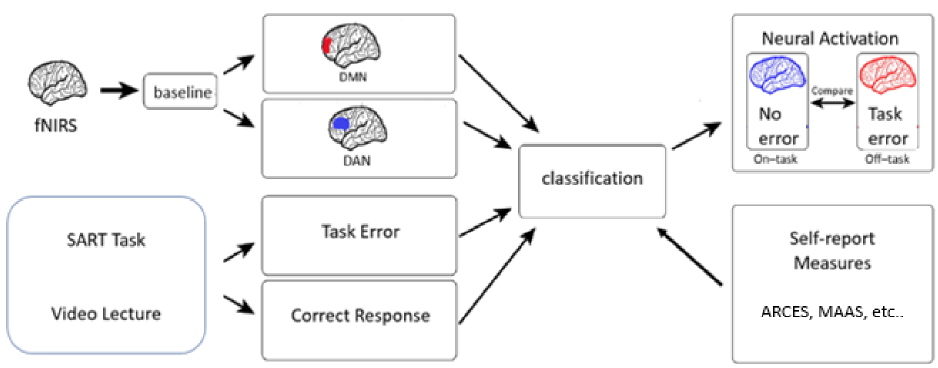

Figure 1. Brain activation data was collected while participants complete the two attentional tasks. Neural activation corresponding to task responses (e.g., error or correct response) were classified into on-task or off-task states. Self-report measures were used for prediction. DMN = default mode network; DAN = dorsal attentional network; ARCES = attention-related cognitive errors scale; MAAS = mindful attention awareness scale.

2.1 Research Questions and Hypotheses

For the purposes of this study, mind wandering was defined as off-task or task-unrelated thought and is functionally operationalized as activity in the mPFC (Mittner et al., 2016; Mason et al., 2007). Although the mPFC is only a subcomponent of the DMN, they are used interchangeably throughout this paper. Behaviourally, the making of task-related errors can represent off-task thought. Focused attention was defined as on-task or task-related thought, and is functionally operationalized as activity in dorsal lateral prefrontal cortex (dlPFC; Mittner et al., 2016; Mason et al., 2007). This can be represented by correct responses on a task. The proposed study sought to answer the following questions: (1) Can fNIRS be used to distinguish between mind wandering and non-mind wandering episodes? (2) What predicts failures in focused attention?

The following hypotheses follow from the above research questions:

(1) fNIRS-measured DMN activation will correspond with errors in both a measure of sustained attention and real-life analog task;

(2) fNIRS-measured dlPFC activation will be negatively correlated with errors made during both tasks;

(3) fNIRS-measured DMN activation will be inversely related to fNIRS-measured dlPFC activation;

(4) Higher scores from measures of SCT will predict greater fNIRS-measured DMN activation, and errors in the real-life analog task.

(5) Higher scores from measures of spontaneous mind wandering will predict more greater fNIRS-measured DMN activation, and errors in the real-life analog task.

CHAPTER 3

METHODS

3.1 Participants

Following ethics approval from the University of Windsor's Research Ethics Board, participants were recruited from the Psychology Department's participant pool. Running a power analysis for a neuroimaging paradigm is complicated and not always appropriate because of the vast number of correlated voxels (Hayasaka, Peiffer, Hugenschmidt, & Laurienti, 2007). Thus, sample size was determined based on neuroimaging literature rather than a computed power analysis. Pajula and Tohka (2016) recommend a minimum of 20-30 participants for group level analysis of fMRI data. For best results and optimal reliability, they suggest using a sample of 30 or more people. As fNIRS uses the same theoretical framework as fMRI, these guidelines have been used in fNIRS research. Due to scheduling and recruitment problems with the university's participant pool and limited time for data collection, only 17 participants were recruited.

Given that all testing is done in English, participants were required to be fluent in English. Undergraduates (age 18-25 years) were recruited in an effort to reduce error related to other risk factors and variables associated with inattention. Students who participated had a mean age was 20.75 (SD = 1.34) and an average GPA of 3.26 (out of 4.0). The majority of participants were employed part-time (62.5%) with the remaining being unemployed (37.5%). At the time of testing, most students reported feeling rested (62.5%). Students who reported a history of traumatic brain injury (operationalized as an injury involving that head that included loss of consciousness or required academic accommodations for at least one month) or have been diagnosed with a neurological disorder impacting cognition, attention, or motor skills (e.g., ADHD, Parkinson's disease) were excluded from participation.

Due to the influence on heart rate, participants were asked to refrain from smoking cigarettes and/or marijuana as well as consuming caffeinated and/or alcoholic beverages for eight hours prior to testing sessions, which is a standard practice in fNIRS studies (e.g., Diukova et al., 2012; Weyand & Chau, 2015). Similarly, they were also asked to avoid vigorous exercise given its effect on blood flow (Herold, Wiegel, Scholkmann, & Muller, 2018). In addition to having acute effects on cerebral blood flow, caffeine withdrawal can also impact blood flow (Joris, Mensink, Adam, & Liu, 2018). The same applies to alcohol and nicotine. Thus, an abstinence period of eight hours was chosen to mediate between the effects of acute use and withdrawal of a substance (caffeine, alcohol, etc.) on cerebral blood flow. Participants were also instructed to not wear any type of foundation or concealer makeup that would distort the fNIRS data recording.

3.2 fNIRS System and Software

The fNIRS device used in the was data acquisition is a frequency domain system (Imagent, ISS Inc., Champaign, IL). The system features 16-fibre optic cables (light sources) and two detectors, making a total of eight optodes (source-detector pairs) and 16 channels. The light emitted from the fibre optic cables is modulated at a frequency of 110 MHz. Two wavelengths (830nm and 690nm) were used to measure concentration of oxygenated and deoxygenated hemoglobin. The distance between each source and detector pair was set at 3 cm for optimal signal propagation. Two shallow sources were placed 1 cm away from each detector to control for physiological noise. The data from the shallow sources were regressed from the deeper sources using the method described in Gagnon and colleagues (2011).

The fNIRS headband was custom-built from neoprene and fully adjustable with fabric straps (see Figure 2). Probes were held into place with custom designed 3D printed components (see section 3.3 for description) and fastened to the head using a combination of Velcro straps and ladder lock buckles. Headband and probe positioning corresponded to International 10-20 coordinates (see Figure 2, Image b) based on the array design developed by Harrivel, Weissman, Noll, and Peltier (2013). International 10-20 coordinates are typically used for the placement of electroencephalography electrodes and are commonly used across a variety of neuroimaging methods (Lloyd-Fox, Richards, Blasi, Murphy, Elwell, & Johnson, 2014; Herold et al., 2018), including fNIRS. Optode placement was approximated using stretchable elastic bands with 10-20 measurements. Areas of interest were temporarily marked using a charcoal pencil or medical tape. As the fNIRS is not capable of recording deep brain structure activation, brain regions of interest consisted of the cortical components of DMN and dorsal attentional network. Specifically, the mPFC and dlPFC are accessible using the fNIRS device and have both been linked to attentional state. Similar to Harrivel and colleagues' (2013) array, six optodes and two short-signal sources interrogated the regions of interest–with two optodes targeting the mPFC and four optodes targeting the dlPFC. The right hemisphere is thought to be specialized in both directing and sustaining attentional processes (Bartolomeo, 2014; Gitelman et al., 1999). Thus, the array was placed on the right side of the head.

3.3 Probe Design

Each light source pair was fit into a cylindrical probe holder comprised of a rigid plastic material. The depth of the probe could be adjusted to ensure direct contact with the surface of the scalp and fastened into place using small eyeglass screws. Each detector was fitted into a specialized holder that also held the shallow source in place. The probe holders could then be clipped into a flexible housing unit seated in the adjustable headband. Given that hair blocking the signal is a significant problem for data collection, the inside diameter of the unit was designed to be large enough to allow for the easy parting of hair. In addition, the housing was made of a flexible polyurethane material designed to conform to the curvature of the head while maintaining the integrity of the array placement. In other words, the housing does not stretch with the neoprene—preventing any deviations from the standardized distance. This system was designed to maintain consistent distances between optodes, facilitate replicability, and reduce possible added noise, while maximizing the comfort of the headband.

Figure 2. fNIRS Device and Headband

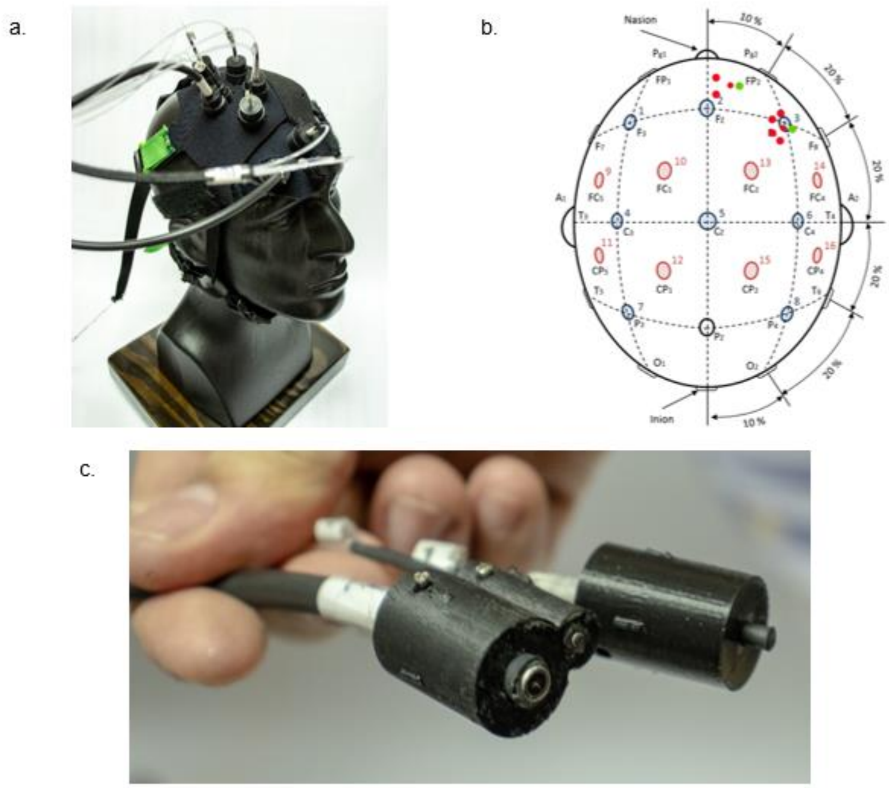

Figure 2. fNIRS headband, array design, and probe holders.
(a) 2.5 mm neoprene headband with adjustable straps designed to house the flexible probe holders firmly in place. (b) *10-20 coordinates for fNIRS optode placement.* Detectors are represented as green dots. Sources are represented as red dots. Deep sources are placed at a distance of 3 cm and shallow sources at a 1 cm distance from their corresponding detectors. *Adapted from* "How to Make Your OpenBCI EEG Headset Comfortable" by Viguix, 2016. Retrieved from http://openbci.com/community/how-to-make-your-openbci-eeg-headset-comfortable-3/ (c) 3D printed probe holders with a detector and short distance source.

3.4 Experimental Procedure

The Sustained Attention to Response Task (SART) is a well-established measure of attentional states and is described below. In addition to the SART task, participants watched a video lecture approximately 20 minutes in length. Both tasks tap into the vigilance decrement (i.e., the tendency for attention and consequently, performance to decrease as a function of time; Risko et al., 2012). In other words, the longer attention is sustained, the greater the frequency of attentional failures. In a classic study, Johnstone and Percival (1976) reported that students in class started showing lapses in attention 10-18 minutes into the lecture, but there have been multiple recent media reports suggesting that the modern attention span is becoming shorter. The purpose of the video lecture was two-fold. It provided a real-life analog task for ecological validity and addressed differences in context. A lecture requires greater attentional demands than engaging in tasks that can be automatized. Lectures require sustained and undivided attention for long periods of time.

All testing took place in the basement of Chrysler Hall South (room 64) on the University of Windsor campus. During fNIRS recording, the room was dimly lit to avoid signal noise from ambient light. Time of day and various confounds, such as participant energy level, was accounted for by a task feedback form completed at the end of the session (see Appendix K for more details). Participants sat approximately 56 cm away from the computer screen so that they could comfortably reach the keyboard. The session began with the experimenter reviewing consent and answering any questions the participant had. Demographic information was collected, and the experimenter ensured that the participant met all inclusion criteria and fulfilled all prerequisites for participation (e.g., no makeup on forehead, no caffeine, etc.). Consent and demographics took approximately 10 minutes.

Next, the experimenter set up the fNIRS headband and turned on the device (approximate time: 10-20 mins). Signal quality was checked and any necessary adjustments were made before continuing on to the tasks. The SART and video lecture were counterbalanced to control for order effects. Completion of both tasks took approximately 30 minutes. Following the video lecture, participants completed a self-evaluation of attention before and after the short answer quiz (~10 mins). Following the two tasks, the fNIRS device was turned off and unhooked (~2 mins). Participants then completed the self-report measures and a task feedback form, designed to account for any environmental confounds that may arise. Completing the questionnaires took approximately 20 minutes. Last, the experimenter debriefed the participant and answered any questions regarding the testing session (~5 mins). The entire data collection session for each participant took approximately 1.5 hours to complete.

3.5 Sustained Attention to Response Task (SART)

The SART is a computerized go/no-go task that is designed to induce lapses in attention. It is simple and repetitive, providing ample opportunity for automation associated with boredom and practice effects. Thus, participants are at increased likelihood of mind wandering. Participants were instructed to press a button whenever a number was presented, with the exception of the target number (3). When presented with the target number, participants were instructed to withhold their response (i.e., not press any button). Because the task is simple, errors are thought to be associated with concentrated attentional failures, in contrast to more difficult tasks where errors would be indicative of cognitive failures.

A review by Smilek, Carriere, and Cheyne (2010) suggested that the SART is an ecologically-valid measure of attention-related errors. In addition, these authors described SART errors as related to DMN activation and individual reports of the tendency to mind wandering. The task was administered using PsychoPy v1.85.6 (Peirce, 2007), an open source software. Participant responses were synchronized to the fNIRS recording using markers and timestamps. Markers were manually triggered by the experimenter at the start and end of the baseline and SART task. During the task, participants are presented with a number (ranging from 1-9) one at a time. Participants are instructed to press the 'space' key whenever they see a non-target number. When presented with the target number 3, they are instructed to withhold their response. The response is considered an

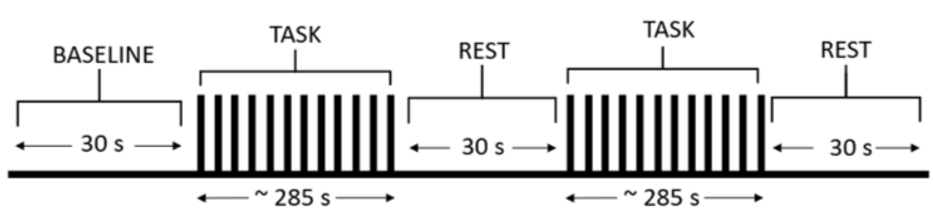

Figure 3. Sustained Attention to Response Task Procedure.
Note. s = seconds. Rest blocks consist of unconstrained thought. Each task block is comprised of approximately 190 trials.

error when the button is pressed for the target (3) number (false-positive) or when it is not pressed for the non-target numbers (false-negative). Only commission errors (false-positives) were considered for analysis. The task is presented on a black background with white lettering to avoid interference from any ambient light emitted from the computer screen. Numbers are approximately 3 cm high, in Arial front, and are presented for 500 milliseconds followed by a visual mask for 1000 milliseconds. Each task block is comprised of 190 trials (a number and mask), with each trial being 1500 milliseconds long. The entire task consists of a 30-second baseline period, two task blocks, and two 30-second rest blocks (see Figure 3). The fNIRS literature recommends that the baseline be between 10 and 30 seconds to attain a sufficient signal-to-noise ratio (Herold et al., 2018). The task was completed in 10 minutes. Brain activation during task blocks can be compared to activation during rest blocks for further analysis. In addition to providing a baseline period, rest blocks are helpful for reducing habituation effects and burnout during repetitive tasks.

3.6 Video Lecture, Self-Evaluation of Attention Measure, and Quiz

The video lecture was designed to capture mind wandering episodes during a task that requires prolonged, focused attention where responses cannot be automatized. The lecture used was The Space Between Self-Esteem and Self Compassion: Kristin Neff at TEDxCentennialParkWomen and was 19-minutes long. Dr. Neff has provided her assent to her lecture being used for this study (K. Neff, personal communication, March 29, 2018). The video link is provided here: https://www.youtube.com/watch?v=IvtZBUSplr4.

The video fits the following criteria:

(1) It is of similar interest level and subject matter to the typical larger course lecture in a university. Specifically, the task was intended to induce some mind wandering episodes, while also generally engaging the attention of the typical psychology student.

(2) The content and language are easily understandable (i.e., not overly complex), so that first year students would not immediately ‘zone out’ or become distracted by competing thoughts. It was thought that providing accessible content and simple quiz questions would reduce the likelihood that errors would occur due to task difficulty.

(3) The content is not contentious and does not elicit a strong emotional reaction. Emotionally valanced subject matter may cause participants to get upset, which would influence heartrate and cerebral blood flow. Because we are not interested in the effects of emotions, it is germane to keep the material as emotionally neutral as possible.

(4) The video was thought to be something that an undergraduate student would not typically choose to watch independently. If participants have familiarity with the material, their responses would reflect knowledge or memory rather than true attentional states.

Participants were informed that they would be watching a video lecture and were not notified about the quiz before watching the video. This was to avoid priming participants to attend more than they would normally. A self-evaluation measure of attention was administered before and after the quiz.

In order to test the hypotheses related to brain activation using fNIRS data, we used brain activation data from the time points related to the comprehension questions with response accuracy coded as correct/incorrect. Weissman and colleagues (2006) noted that mind wandering can be inferred from an increase in DMN activation immediately proceeding task errors. Thus, brain activation occurring 15 seconds prior to the response and 10 seconds after was extracted for analysis.

3.7 Measures

Demographics. Participants filled out a questionnaire regarding demographic information (e.g., age, program of study, etc.). The full questionnaire is in Appendix B. Some questions were included to control for possible confounds, such as the effects of medications on cerebral blood flow or the effects of caffeine or nicotine withdrawal (for heavy users) on performance.

Self-Evaluation of Attention Measure. Questions on this measure included “On a scale of 1-10 (with 1 = not at all and 10 = very well), how well did you think you paid attention to the lecture?” and “How well do you think you paid attention to the lecture now that you have answered those comprehension questions? (On a scale of 1-10)”. This was intended to assess whether participants' meta-awareness of their ability to attend changed after answering questions that directly tested their comprehension. Quiz items were 10 simple, short-answer questions (see Appendix J for full quiz items, answers, and time points) that were designed to assess various forms of attention. For instance, some questions probed more superficial, visual attention (e.g., "What animal was wearing a crown?"). In this case, it does not require much attention to notice the picture of a dog wearing a crown. Other quiz items assessed more focused attention, such as "Name one of the three core components of self-compassion as defined by Kristin Neff." Quiz items corresponded to material presented at specific time points in the video. For instance, acceptable answers for the above question and the corresponding time points are: self-kindness (6:55), common humanity (7:50), and mindfulness (8:55).

Barkley Adult ADHD Rating Scale-IV: Slow Cognitive Tempo Scale (BAARS-IV-SCT). Mind wandering is complex with multiple contributing factors. The SCT measure (see Appendix C) of the BAARS-IV features 9 items on a 4-point Likert scale. Response choices range from never or rarely (1) to very often (4). Respondents were asked to rate their behaviour within the last 6 months. Items include statements such as "I am prone to daydreaming when I should be concentrating on something or working" and "I have trouble staying alert or awake in boring situations". See Table 1 for scale descriptives and alpha coefficients for all measures used in the current study.

The BAARS-IV is shown to be a reliable and valid measure of SCT. The author of the measure reported it had high internal consistency for the Current ADHD Inattention scale (Cronbach's α= .90), which includes the SCT measure, in the normative sample (Barkley, 2011). The SCT scale also had high test-retest reliability (r=.88) when administered over a 2 to 3-week period in the normative sample. Factor analysis demonstrated the scale to have good construct and criterion validity in the normative sample.

Table 1

Descriptive Statistics of Scales and Scale Items

Scale	*N*	*M* (*SD*)	Range	α
MAAS-T	16	52.75 (10.65)	2.88 - 4.29	0.81
MAAS-S	16	13.88 (4.03)	1.88 - 3.13	0.45
BAARS-IV-SCT	16	22.06 (4.65)	1.93 - 2.94	0.76
PSS-10	16	22.38 (4.13)	1.88 - 3.06	0.5
MW-D	16	16.28 (5.55)	3.5 - 4.2	0.84
MW-S	16	17.63 (4.15)	3.69 - 4.81	0.65
PALS	16	33.75 (6.91)	1.7 - 4.38	0.86
ARCES	16	38.25 (5.51)	2 - 3.63	0.73
Quiz	16	0.49 (1.59)	0.13 - 0.75	0.28
Evaluation of Attention	16	12.25 (3.34)	5.81 - 6.44	0.8

Note. N = number of participants; MAAS-T = Mindful Awareness Attention Scale-Trait; MAAS-S = Mindful Awareness Attention Scale-State; BAARS-IV-SCT = Sluggish Cognitive Tempo Measure; PSS-10 = Perceived Stress Scale; MW-D = Mind Wandering Deliberate Scale; MW-S = Mind Wandering Spontaneous Scale; PALS = Patterns of Achievement Learning Scale; ARCES = Attention Related Cognitive Errors Scale.

Attention-Related Cognitive Errors Scale (ARCES). The ARCES is a 12-item questionnaire featured on a 5-point Likert Scale. Responses range from never (1) to very often (5). Scale items include statements such as “I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice)” and “I have absent-mindedly placed things in unintended locations (e.g., putting milk in the pantry or sugar in the fridge)”. The scale was designed by Smilek, Carriere, and Cheyne (2010) to better capture attention-related errors, which could also be used alongside the SART. The paper describing the psychometric properties of the measures reported high internal consistency (Cronbach’s α=.90) and good specificity (Carriere, Seli, & Smilek, 2013). Smilek and colleagues (2010) found support for the ARCES as a conceptually meaningful measure of attentional failures (errors), distinguishable from lapses in attention and general failures in cognition or memory. See Appendix D for scale items.

State- and Trait-Mindful Attention Awareness Scale (MAAS). The State-MAAS is a 5-item scale that assesses current state of consciousness reflective of the core mindfulness values. This scale was modified to be applied to the experimental tasks. In other words, the scores indicate the degree to which participants reported mind wandering during the video lecture and SART task. Compared to the trait measure (discussed below), the state measure may be more influenced by situational factors, such as energy level or the novelty of the experimental setting. Items are presented on a 7-point Likert scale, ranging from not at all (0) to very much (6). The scale includes items such as “I was doing something automatically, without being aware of what I was doing.” The authors of the measure reported that the internal consistency for the State-MAAS is high (Cronbach’s α= .92), supporting the scale as a reliable measure (Brown & Ryan, 2003).

The Trait-MAAS is a 15-item measure that assesses the stable tendency to practice and cultivate conscious awareness and attention in everyday life. This scale was used to control for participants’ baseline tendency to mind wander. The scale is on a 6-point Likert scale, with responses ranging from almost always (1) to almost never (6). Some scale items include statements such as “I break or spill things because of carelessness, not paying attention, or thinking of something else” and “I snack without being aware that I’m eating”. Confirmatory factor analysis indicated that the Trait-MAAS has high internal consistency (Cronbach’s α=.82-.87; Brown & Ryan, 2003) in the normative sample. Previous research with the MAAS scales also demonstrate convergent, discriminant, and construct validity, supporting the use of the scale for the purposes of this study (Brown & Ryan, 2003). See Appendix E and F for full scale. The state and trait measures were meant to account for differences in participants’ tendency to mind wander and current attentional state.

Mind Wandering Deliberate (MW-D) and Spontaneous Scales (MW-S). The MW-D and MW-S scales assess the frequency of intentional and unintentional mind wandering. The scales are comprised of 4 items each. Each item is on a 5-point scale, with most item responses ranging from rarely (1) to a lot (5). Items 3 and 7 feature different response choices, ranging from not at all true (1) to very true (5) and almost never (1) to almost always (5), respectively. The authors of the measure describe the scales as having high internal consistency, with a Cronbach’s alpha of .84 for MW-D and .83 for MW-S (Carriere, Seli, & Smilek, 2013). Scale items include phrases such as “I allow my thoughts to wander on purpose” and “When I mind-wander my thoughts tend to be pulled from topic to topic”. See Appendix G for full scale.

Perceived Stress Scale (PSS). The PSS was used to assess participants' perceptions of daily life stressors over the past month (Appendix H). The inclusion of this scale was meant to control for the effects of stress on attention. The PSS, developed by Cohen, Kamarck, and Mermelstein (1983), is a widely used measure of perceived stress within a community sample. There are several versions of this measure–one with 14 items and the other with 10. The 10-item scale was used for the current study as its psychometric properties are better than its longer counterpart. Participants mark their responses on the 5-point Likert scale, ranging from Never to Very Often. Examples of scale items includes: "In the last month, how often have you felt that things were going your way?" and "how often have you felt nervous and stressed?" In a review of the psychometric properties of the PSS, Lee (2012) reported Cronbach's α greater than .70 for 12 studies included in the metanalysis. Overall, the PSS-10 has been found to have strong internal consistency, structural validity, and hypothesis validity (Lee, 2012).

Patterns of Adaptive Learning Scales (PALS). The Performance-Approach Goal Orientation (Revised) and Mastery Goal Orientation (Revised) subscales, created by Midgley and colleagues (2000), were used to assess students' approach to learning in an academic environment. Adopting a performance-approach goal orientation emphasizes demonstrating competence in an academic setting (Midgley et al., 2000). The focus is on the self and individual performance. In contrast, taking a mastery goal orientation emphasizes developing one's competence and focusing on the task at hand. Different learning orientations may explain how participants attend to the experimental tasks. In addition, assessing participants' goal orientations may help control for the effects of motivation. Specifically, those with a mastery orientation may be more motivated to do their best on the tasks because they are more internally motivated. Responses for these scales are on the 5-point Likert scale, ranging from Not at all true to Very true. Items on the Mastery Goal Orientation subscale include "One of my goals is to master a lot of new skills this year" and "It's important to me that I thoroughly understand my class work". Examples of Performance Orientation subscale items include "One of my goals is to show others that I'm good at my class work" and "One of my goals is to look smart in comparison to the other students in my class." See Appendix I for full scale. Both subscales have been found to have strong internal consistency–with Cronbach's alphas above .85 (Midgley et al., 2000).

Feedback Form. The feedback form was administered at the very end of the session before debriefing. The questionnaire featured 9 items that inquired about the comfort of the headband and the physical state of the participant. Seven of the items were presented on a 5-point Likert scale, with question-specific response choices (see Appendix K). Questions were based off similar feedback questionnaires from other fNIRS studies (Gar Wai Ko, 2008). The purpose of the form was to control for potential experimental or physiological confounds (e.g., headband discomfort, task pacing too fast, fatigue).

CHAPTER 4

RESULTS

4.1 Data Collection and Preprocessing

Data collection was done using the BOXY software provided by ISS Inc. The montage was created using AtlasViewer (Aasted, 2015). All preprocessing of neuroimaging data was completed using Homer2 (Huppert, Diamond, Franceschini, & Boas, 2009), MATLAB, and NIRS-SPM MATLAB scripts (Ye, Tak, Jang, Jung, & Jang, 2009). Light intensity data was converted to hemodynamic data using the optical density and modified Beer-Lambert Law commands available in the Homer2 processing stream (Huppert, Diamond, Franceschini, & Boas, 2009). The hemodynamic signal moves along a temporal continuum and over time, the signal can start to drift. A first-order polynomial drift correction was implemented, as is conventional to eliminate system drift from the fNIRS device (Orihuela-Espina, Leff, James, Darzi, & Yang, 2010).

Noise is major issue for fNIRS data. It can be caused by physiological factors (e.g., cardiac and respiratory oscillations), environmental factors (e.g., electronic devices and ambient light), and experimental factors (e.g., placement of the probes and motion artifacts; Huppert, 2016). Much of this noise can be filtered out using high and lowpass filters, such as heart rate and respiratory oscillations—which tend to occur around 1Hz and 0.3Hz, respectively (Pinti, Scholkmann, Hamilton, Burgess, & Tachtidis, 2019). A bandpass filter of .008Hz to 0.5Hz was used to reduce motion artifacts and physiological noise, while still preserving low frequency signals characteristic of DMN activation (Harrivel et al., 2013, Fox et al., 2007). Slow-wave oscillations (e.g., Mayer waves) can overlap with the hemodynamic response, making them difficult to remove without removing the signal from cortical activity (Tak & Ye, 2014). Leaving Mayer waves in the signal can also inadvertently inflate type-I error (Pinti et al., 2019). Thus, Gagnon et al.'s (2011) method was used to address this issue by regressing out the signal from the short-distance channels. Short-signal separation is becoming a widely used method to remove physiological noise from the cortical signal (Tak & Ye, 2014). These channels pick up signals from superficial layers of tissue (i.e., scalp), which do not reflect neural activation. It is an effective means of reducing signal contamination without compromising the true cortical signal.

4.2 Behavioural Results

Of the 17 participants recruited, 16 completed the entire study due to technical issues, and only 14 had usable fNIRS data (see fNIRS Analysis for details). Roughly half of the participants found the fNIRS headband to be comfortable and very comfortable, while 25% found it to be uncomfortable. Theoretically, an uncomfortable headband could distract participants from the task at hand. When asked if they found the headband distracting, the majority of people said no. Only two participants said they found the headband a bit distracting. Thus, the comfort of the headband was not considered to be a confound. The majority of people reported being somewhat or mostly focused on both the SART (93.8%) and video lecture task (68.8%).

On average, participants perception of their ability to attend to the lecture decreased after completing the quiz. Students reported a mean rating of 6.44 (SD = 1.71) out of 10 before completing the quiz and 5.81 (SD = 1.94) after the quiz. However, this difference was not statistically significant, $t(15) = 1.67$, $p = .12$, $d = 0.35$, suggesting that participants' level of insight did not significantly change after being directly tested on their recall of the information from the lecture.

On average, participants answered 5.38 out of 10 quiz items correctly (SD = 1.59). Out of the 380 SART trials, participants made an average of 56.25 total errors (SD = 34.51), with a mean of 14.12 commission errors (SD = 7.37). Thus, participants completed the task with a 15% total error rate, with 25% of those being commission errors (4% commission error rate).

Paired samples t-test indicated a significant difference in SART reaction time in response to errors compared to correct responses, $t(14) = -7.19$, $p < .001$, $d = 2.05$, with participants tending to respond faster when making errors (M = .29 seconds, SD = .02) compared to when they answered correctly (M =.33, SD = .02). This replicates findings from previous studies which found that faster reaction times often precede SART errors

(Smilek, Carrier, & Cheyne, 2010; Cheyne et al., 2006; Cheyne, et al., 2009; Smallwood et al., 2007).

4.3 fNIRS Analysis

After raw data was preprocessed to reduce motion artifacts, environmental noise, and physiological noise, it was baseline-corrected and normalized. Out of the 16 people that participated, 14 were included in the fNIRS analysis. One participant was excluded from fNIRS analysis due to poor signal quality and another was excluded due to measurement error (i.e., the probes shifted from head movement). Adequate quality signal is considered to have a signal-to-noise ratio equal or greater to 1, meaning that the signal would be equal to/or greater than the level of noise (Hocke, Duszynski, Debert, Dleikan, & Dunn, 2018). In addition, only three of the four optodes interrogating the dlPFC were included for final analysis due to noise.

Feature extraction was conducted to isolate errors and non-errors (i.e., correct responses) made during both tasks. The SART is thought to best capture mind wandering because of its low demands on attention and its highly repetitive nature (Jackson & Balota, 2012). Participants tend to automate their responses, which are exemplified in commission errors. Thus, only commission errors (i.e., false positives) were considered from the SART task because it could not be determined if an omission error (false negative) was due to inattention or slow reaction time. Participants have 500ms to respond with a button press before the task moves onto the next trial. It is more likely that a participant would fail to respond fast enough, rather than failing to press the button altogether. Commission errors are thought to reflect marked task disengagement (Schooler et al., 2014). Thus, they were considered to be the best estimate of inattention-related errors.

Quiz items from the lecture correspond to specific moments in time in the video. Brain activation at those times were then extracted and coded in accordance to participants' responses (correct or incorrect). The same was done for the SART task. Two features (errors and non-errors) were extracted from brain data for each task (SART and Video) and separated by brain region (mPFC and dlPFC). See Figure 4 for the analytical design.

Figure 4. Analytical Design

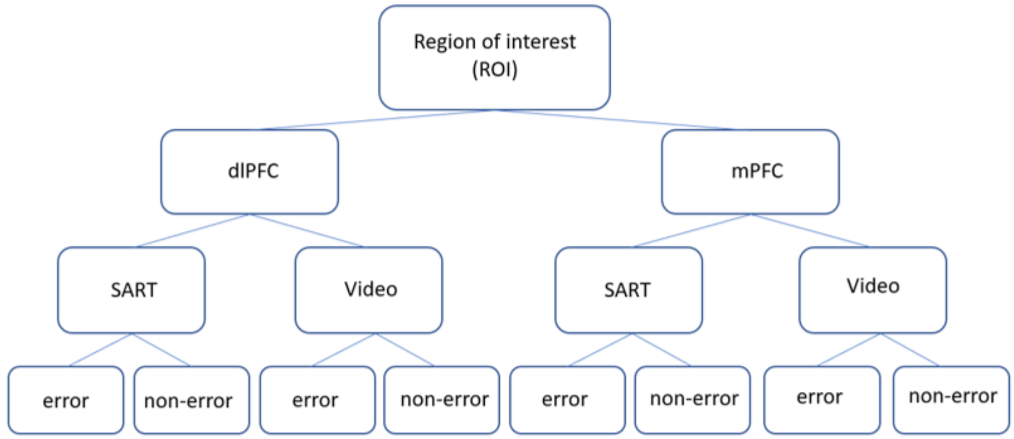

Figure 4. Analysis was conducted as a nested design, whereby brain activation was separated by brain region (ROI), task, and response. ROI = region of interest; DMN = default mode network; and dlPFC = dorsal lateral prefrontal cortex.

Changes in oxygenated hemoglobin (HbO) concentration was segmented into 25-second epochs. Block averages of 30-seconds are quite common in fNIRS research; however, there is no overall consensus regarding the size of the temporal window (Orihuela-Espina et al., 2010). For the purposes of the study, slightly smaller epochs were used in an attempt to reduce noise from overlapping error trials. Given that increases in DMN activation tend to occur shortly before inattention-related errors occur, epochs began 15 seconds before stimulus onset (i.e., when the response was made) and ended 10 seconds post-stimulus (Durantin et al., 2015; Harrivel et al., 2013; Weissman, Roberts, Visscher, & Woldorff, 2006). Once segmented into blocks, HbO data was baseline corrected by subtracting the median value of the first 2 seconds of each block. This was done to normalize the signal and minimize individual differences (Pfeifer, Scholkmann, & Labruyere, 2017). Herold and colleagues (2018) recommend a shorter baseline period (~2s) for event-related designs. Data was averaged across trials, channels, and then participants. Median level changes in the hemodynamic response were chosen for analysis because they are more robust to outliers than mean level changes–especially with smaller sample sizes (Holper et al., 2010). To account for the delay (~4-6 seconds) in the rise of the hemodynamic response, the median change was calculated for the 7 seconds after the start of the block to stimulus onset (Orihuela-Espina et al., 2010; Herold et al., 2018). This was done to calculate the median change after the rise in signal. Given that DMN activation tends to occur before an error, we were more interested in what happens prior to stimulus onset.

Pairwise t-tests indicated a significant difference between mPFC activation for errors and non-errors made on the SART, $t(13)=2.39$, $p = 0.03$, $d = 0.74$. mPFC activation increased before an error compared to a non-error. There was no significant difference in mPFC activation for errors and non-errors made during the video task, $t(13)=-0.72$, $p = 0.94$, d =0.02 . Similarly, there was no significant difference between median level dlPFC activation for errors and non-errors on the SART, $t(13)=-.125$, $p = 0.90$, $d = 0.05$, or the real-life analog task, $t(13)=0.80$, $p = 0.44$, $d = 0.32$.

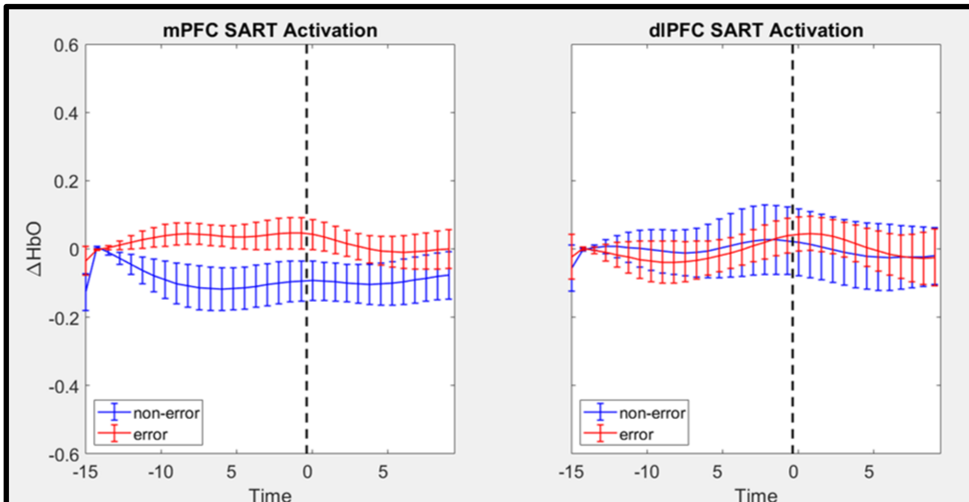

Figure 5. Relative changes in oxygenated hemoglobin (HbO) concentration for the SART task within a 25-second temporal window. The 0 mark represents stimulus onset (when an error or non-error occurs).

Mean level changes in HbO concentration over the 25 second window and standard error of the mean were graphed to visualize potential trends in the data (see Figure 5). Visual inspection of the data indicates the expected trend in mPFC activation for the SART task. mPFC activation is higher prior to error onset compared to activation before a non-error.

Although the difference is quite small, the expected trend is also present in dlPFC activation for the SART task. dlPFC activation is higher before a non-error occurs.

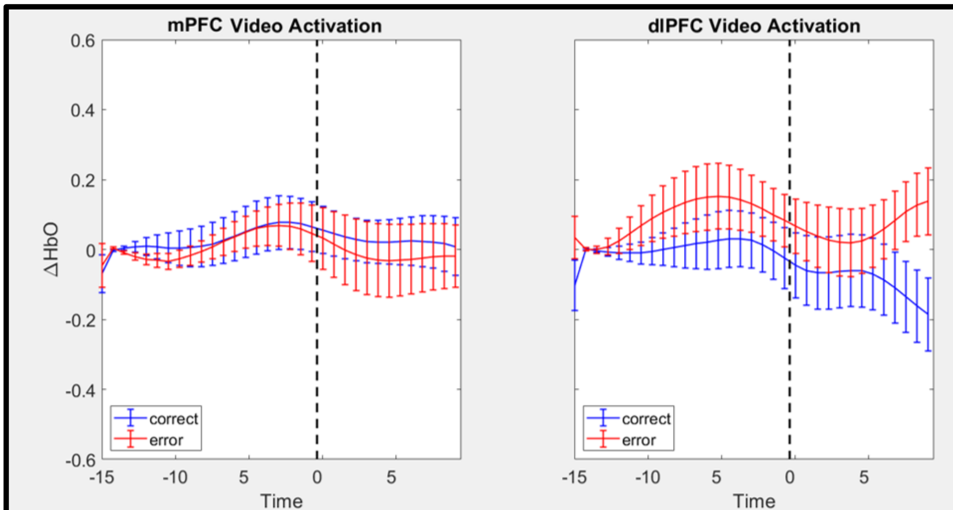

Figure 6. Relative changes in oxygenated hemoglobin concentration for the video analogue task within a 25-second temporal window. The 0 mark represents stimulus onset (when an error or correct response occurs).

Unfortunately, this trend is less clear due to overlapping variability between the two conditions. The results are less clear for the real-life analog task (Figure 6). There is substantial overlap in mPFC activation for errors and correct responses for the video. Interestingly, dlPFC activation for the video shows the opposite of what is expected, with activation being higher prior to errors. Once again, there is significant overlap in variability and differences are small. DMN activation is thought to be negatively correlated with dlPFC activation. Bivariate correlations indicated that only DMN activation during correct responses in the video task was significantly related to dlPFC activation. Contrary to what was hypothesized, activation was positively correlated, (Pearson's r =.72, p = .003), meaning that dlPFC activation increased as DMN increased for correct answers on the video task.

The linear regression model is the most commonly used statistical analysis in fMRI and fNIRS research to analyze the differences in brain activation between different tasks or conditions (Huppert, 2016). The General Linear Model (GLM) is a robust method to work around violations of assumptions (Huppert, 2016). It can be used for specific hypothesis testing and is good for event-related designs (Pinti et al., 2019). It also takes into account the entire time course of the signal and is more statistically powerful than using the average changes over blocks (Pinti et al., 2019). GLM uses the regression equation, $Y = X^*\beta + \varepsilon$, to create and test models for predicting brain activation in response to certain stimuli (Huppert, 2016). The linear model assumes that the hemodynamic response function (HRF) is time invariant, meaning that it follows the same pattern and time course regardless of context. The equation takes into account the experimental design (i.e., the design matrix), the predictors (i.e., regressors) and residual variance (i.e., the error term) to test how well the data fits the model. Contrast vectors can be used to directly test hypotheses about the differences between regressors. The GLM equation can be modified to solve issues of noise and assumption violations. For instance, Huppert (2016) recommends using the autoregressive (AR1) model to reduce serially correlated noise. This step, called pre-whitening, reweights the data and regressors to remove physiological noise. Thus, GLM was determined to be an appropriate method for analysis.

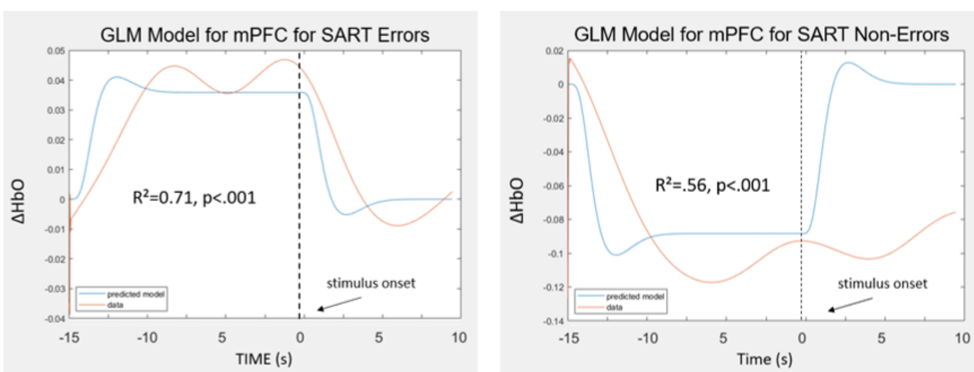

Figure 7. The GLM model for medial prefrontal (mPFC) activation during the SART task. Left: The predicted model for mPFC activation during the SART error condition. Right: The predicted model for mPFC activation during the non-error condition. The 0 mark indicates stimulus onset. The blue line represents the predicted model, while the red line represents the actual data. The Y axis represents relative changes in oxygenated hemoglobin (HbO).

HbO data were down-sampled from 39Hz to 10Hz. A standard boxcar function was convolved with the HRF to create a predicted model of what the data would look like for each condition. Specifically, model 1 predicted that mPFC activation would increase within the 15 seconds before an error occurred, while model 2 predicted a decrease before a non-error. In comparison, model 3 predicted that dlPFC activation would increase within the 15 seconds before a non-error and model 4 predicted a decrease before an error. These predicted models were then compared to the actual data within their respective condition for each task. In Figure 7, the predicted models for mPFC activation during the SART conditions are depicted. All models reached statistical significance, indicating model fit. However, the p-value must be interpreted with caution because the true degrees of freedom are unknown. For models 1 and 2, R^2 coefficients indicated good fit (i.e., that the models explained a good proportion of the variance). Model 1 explained 71% of the variance in mPFC activation during SART errors. Model 2 explained 56% of the variance in mPFC activation during a non-error. Model 3 and 4 indicated good fit, but only accounted for 4% and 12% of the variance in dlPFC activation during the SART. When the same models were applied to HbO data for the video task, only models 1 and 2 were statistically significant. These models explained 15% (for errors) to 51% (for non-errors) of the variance in mPFC activation during the real-life analog task. Overall, it seems that only mPFC activation can be used for reliable prediction.

In addition to GLM, a fixed effects model employing a 1st order autoregressive (AR1) covariance matrix was used to investigate the effects of ROI, task, and response on brain activation. Measures of high sluggish cognitive tempo and spontaneous mind wandering were also added to the initial model. A fixed-effects model is appropriate because it addresses the issue of serially correlated error terms and takes into account that each participant has multiple responses (Seltman, 2018). In addition, individual variability is accounted for by including individual subject differences as a random effect in the model. Variables were only kept in the model if they significantly explained more variance than the previously run model. The final model included only measures of spontaneous mind wandering (MW-S) and sluggish cognitive tempo. This means that for overall median change in HbO concentration, there was no significant main effect of task (SART vs. video), brain region (mPFC vs. dlPFC), and response (error vs. non-error). Only spontaneous mind wandering, $F(1, 34.3) = 7.35$, $p = .01$, and sluggish cognitive tempo,

$F(1, 34.3) = 5.89$, $p = .02$, had a significant effect on overall brain activation. Participants were categorized into groups of high and low spontaneous mind wanderers using the median MW-S score as a cut-off. Using the same method, participants were also categorized into high and low SCT groups. Participants in the high spontaneous mind wandering group indicated less brain activation regardless of brain region, task, and response, $t(34.3) = -2.71$, $p = .01$, 95% CI[-24, -.03]. Those reporting high ratings of sluggish cognitive tempo demonstrated greater overall activation, $t(34.3) = 2.4$, $p = .02$, 95% CI[.02, .23]. Schwartz's Bayesian Criterion (BIC) was the lowest for the last model, indicating it is the most appropriate model for the data.

There was no significant difference in task performance between high and low rated sluggish cognitive tempo groups. Participants who fell into the high spontaneous mind wandering group achieved an average quiz score of 4.71 out of 10 ($SD = 1.43$), while those in the low spontaneous mind wandering group scored an average of 5.9 ($SD = 1.5$). Although the difference is not statistical significance, $F(1, 14) = 2.35$, $p = .15$, $\eta^2 = .14$, it is notable that participants in the lower spontaneous mind wandering group scored roughly 12% higher than the high spontaneous mind wandering group. Bivariate correlations indicated a significant negative association between spontaneous mind wandering scores and quiz performance (Pearson's $r = -.46$, $p = .04$, 1-tailed). Taken together, these findings suggest that a greater tendency to mind wander spontaneously is associated with reduced performance on the video task quiz. There was no effect of spontaneous mind wandering on SART performance, $F(1, 14) = .326$, $p = .572$, $\eta^2 = .01$.

CHAPTER 5

DISCUSSION

The current study investigated the viability of fNIRS as an objective measure of mind wandering and explored predictors of attentional failures. The results partially demonstrated the expected trend in brain activation during mind wandering and non-mind-wandering episodes. The study's hypotheses are reviewed and discussed below.

Hypothesis 1 was partially supported: Imaging data suggest default mode network activation corresponded with errors made in a measure of sustained attention, but this was not replicated in the real-life analog task. The visual trend illustrated in Figure 5 was further corroborated by pairwise t-tests, indicating a statistically significant difference in medial prefrontal cortex activation during errors compared to non-errors. Hypothesis 2, which proposed that imaging data would show dorsolateral prefrontal cortex activation to be negatively correlated with errors made during both tasks, was not supported. Based on visual inspection, it seems that activation during the SART fits this trend. Unfortunately, differences were not enough to reach statistical significance. For the video task, dorsal lateral prefrontal activation was actually the opposite of what was expected—activation was greater prior to an error compared to a correct response. Once again, this trend was not statistically significant. Given that the effects sizes were small to medium, the lack of statistical significance may be related to a power issue. Results from the statistical analyses indicated that our hypothesis-driven predictions about the hemodynamic response to errors fit the actual data. However, this was only true for the default mode network.

Hypothesis 3 proposed that imaging results would show default mode network activation to be inversely related to dorsolateral prefrontal cortex activation. In other words, we expected that activation in the dorsolateral prefrontal cortex would decrease as activity in the default mode network increased. This hypothesis was not supported. Contrary to what was expected, dorsolateral prefrontal cortex activation increased as default mode network activation increased. This association was only statistically significant for correct responses on the video task.

It was hypothesized that higher scores from measures of slow cognitive tempo and spontaneous mind wandering would predict greater default mode network activation, and errors in the real-life analog task. Higher reported ratings of slow cognitive tempo was significantly associated with brain activation overall, but not for default mode network activation or errors specifically. Those with higher ratings of slow cognitive tempo demonstrated greater brain activation regardless of task or response. This may reflect less efficient information processing associated with the mental slowness characteristic of slow cognitive tempo (Fassbender, Krafft, & Schweitzer, 2015). Opposite to what was expected, those with a greater tendency to mind wander spontaneously demonstrated less brain activation overall, regardless of ROI, task, or response. Findings suggested that a greater propensity to spontaneously mind wander was associated with reduced performance on video lecture quiz, but not the SART. This partially supports the hypothesis that greater self-reported spontaneous mind wandering would predict more errors in the real-life analog task.

5.1 Limitations and Future Directions

A major concern that Huppert (2016) noted with fNIRS research is that the data inherently violates many assumptions necessary for linear regression. For instance, independence of observations is violated as the channels and wavelengths are not independent from one another. fNIRS data is on a time series meaning that changes in signal from one timepoint to another are serially correlated. Often, the signals from optodes located within the same region are correlated, potentially contributing to violations of multicollinearity. Additionally, the noise in fNIRS data is heteroscedastic and not normally distributed. Fortunately, as Huppert (2016) explained, homoscedasticity does not necessarily mean the statistical model is inaccurate, but it would certainly lower statistical power and effect size. Statistical power is already a concern because of the study's small sample size. In order to create a reliable prediction equation, Pituch and Stevens (2016) recommend having a sample size of at least 15 to every predictor.

The array and headgear were custom built specifically for the study. Even though they were designed to minimize motion artifacts and environmental noise, such confounds were inevitable. Hair occluding the path between source and detectors may have degraded the quality of the signal. The array was also designed to be fully adjustable and interrogate the same brain regions across different head sizes. Although it is possible to roughly estimate the location of brain activation using participant head size, fiducials, and international 10-20 measurements as a guide, it is not possible to perfectly localize using the fNIRS device. Thus, it should be noted that the study's findings are largely inferential. It is not possible to definitively link mind wandering with changes in the fNIRS data, but it can be inferred in light of behavioural responses to the stimuli. Such inferences are in line with current fNIRS research (Durantin et al., 2015; Harrivel, Weissman, Noll, & Peltier, 2013).

The experimental design employed in the current study may be another limitation. Although fNIRS can be used with event-related designs, it is easier to isolate task conditions using a block design. Similar to work by Durantin and colleagues (2015), the close spacing between SART trials could have complicated the extraction of the hemodynamic signal around features of interest (errors and non-errors). Temporal windows around errors had to be non-overlapping, making it difficult to isolate and extract non-errors. In order to avoid overlap between epochs, we were limited to extracting only fNIRS data occurring around commission errors. Omission errors were not considered for analysis because it was not possible to definitively ascertain that they occurred due to lapses in attention. Given that the trials occur very close together, it is likely that omission errors reflect slow reaction time. If a participant fails to respond within 500ms, the trial times out, moves onto the next, and the response is recorded as an omission error. It is possible that participants could 'zone out' to the point where their reaction time slows; however, research shows that errors are associated with faster reaction times (Cheyne et al., 2006; Cheyne, et al., 2009; Farrin, Hull, Unwin, Wykes, & David, 2003; Smallwood et al., 2007). Our results corroborated this. Participants responded faster before making mistakes. The short SART trials may have actually caused more omission errors related to slow reaction time. Thus, a future direction might involve modifying the SART task to include longer trials and intra-trial intervals.

The SART task was designed to require little-to-no cognitive effort. This was done to capture attention-related errors, rather than cognitive-related errors. However, it is possible that the task failed to substantially activate the dorsal lateral prefrontal cortex because it was too easy. Follow-up of this study may include the addition of a continuous performance or vigilance task. However, these would capture different types of attentional states and activate different brain regions (e.g., those associated with vigilance). The SART is repetitive, meaning that it requires minimal vigilant attention to complete the task (Harrivel et al., 2013).

There were several limitations related to the real-life analog task. Most notably, the results from the quiz could have been confounded by the effects of memory lapses on performance. It would be impossible to design quiz items that fully isolate the effects of attention in the absence of memory processes. Participants must recall information to answer the quiz. It might be possible to reduce memory confounds by including more questions that would be easy to remember as long as participants were paying attention. Mind wandering can activate brain regions involved in memory (Christoff et al., 2016). Consequently, it is crucial that the effects of memory-related errors on task performance be minimized. One way to address this issue may be the inclusion of thought probes throughout the video and the addition of questions that tap into recognition (e.g., multiple choice or forced-choice items).

Another possible limitation of the real-life analog task is that the content of the video may have induced introspective thought among participants. The video is designed to promote self-reflection and as a result, it may inadvertently induce mind wandering and self-referential thought. This is likely not dissimilar from the self-reflection students do in a typical lecture, especially in a psychology class. Theoretically, increases in self-referential thinking would draw attention away from the content of the lecture. These attentional lapses would be reflected in errors on the quiz. Therefore, this limitation appears to be minor.

Due to difficulties with the university participant pool, the current study's sample size was small. Future directions include collecting more data and analyzing other features, including deoxygenated hemoglobin, contrast-to-noise ratios, and changes in slope. Preprocessing the data is labour intensive and as a result, only oxygenated hemoglobin (HbO) data was processed and analyzed for this study. In the future, investigating deoxygenated hemoglobin may provide a more complete picture of the data in relation to the neural correlates of mind wandering.

5.2 Implications

Research on attentional processes and mind wandering has important implications for student learning and success. With technology more readily accessible, distraction is ever-present, increasing the temptation for students to 'tune out' and disengage. Although mind wandering is not inherently negative, it can be detrimental in certain circumstances. Research indicates that mind wandering in educational settings is of particular concern given the attentional demands required for learning. Our results corroborated the association between spontaneous mind wandering and reduced recall performance. The deleterious effect of chronic stress on attention further emphasizes the need for insight that can be gained from research in this area. University is an anxiety-provoking endeavour, even for the highest performing students. If additional stressors exacerbate difficulties concentrating in class, a cycle can be triggered and perpetuated wherein trouble attending leads to greater anxiety and vice versa, ultimately leading to academic failure. Therefore, it is crucial that students learn strategies to focus more effectively and to better deal with stress.

It is also apparent that student engagement is central to learning and retention. Students must be engaged to properly encode and thereby retain information. Further findings may inform lecture formatting and curriculum design to optimize academic engagement and develop interventions to reduce mind wandering. Perceptual load theory would suggest that effective lesson planning involves balancing between making the information accessible yet challenging enough to minimize available cognitive resources for mind wandering. Developing the tools to better identify mind wandering may provide greater understanding of potential barriers to learning and help guide efforts in making education more accessible.

Mind wandering also has important implications for fNIRS research. Given its frequent occurrence and illusive nature, mind wandering may act as a potential confound in experimental research (Herold et al., 2018). Experimental designs with tasks that include long rest periods or allow for behaviour to be automatized may inadvertently induce mind wandering. This is especially problematic for neuroimaging research—as activity due to mind wandering may mask the true processes targeted for study. It is researchers' best interest to control for the effects of attentional lapse as much as possible. Identifying and measuring mind wandering episodes is a major step to accomplishing this.

5.3 Conclusion

The results of this study reaffirm the notion that mind wandering is a complex concept. It can be deliberate or spontaneous, task-related or unrelated, internally or externally oriented, and vary in degree of disengagement. When considering the neural correlates of mind wandering, the default mode network is consistently cited as the main region active during inattention. default mode network activation is not exclusive to mind wandering, but can also reflect the retrieval of memories, future planning, and autobiographical thought (Mittner et al., 2016; Christoff et al., 2016).

Preliminary findings are promising, suggesting that fNIRS can be used to measure mind wandering as functional imaging results line up with analog performance and self-reports. Results further indicate patterns of brain activity can be used to classify mind wandering episodes during the SART task. The expected patterns of neural activation were only apparent in the default mode network, while less clear in the dorsal lateral prefrontal cortex. The dorsal lateral prefrontal cortex is part of several different interconnected neural structures, including the frontoparietal control network (Christoff et al., 2016; Dixon et al., 2018). Thus, activation in this area may reflect a variety of processes other than attention. Further study is necessary to reliably predict correct responses reflective of attention using fNIRS.

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APPENDICES

Appendix A

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Optical Imaging and Attention: Insight into Student Engagement and Learning

You are asked to participate in a research study conducted by Rebecca Nurgitz as part of her master's thesis under the supervision of Dr. Carlin Miller from the Department of Psychology, University of Windsor. If you have any questions or concerns about the research, please feel to contact Rebecca Nurgitz at xxxx@uwindsor.ca or Dr. Miller at (519) 253-3000 ext. XXXX.

PURPOSE OF THE STUDY

The purpose of this study is to collect data on how students engage with different types of content using functional near-infrared spectroscopy (fNIRS). fNIRS is a neuroimaging device that measures brain activity via blood flow in the brain. This device will be used to measure attention during a computerized task and during a video lecture. Finding a reliable measure of attention, particularly one that relates to real-life situations, has significant relevance for student learning and success. Results from this study may contribute to the development of programs to increase student engagement in learning settings, particularly in large-format lecture classes where one-on-one interactions are less common.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

- Read and sign a consent form (5-minutes).
- Provide your background information (age, program of study), academic status, and neurological history (5 minutes).
- Complete tasks that measure a variety of cognitive abilities (attention, memory, reaction time) while wearing the fNIRS headband (30-40 minutes)
- Complete several self-report measures (20-30 minutes).

This study will take place in a small, enclosed lab setting, and last approximately 90-minutes. You will not be contacted for any follow-up sessions related to this study.

POTENTIAL RISKS AND DISCOMFORTS

There are no known risks from participating in this study. On rare occasion people may experience mild emotional discomfort or mental fatigue during some of the tasks, but any negative reactions are expected to be mild and temporary. You will be wearing a neoprene headband that is used to measure brain activation. fNIRS is safe to use, however, the device uses class 2 lasers which can be harmful if mishandled. The researcher has certified training to handle the device and will give you clear, explicit instructions before the device is switched on. To set up the headband, the researchers will have to touch your head and hair. You will be asked to sit as still as possible while wearing the headband. Some people may feel discomfort from the headband or from sitting in one position for an extended period. It is possible that some people may experience mild and transient anxiety, as the testing takes place in a small, dark room. If you feel uncomfortable answering any question or performing any task, you can choose to discontinue that section of the study without penalty. If you feel the need to talk to anyone about your feelings or wish to seek assistance, you will be provided a list of resources you can contact in the letter of explanation, at the end of the study.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

There is no direct benefit to participating in this study. However, the information gained from the overall study may contribute to research around attention and student engagement. You can also learn about optical imaging and attention. When the session is over, the purpose and hypotheses of the study will be described in more detail.

COMPENSATION FOR PARTICIPATION

Participants will receive 1.5 bonus points for 90 minutes of participation towards the psychology participant pool, if registered in the pool and enrolled in one or more eligible courses. In recognition of the effort associated with participation in in-lab research, you will receive an additional 0.5 bonus credits.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission.
You will not put your name or student number on the questionnaires or other study materials. You will be asked to sign only this consent form (if you decide to participate), and it will be filed separately from your data. Data obtained in this study will remain confidential and will only be accessible by the researchers involved in this study. Questionnaires will be linked to a unique ID code only and not to your name. Personally identifying information will be stored in a password-protected file on a password-protected computer and also kept separate from the data collected during the study, which will only be identified by a randomly assigned research ID. As your data will only be linked to an ID code, you will not be able to withdraw your information from the study after you leave the testing session. No personally identifying information will be stored electronically. The study results may be published at a later date, but only in aggregate form. Your data will be kept for five years following the last publication of the data. If the data are not used for subsequent research, they will be destroyed.

PARTICIPATION AND WITHDRAWAL

Participation in this study is voluntary. Your choice of whether or not to participate will not affect your grades or academic status. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. You may also refuse to answer any questions you don't want to answer and still remain in the study. Should you decide to withdraw from the study, compensation will be based on the time spent completing the study. Therefore, you will receive 0.5 points for every 30 minutes of participation. The investigator may withdraw you from this research if circumstances warrant it. You have the option of removing your data from the study until you leave the testing session. If you have any concerns regarding your data from the study, e-mail Rebecca Nurgitz at XXXX@uwindsor.ca. After leaving the test session, you will not be able to withdraw your data as no personally-identifying information will be linked to your responses, and results will be stored anonymously and indefinitely.

ELIGIBILITY

To be eligible for this study, you must be fluent in English, between the aged of 18 and 25 years old, and able to use a mouse and keyboard and sit in a chair for 30-40 minutes. Students who report a history of traumatic brain injury (loss of consciousness or required accommodations for at least one month) or have been diagnosed with a neurological disorder impacting cognition, attention, or motor skills (e.g., ADHD, Parkinson's) will be excluded from participation. Individuals with visual and/or hearing impairments that prevent the completion of tasks required for the testing session will also be excluded.

Prerequisites: Refrain from intensive exercise, smoking cigarettes and/or marijuana, and consuming caffeinated and/or alcoholic beverages for 8 hours before testing sessions. Do not wear makeup on your forehead. Failure to comply will result in partial credit. Compensation will be prorated depending on the time completed in the study (0.5 points for every 30 minutes of participation).

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Research findings will be available to participants online at the University of Windsor's Research Results Summary Website. These findings will be available on October 1st, 2020. Web address: http://scholar.uwindsor.ca/research-result-summaries/

SUBSEQUENT USE OF DATA

These data may be used in subsequent publications and in presentations, without any identifying information.

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time. You may also request to withdraw your data anytime before the end of the testing session. After leaving the test session, you may not be able to withdraw your data as no personally-identifying information will be linked to your responses, and results will be stored anonymously and indefinitely. This study received ethics clearance through the University of Windsor Research Ethics Board. If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study "Optical Imaging and Attention: Insight into Student Engagement and Learning" as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant

______________________________________ ____________________
Signature of Participant Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_____________________________________ ____________________
Signature of Investigator Date

LETTER OF INFORMATION FOR CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Optical Imaging and Attention: Insight into Student Engagement and Learning

You are asked to participate in a research study conducted by Rebecca Nurgitz as part of her master's thesis under the supervision of Dr. Carlin Miller from the Department of Psychology, University of Windsor. If you have any questions or concerns about the research, please feel to contact Rebecca Nurgitz at xxxx@uwindsor.ca or Dr. Miller at xxxx@uwindsor.ca or (519) 253-3000 ext. XXXX.

PURPOSE OF THE STUDY

The purpose of this study is to collect data on how students engage with different types of content using functional near-infrared spectroscopy (fNIRS). fNIRS is a neuroimaging device that measures brain activity via blood flow in the brain. This device will be used to measure attention during a computerized task and during a video lecture. Finding a reliable measure of attention, particularly one that relates to real-life situations, has significant relevance for student learning and success. Results from this study may contribute to the development of programs to increase student engagement in learning settings, particularly in large-format lecture classes where one-on-one interactions are less common.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

- Read and sign a consent form (5 minutes).
- Provide your background information (age, education, and program), academic status, and neurological history (5 minutes).
- Complete tasks that measure a variety of cognitive abilities (attention, memory, reaction time) while wearing the fNIRS headband (30-40 minutes)
- Complete several self-report measures (20-30 minutes).

This study will take place in a small, enclosed lab setting (Chrysler Hall South room XX), and last approximately 90-minutes. You will not be contacted for any follow-up sessions related to this study.

POTENTIAL RISKS AND DISCOMFORTS

There are no known risks from participating in this study. On rare occasion people may experience mild emotional discomfort or mental fatigue during some of the tasks, but any negative reactions are expected to be mild and temporary. You will be wearing a neoprene headband that is used to measure brain activation. fNIRS is safe to use, however, the device uses class 2 lasers which can be harmful if mishandled. The researcher has certified training to handle the device and will give you clear, explicit instructions before the device is switched on. To set up the headband, the researchers will have to touch your head and hair. You will be asked to sit as still as possible while wearing the headband. Some people may feel mild discomfort from the headband or from sitting in one position for an extended period. It is possible that some people may experience mild and transient anxiety, as the testing takes place in a small, dark room. If you feel uncomfortable answering any question or performing any task, you can choose to discontinue that section of the study without penalty. If you feel the need to talk to anyone about your feelings or wish to seek assistance, you will be provided a list of resources you can contact in the letter of explanation, at the end of the study.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

There is no direct benefit to participating in this study. However, the information gained from the overall study may contribute to research around attention and student engagement. You can also learn about optical imaging and attentional processes. When the session is over, the purpose and hypotheses of the study will be described in more detail.

COMPENSATION FOR PARTICIPATION

You will receive 1.5 bonus points for 90 minutes of participation towards the psychology participant pool, if registered in the pool and enrolled in one or more eligible courses. In recognition of the effort associated with participation in in-lab research, you will receive an additional 0.5 bonus credits.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission.

You will not put your name or student number on the questionnaires or other study materials. You will be asked to sign only this consent form (if you decide to participate), and it will be filed separately from your data. Data obtained in this study will remain confidential and will only be accessible by the researchers involved in this study. Questionnaires will be linked to a unique ID code only and not to your name. Personally identifying information will be stored in a password-protected file on a password-protected computer and also kept separate from the data collected during the study, which will only be identified by a randomly assigned research ID. As your data will only be linked to an ID code, you will not be able to withdraw your information from the study after you leave the testing session. No personally identifying information will be stored electronically. The study results may be published at a later date, but only in aggregate form. Your data will be kept for five years following the last publication of the data. If the data are not used for subsequent research, they will be destroyed.

ELIGIBILITY

To be eligible for this study, you must be fluent in English, between the aged of 18 and 25 years old, and able to use a mouse and keyboard and sit in a chair for 30-40 minutes. Students who report a history of traumatic brain injury (loss of consciousness or required accommodations for at least one month) or have been diagnosed with a neurological disorder impacting cognition, attention, or motor skills (e.g., ADHD, Parkinson’s) will be excluded from participating. Individuals with visual and/or hearing impairments that prevent the completion of tasks required for the testing session will also be excluded.

Prerequisites: Refrain from intensive exercise, smoking cigarettes and/or marijuana, and consuming caffeinated and/or alcoholic beverages for 8 hours before testing sessions. Do not wear makeup on your forehead. Failure to comply will result in partial credit. Compensation will be prorated depending on the time completed in the study (0.5 points for every 30 minutes of participation).

PARTICIPATION AND WITHDRAWAL

Participation in this study is voluntary. Your choice of whether or not to participate will not affect your grades or academic status. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. You may also refuse to answer any questions you don’t want to answer and still remain in the study. Should you decide to withdraw from the study, compensation will be based on the time spent completing the study. Therefore, you will receive 0.5 points for every 30 minutes of participation. The investigator may withdraw you from this research if circumstances warrant it. You have the option of removing your data from the study until you leave the testing session. If you have any concerns regarding your data from the study, e-mail Rebecca Nurgitz at xxxx@uwindsor.ca. After leaving the test session, you will not be able to withdraw your data as no personally-identifying information will be linked to your responses, and results will be stored anonymously and indefinitely.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Research findings will be available to participants online at the University of Windsor’s Research Results Summary Website. These findings will be available on October 1st, 2020. Web address: http://scholar.uwindsor.ca/research-result-summaries/

SUBSEQUENT USE OF DATA

These data may be used in subsequent publications and in presentations, without any identifying information.

RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_____________________________________ ____________________

Signature of Investigator Date

Debriefing Form

Optical Imaging and Attention: Insight into Student Engagement and Learning

You have participated in a research study conducted by Rebecca Nurgitz and Dr. Carlin Miller, from the Department of Psychology at University of Windsor, Windsor, Ontario.

Background Information: Mind wandering can be detrimental to learning and memory. This is especially true for university students, who may be at greater risk to be distracted by readily available technology (e.g., laptops, cell phones, smart watches) while in learning environments. As mind wandering is a complex construct, it is difficult to capture and quantify in many research studies.

Purpose of the Study: In this study, we wish to investigate mind wandering within the context of learning engagement in university students using functional near-infrared spectroscopy (fNIRS). Specifically, the study measures the frequency and kind of mind wandering that occurs in response to different kinds of content. This research has real-world relevance because students commonly experience lapses in attention, especially in classroom environments. We are also interested in exploring what factors predict greater instances of mind wandering.

Design of the Study:

Although you were led to believe that we were measuring attention and performance, we were actually interested in mind wandering. We regret this deception, but felt that it was necessary to mask the true nature of the study to maintain the validity of the results.

You were also asked to watch and answer questions about a video lecture while wearing the fNIRS headband. Then you were asked to complete the following measures and tasks:

- computerized sustained attention to response task (with fNIRS headband);
- a measure of perceived stress
- a self-evaluation of attention and effort
- various self-report measures of mind wandering and attitudes towards learning
- a questionnaire on academic behaviours
- some standard demographic questions
- a measure of sluggish cognitive tempo
- a feedback questionnaire

Expected Results:

- We expect to find that higher reports of perceived stress will correspond with greater instances of mind wandering.
- We expect that brain activation in areas associated with mind wandering will correspond to more task errors.

Questions and Concerns:

If completing any of these measurements or participating in this study raises psychological concerns that you would like to discuss, please contact the:
Student Counselling Centre (SCC) located in room 293 CAW Student centre
(519) 253-3000 Ext. 4616, scc@uwindsor.ca

If you have questions about this study or would like to remove your data from the study, please contact one of the below investigators. You may also contact us after October 2020 if you would like to receive a copy of the results from this study.

Rebecca Nurgitz xxxx@uwindsor.ca
Dr. Carlin Miller xxxx@uwindsor.ca or (519) 253-3000 ext. XXXX

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

If you have question about receiving your bonus credit for participation, please contact: Psychpool: psycpool@uwindsor.ca

References for further reading:

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Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology, 26(*2), 234-242. doi:10.1002/acp.1814

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Appendix B.

Demographic Questionnaire

1. Age: 1. Year of study (circle one): 1 2 3 4 other:

3. Program of study (Major):

4. GPA:

5. Handedness (circle one): Right Left

6. Do you currently receive any sort of accomodations or assistance related to focused attention in class?

7. How many times per week do you exercise?

8. At what level do you generally exercise? (Light, moderate, vigorous)

9. Do you drink coffee/caffeinated beverages? If yes, how many cups/day do you usually drink?

10. Do you smoke cigarettes? If yes, how man do you usually smoke/day? Can you refrain from smoking for the next 2 hours?

11. Some people take medication for various reasons (e.g., anxiety, birth control, etc.) that might affect blood pressure. Are you currently taking any of the following medications? Yes or No.

Birth Control Pills	St. John's Wort	Suprane (Deflurane)
Beta-blockers (e.g., propranalol)	Ketamine (tranquilizer)	Meridia (Sibutramine)
Psychostimulants (e.g., Adderall, Ritalin, Vyvanse)	Cortisone	Tegretol (Carbamazepine)
Antidepressants (e.g., Venlafaxine)	Estrogens	Catapres (Clonodine)
Clozaril (Clozapine)	Buspar (Buspirone)	Reglan (Metoclopramide)

12. What is your current state (fatigued, energized, rested, restless)?

13. Are you currently employed? If yes, please indicate whether you work full or part-time.

Appendix C

The Barkley Adult ADHD Rating Scale-IV: Sluggish Cognitive Tempo Scale

BAARS-IV- SCT: Self-Report

Please circle the number next to each item below that best describes your behaviour DURING THE PAST 6 MONTHS.

	Never or rarely	Sometimes	Often	Very Often
1. Prone to daydreaming when I should be concentrating on something or working	1	2	3	4
2. Have trouble staying alert or awake in boring situations	1	2	3	4
3. Easily confused	1	2	3	4
4. Easily bored	1	2	3	4
5. Spacey or "in a fog"	1	2	3	4
6. Lethargic, more tired than others	1	2	3	4
7. Underactive or have less energy than others	1	2	3	4
8. Slow moving	1	2	3	4
9. I don't seem to process information as quickly and accurately as others	1	2	3	4

Appendix D

Attention Related Cognitive Errors Scale (ARCES)

There are 12 Questions. Please answer by circling a number that best describes your experience.

1. I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice).

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

2. I go into a room to do one thing (e.g., brush my teeth) and end up doing something else (e.g., brush my hair).

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

3. I have lost track of a conversation because I zoned out when someone else was talking.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

4. I have absent-mindedly placed things in unintended locations (e.g., putting milk in the pantry or sugar in the fridge).

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

5. I have gone into a room to get something, got distracted, and wondered what I went there for.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

6. I begin one task and get distracted into doing something else.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

7. when reading I find that I have read several paragraphs without being bale to recall what I read.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

8. I make mistakes because I am doing one thing and thinking about another.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

9. I have absent-mindedly mixed up targets of my actions (e.g., pouring or putting something into the wrong container).

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

10. I have to go back to check whether I have done something or not (e.g., turning out lights, locking doors).

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

11. I have absent-mindedly misplaced frequently used objects, such as keys, pens, glasses, etc.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

12. I fail to see what I am looking for even though I am looking right at it.

Never	Rarely	Sometimes	Often	Very often
1	2	3	4	5

Appendix E

The State Mindful Attention Awareness Scale (State-MAAS)

Instructions: Using the 0-6 scale shown, please indicate to what degree were you having each experience described below when you were completing the tasks. Please answer according to what really reflected your experience rather than what you think your experience should have been.

0	1	2	3	4	5	6
not at all			somewhat			very much

______ 1. I was finding it difficult to stay focused on what was happening.
______ 2. I was doing something without paying attention.
______ 3. I was preoccupied with the future or the past.
______ 4. I was doing something automatically, without being aware of what I was doing.
______ 5. I was rushing through something without being really attentive to it.

Appendix F

The Trait Mindful Attention Awareness Scale (Trait-MAAS)

Day-to-Day Experiences

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what *really reflects* your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

I could be experiencing some emotion and not be conscious of it until some time later.	1	2	3	4	5	6
I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6
I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6
I rush through activities without being really attentive to them.	1	2	3	4	5	6
I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	1	2	3	4	5	6
I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6

1 Almost Always	2 Very Frequently	3 Somewhat Frequently	4 Somewhat Infrequently	5 Very Infrequently	6 Almost Never

I drive places on 'automatic pilot' and then wonder why I went there.	1	2	3	4	5	6
I find myself preoccupied with the future or the past.	1	2	3	4	5	6
I find myself doing things without paying attention.	1	2	3	4	5	6
I snack without being aware that I'm eating.	1	2	3	4	5	6

Appendix G

Mind Wandering Deliberate (MW-D) and Spontaneous (MW-S) Scales

For the following statements please select the answer that most accurately reflects your everyday mind wandering.

(MW-D)

1. I allow my thoughts to wander on purpose.

Rarely						A lot
1	2	3	4	5	6	7

2. I enjoy mind-wandering.

Rarely						A lot
1	2	3	4	5	6	7

3. I find mind-wandering is a good way to cope with boredom.

Not at all true						Very true
1	2	3	4	5	6	7

4. I allow myself to get absorbed in pleasant fantasy.

Rarely						A lot
1	2	3	4	5	6	7

(MW-S)

5. I find my thoughts wandering spontaneously.

Rarely						A lot
1	2	3	4	5	6	7

6. When I mind-wander my thoughts tend to be pulled from topic to topic.

Rarely						A lot
1	2	3	4	5	6	7

7. It feels like I don't have control over when my mind wanders.

Almost never						Almost always
1	2	3	4	5	6	7

8. I mind-wander even when I'm supposed to be doing something else.

Rarely						A lot
1	2	3	4	5	6	7

Appendix H

Perceived Stress Scale (PSS)

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Appendix I

Patterns of Adaptive Learning Scales (PALS)

1. It's important to me that other students in my class think I am good at my class work.

1	2	3	4	5
Not at all true		Somewhat true		Very true

2. One of my goals is to show others that I'm good at my class work.

1	2	3	4	5
Not at all true		Somewhat true		Very true

3. One of my goals is to show others that class work is easy for me.

1	2	3	4	5
Not at all true		Somewhat true		Very true

4. One of my goals is to look smart in comparison to the other students in my class.

1	2	3	4	5
Not at all true		Somewhat true		Very true

5. It's important to me that I look smart compared to others in my class.

1	2	3	4	5
Not at all true		Somewhat true		Very true

6. It's important to me that I learn a lot of new concepts this year.

1	2	3	4	5
Not at all true		Somewhat true		Very true

7. One of my goals in class is to learn as much as I can.

1	2	3	4	5
Not at all true		Somewhat true		Very true

8. One of my goals is to master a lot of new skills this year.

1	2	3	4	5
Not at all true		Somewhat true		Very true

9. It's important to me that I thoroughly understand my class work.

1	2	3	4	5
Not at all true		Somewhat true		Very true

10. It's important to me that I improve my skills this year.

1	2	3	4	5
Not at all true		Somewhat true		Very true

Appendix J

Self-Evaluation of Attention Measure and Video Quiz

A. (*Administered before quiz*): On a scale of 1-10 (with 1 being *not at all* and 10 being *very much*), how well did you think you paid attention to the lecture?

B. *(Administered after quiz):* How well do you think you paid attention to the lecture now that you have answered those comprehension questions? (On a scale of 1-10)

Video Quiz Questions and Answers

*Corresponding time points are in brackets.

1. What was once considered to be the ultimate marker of psychological health?

Answer: Self-esteem (2:40)

2. What animal was shown wearing a crown?
Answer: a puppy/dog (3:07)

3. What is self-esteem contingent on?
Answer: Success (5:07)

4. Name one of the three core components of self-compassion as defined by Kristin Neff.
Accepted answers: Self-kindness (6:55), common humanity (7:50), mindfulness (8:55)

5. Is self-criticism motivation? Explain in one sentence.
Answer: No, it undermines motivation (10:15-10:18)

6. Criticism activates what part/system of our body?
Answer: the flight/flight system or the adrenal system (10:19-11:15)

7. When do we do our best?
Answer: when we feel safe and comforted (12:15)

8. Name one thing that self-compassion is strongly related to.
Accepted answers: mental well being or psychological health (14:11), happiness (14:22), less depression (14:15), less anxiety (14:16), less stress (14:17), less perfectionism (14:18), life satisfaction (14:23), greater motivation (14:26), taking greater self-responsibility (14:28), healthier lifestyle choices

(14:30), greater sense of connectedness to others (14:35), and stronger interpersonal relationships (14:37)

9. What is one benefit of self-compassion over self-esteem?
Accepted answers: It has all the benefits of self-esteem without the pitfalls (14:50), not associated with narcissism (14:55), not associated with social comparison (14:58) or ego defensive aggression (15:00), it provides a more stable sense of self-worth (15:20)

10. What is the #1 domain in which women invest their self-esteem?
Answer: their perception of how attractive they are (5:40)

Appendix K

Feedback Questionnaire

1. How was the pacing? Did you feel that it was too fast or too slow? Would you have preferred to proceed faster or slower through the tasks?

2. How much effort did it take to stop from pressing the button for the number 3?

No effort		Some effort		A lot of effort
1	2	3	4	5

3. Do you feel physically tired or fatigued?

Not tired		Somewhat tired		Very tired
1	2	3	4	5

4. How hard was it to focus on the task?

Very easy		neither/nor		Very hard
1	2	3	4	5

5. Was the headband comfortable?

Very uncomfortable		Somewhat uncomfortable		Very comfortable
1	2	3	4	5

6. If you answered ‘1: Very uncomfortable’ on the previous question, did you find you were distracted because of the headband?

Not distracted		Somewhat distracted		Very distracted
1	2	3	4	5

7. Were you able to stay focused during the tasks?

Lecture:

Stayed focused		Somewhat focused		Couldn’t focus
1	2	3	4	5

Computer task:

Stayed focused		Somewhat focused		Couldn’t focus
1	2	3	4	5

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