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DOES WORKING MEMORY CAPACITY MODULATE THE RELATIONSHIP BETWEEN TASK DEMAND AND INTENTIONAL MIND WANDERING?

A Thesis
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Psychological Science

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by
Stephen Le Vern Ware Jr.
August 2021

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ABSTRACT

Mind wandering (MW) is affected by multiple factors. Among those factors, the present study investigated the effects of working memory capacity on task demands on types of mind-wandering. It was hypothesized that individuals with high working memory capacity (WMC) would show more intentional mind wandering in a low demanding task, and in this case, task performance would not be impaired. On the other hand, individuals with low working memory capacity would show more unintentional mind wandering in the high demand condition; therefore, task performance would be affected. Task demand was manipulated with verbal n-back tasks and WMC was measured with working memory span tasks. The hypotheses were not supported by the results. It was found that intentional MW occurred more frequently in the high demand condition relative to the low demand condition, while no difference was found between conditions for unintentional MW. Additionally, in the high demand condition, individuals with high WMC were more likely to have performance decline as unintentional MW increased. Furthermore, a positive relationship between WMC and motivation was observed. Theoretical implications are discussed.

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CHAPTER ONE

INTRODUCTION

The tendency for thoughts to drift from a current task into unrelated thoughts, such as daydreaming or planning, can be referred to as mind-wandering (MW) or task-unrelated-thoughts (TUTs) (Smallwood & Schooler, 2006; McVay & Kane, 2009). This phenomenon is a mainstream topic in cognitive psychology and neuroscience. Recently, research on MW has been carried out in education (e.g., Pachai, Acai & LoGiudice, 2016; Kane, Smeekens & Von Bastian, 2017), in driving (e.g., Baldwin, Roberts & Barragan, 2017), and in aging (e.g., Maillet, Beaty, Jordano & Touron, 2018). For example, Wammes (2016) showed that undergraduate students' MW rates fluctuate in lectures throughout a 12-week semester. Kane et al (2007), showed that 30% of thought content consists of MW in a day. The prevalence of research on MW has grown across the field of psychology and neuroscience.

Experimental designs within cognitive psychology and neuroscience were previously content with controlling the occurrence of MW because MW has been considered as "noise" (Christoff, Irving, Fox, Spreng & Andrews-Hanna, 2016). When the default mode network (DMN) was discovered to be the most active regions of the brain during rest (e.g., Mason et al., 2007), "noise" became a topic of interest in attention research. Mind wandering was defined as "a shift in the contents of thought away from an ongoing task and/or from events in the external environment" (Smallwood & Schooler, 2015). This definition emphasizes MW as thoughts that are characterized by its content (Christoff et al., 2016); however, it does not reflect on how these thoughts arise or change over time. Rumination is a negative emotion-based MW episode, where an individual shifts their thought to personal concerns while engaging in a task (Smallwood & O'Connor,2013). In general, thoughts are dynamic in nature and our definition of MW should include a broad perspective that includes personal concerns and goals (Christoff et al., 2016).

Measures of Mind-Wandering

According to Weinstein (2018), the state of MW is typically captured by two different methods. The first and most common is a subjective method which is observed through self-report of participant's own internal states and relies on meta-cognition. Within the subjective method there are two sub-methods: probe-caught and self-caught methods. In the probe-caught method, a probe is presented at one point during a task. The probe might be an open-ended question, which asks participants to report their thinking verbatim in response to a probe. This methodology is used less due to the need for experimenters to individually collect data and code the thoughts. The more popular method uses closed-ended questions, in which participants are asked to respond to thought probes on either a dichotomous or Likert scale. For example, the probe could be a question "Were you on task or MW?", and participants are presented with two options: "on task" or "off-task/MW" (Kam & Handy, 2014). Another example of thought probe might be "Stop. Please indicate whether you were on-task or off-task, just prior to the onset of this screen," and participants have six points on a Likert scale with "on-task" on one side and "completely off task" on the other side (Levinson, Smallwood & Davidson, 2012).

Self-caught methods require participants to indicate when their attention has shifted away from the task. The self-caught method is more in line to an actual MW episode due to the likelihood that when an individual mind-wanders, they respond to an internal cue rather than an external cue (i.e., thought probe) (Varao-Sousa & Kingstone, 2019). While the ecological validity of this method is superior, there is a lack of experimental control. Altogether, the self-caught method is used less frequently because it requires participants to monitor their thought processes during the task (Schooler, 2002).

As a survey research method, thought probes have conceptual issues in collecting data and making empirical inferences. For example, Vinski & Watter (2012) demonstrated that demand characteristics play a role in higher reports of MW. On the contrary, there is also evidence supporting the claim that the presence of thought probes does not influence task performance or frequency of MW (Wiemers & Redick, 2019). When using thought probes, there are four key components to understanding how participants might answer questions: (1) understanding the question, (2) utilizing relevant information from memory, (3) extracting a single answer, and (4) mapping their answer to an available response (Krosnick & Presser, 2010). In regard to thought probes, understanding the question is not an issue because participants typically get some practice trials with primary tasks and thought probes. The second component is also not an issue as most probes are asking participants of the current content of thoughts in the moment (not relying on long-term memory, Weinstein, 2018). However, the third and fourth components are relevant for probe caught MW, as the wording of the probes and the available responses might influence how an individual will respond.

Thus, participants could use heuristics or biases when answering thought probes, such as; optimizing or satisfying social desirability and acquiescence bias. Another methodological issue that should be considered when using self-report measures is that individuals have the tendency to respond to the ‘best’ or more desirable option to attempt to satisfy the experimenter. Additionally, the amount of thought probes presented in a task can create response biases resulting in a high report of mind wandering episodes (Seli, Carriere, Levene & Smilek, 2013).

The second method is objective/indirect measures, which has been empirically evaluated by task-performance variables (i.e. accuracy). For example, research has investigated the effect of training in mindfulness meditation on MW, using a Sustained Attention to Response Task (SART) (Rahl et al., 2017). SART is a computerized task that instructs participants to respond to high frequent non-targets and to withhold a response from low frequent targets. For example, digits 1-9 are shown one at a time and participants are required to press a key except for 3. MW was measured by discrimination rate in the SART, calculated by the number of correct responses to non-targets minus the number of incorrect responses to non-targets (Rahl et al., 2017). Participants were randomly assigned to three brief mindfulness training conditions that differed in the way instructions were given. One condition focused on attention monitoring and acceptance, the second condition focused on attention monitoring only, and the third condition emphasized relaxation training or active reading. Before the training sessions, participants were measured on dispositional mindfulness and completed the SART. The training sessions were administered via audio tapes for three consecutive days and then were followed by a SART. It was found that the attention-monitoring plus acceptance mindfulness group showed a higher discrimination rate compared to the active control groups, suggesting that mindfulness reduces the amount of MW in the SART.

Cheyne, Carriere and Smilek (2006) investigated a relationship between SART performance and a subjective measure of attention lapse based on the Cognitive Failure Questionnaire (CFQ) developed by Broadbent et al. (1982). It was found that the measure of attention lapse and the SART performance were related. In another study by Reichle, Reineberg & Schooler, (2010), eye movement was utilized as a physiological measure while reading to assess mindless reading. Participants were instructed to read *Sense and Sensibility* by Jane Austen over multiple days, while the eye movements measurement provided information on when an individual would 'zone-out' (self-caught and probe-caught MW). Results reveled that fixation-duration (e.g. duration of fixation on a word during the first read) was longer when people mind-wandered with awareness (self-caught). Secondly, it was found that people were more likely to look elsewhere when mindlessly reading compared to normal reading; suggesting that readers started MW when they are not looking at the text. Furthermore, eye-movements are an indication that an individual is engaged in lexical and linguistic processing while reading but not MW. These studies provide empirical evidence that objective measures of MW correlate with subjective measures. Measuring MW can be objective/indirect with reaction times, eye movements and other physiological measures or subjective/direct through self-caught and probe caught methods. MW has been measured and assessed thoroughly in the literature, with multiple ways to empirically gather information on an individual's thought content during a task, other interlevel differences have been associated with the tendency to mind-wander. Specifically, individual differences in working memory capacity (WMC) have shown to predict levels of MW.

Working Memory Capacity

In its original version, Baddeley and Hitch's (1974) model of working memory assumes three subdivisions of working memory: (1) the central executive, (2) visuospatial sketch pad and (3) phonological loop. This tripartite system emphasizes attentional control with the central executive, verbal information for phonological loop and manipulation of visuospatial information for visuospatial sketchpad. The two slave systems in working memory compete for attentional resources that are influenced by limited resources. Later, a fourth component was added, an episodic buffer, which facilitates the storage of how information binds into long-term memory due to conscious awareness for retrieval (Baddeley, 2000).

In the decades following, working memory have been measured in labs through methods that incorporate a processing and storage component, known as complex span tasks (CST). In contrast, simple span tasks (e.g., Digit Span) do not incorporate a processing component and only measure storage processes in short-term memory (Redick et al., 2012). Commonly used CSTs include Operation Span (OSPAN) (verbal and arithmetic) (Turner & Engle, 1989), Reading Span (RSPAN) (verbal) (Daneman & Carpenter, 1980), and Symmetry Span (SSPAN) (spatial) (Shah & Miyake, 1996). There are two theoretical perspectives on what these tasks measure. There is a domain-specific perspective, focusing on the content of the task and its outcomes (Oswald et al, 2015). The domain-specific perspective has support via convergent and discriminant validity, showing a high correlation between specific working memory tasks and their specific outcomes (Daneman & Carpenter, 1980). For example, Shah and Miyake (1996) found a distinction in verbal-spatial abilities in individual's performances in the RSPAN and SSPAN. According to Oswald and colleagues (2015) the domain-general perspective emphasizes that the processing, storage and recall components of working memory tasks are the same. Support for this perspective comes from distinguishing latent variables from observable variables. For example, in latent variable modeling, WMC is operationalized by the high correlations between verbal and spatial CST (e.g. Engle et al 1999). Additionally, Kane et al. (2007) showed that all CST accounted for variances in verbal and spatial abilities. Outside of the complex span tasks the n-back task has been used as a measure of working memory (e.g. Kane et al., 2007; Jaeggi, Buschkuehl, Perrig & Meier, 2010; Schmiedek et al., 2009).

The N-back Task

The n-back task instructs individuals to match stimuli presented in a sequence that appeared n items ago. It was originally described as a visuo-spatial task with load factors ranging from 0-6 (Kirchner, 1958; Mackworth, 1959). According to Jonides et al (1997), encoding, storage, rehearsal, matching, temporal ordering, inhibition and response processes are needed to successfully perform the n-back task. Encoding processes refer to the interpretation of stimuli, storage and rehearsal processes to keep relevant information in working memory, matching to make a decision, temporal ordering to recall the order in which stimuli is presented, inhibition to reduce interference from previous trials and response to make the final decision. However, the n-back and CST do not measure the same construct. For example, Kane et al., (2007) showed that the n-back task demands recognition and is not related to serial recall demands in CST. However, when the n-back task was modified by presenting participants with words instead of numbers or letters, there was a strong positive correlation with OSPAN (Shelton, Metzger, & Elliot, 2007); furthermore, the n-back task incorporates processes associated with recognition demands, such that individuals have to manipulate information in working memory then recognize if stimuli were presented n items ago. In conclusion, the n-back tasks are a measure of individual differences in working memory and is a useful tool for research in working memory because they can predict individual differences in fluid intelligence in manipulating levels of load (i.e. 0-back vs 2-back) (Kane et al., 2017; Jaeggi et al., 2010).

Theoretical Frameworks for Mind-Wandering

WMC has been studied in various ways within cognitive psychology. It has been suggested to be an important factor in MW. The executive failure model (McVay & Kane, 2009) and resource demand model (Smallwood & Schooler, 2006) are the frequently mentioned models that emphasize the role of WMC in MW. According to the resource demand model (Smallwood & Schooler, 2006), MW occurs because individuals are aware of the switch from on task thoughts to off task thoughts; specifically, controlled processes formulate information into awareness and decoupling processes allow working memory resources to play a role when internal stimuli (thoughts) interfere with the external environment. Therefore, MW occurs when controlled processes are minimal for a task, allowing freed working memory resources to be allocated for MW. MW is linked with how information is controlled with awareness and this can be observed with tasks that require an individual to allocate and maintain information in WM. With WMC as an individual difference, the resource demand model predicts that MW would occur less for individuals with lower WMC; suggesting that working memory is needed for MW to exist.

The resource demand model has been supported with empirical evidence in numerous studies (e.g. Smallwood, Brown, Baird, & Schooler, 2012; Smallwood, 2013; Smallwood& Schooler, 2006). Specifically, Levinson, Smallwood and Davidson (2012) investigated how WMC would influence the amount of TUTs in demanding and nondemanding tasks. Two hypotheses were examined: (1) maintenance of MW requires WMC and (2) maintenance of MW is not supported by WMC, while MW decreases during demanding tasks because attentional resources need to be allocated to the task. Levinson, Smallwood and Davidson (2012), used a visual search task, in which perceptual load was manipulated (i.e. high vs low). They also used a Breath Awareness Task (BAT) with thought probes as a low demanding task. It was found that individuals with higher WMC mind-wandered more during the low-load condition in the visual search task but no relationship was found between WMC and MW in the high-load condition. Individuals with higher WMC also mind-wandered more than the low WMC individuals during the BAT. These findings supported the resource demand model, such that WMC is needed for the maintenance of MW episodes.

Contrary to the resource demand model, McVay & Kane (2009) proposes that MW is due to a failure in executive control influencing the frequency of automatically generated thoughts. Specifically, the episode of MW results from a failure to allocate attention to a primary task, such that internal thoughts interfere with the external environment. Instead of MW occurring due to substantial availability of attentional resources, the executive failure model states MW occurs because the executive-control system cannot efficiently control interfering thoughts. According to executive attention theories, WMC measures the ability to control attention (Engle & Kane, 2004). Therefore, individuals with lower WMC should have a higher frequency of MW episodes compared to individuals with higher WMC. McVay and Kane (2009), examined WMC's predictive ability in determining whether individual differences in attention control and MW are due to failure of executive functions including goal maintenance and neglect. They attempted to find a link between goal-neglect errors and subjective experiences of MW, using the SART with thought-probes (e.g. "what were you just thinking about?"). The thought-probe had seven different responses: 1) task, 2) task performance, 3) everyday stuff, 4) current state of being, 5) personal worries, 6) daydreams and 7) other. Additionally, SART was administrated as a between subject factor with three conditions (Semantic, perceptual, and perceptual-semantic). The SART instructed participants to respond to non-targets and not respond to targets. In the semantic SART, non-target words were from one category (e.g. animals) while another category (e.g. foods) was used for targets. The categories were counter-balanced across subjects. In the perceptual SART, non-target words (e.g. animals) were lower case while target words (e.g. food) were upper case. Lastly the perceptual-semantic SART, participants were instructed to make perceptual decisions with targets and nontargets differing in both food and animal categories (e.g., animals vs FOODS). WMC variation predicted SART performance and MW, such that individuals with lower WMC had higher rates of MW. Therefore, they concluded that MW is due to executive-control failure to maintain goals in a primary task and generation of MW do not require WM resources (McVay & Kane, 2009). These findings have been replicated and shown in relation to everyday activities.

McVay, Kane and Kwapil (2009) investigated whether low WMC individuals have a higher tendency to disengage from a task that was demanding and engage in MW. The purpose of their study was to examine MW as a failure in executive control, comparing laboratory findings to everyday life activities. They measured WMC by use of complex span tasks (CST), and tested participants over a week in MW episodes. Participants first completed a SART in their lab, based on perceptual and semantic go/no-go responses with thought probes from McVay and Kane (2009). Then participants were given a Palm Pilot, a portable device designed for scheduling, allowing experimenters to ask participants to report their MW anytime throughout a day. Specifically, the notification occurred at random approximately every 90 minutes, between noon and midnight. The first question had a binary response, inquiring if thoughts had wandered from their current activity, if participants indicated “yes”, then five following questions were presented: (1) I was aware my mind was wandering in the moments before the beep, (2) I allowed my thoughts to wander on purpose, (3) I was thinking about personal concerns or things I need to do, (4) I was daydreaming or fantasizing about something, and (5) I was worrying about something. Additionally, 18 questions were used to assess participants mental and environmental context (e.g., I was doing this activity successfully, I like what I’m doing right now, I would prefer to do something else right now, and what I'm doing is mentally challenging). It was shown that low WMC individuals had higher rates of MW in the SART and when they were performing tasks that were effortful or required concentration in their daily life (i.e. stressful, unappealing or boring activities). Similar findings were reported when participants were instructed to complete a choice-response task and responding to thought probes (Kane et al., 2007). Additionally, the executive failure model suggests that MW influences the neglect of goals. It was found that individuals with lower WMC mind wander more than people with high WMC due to attention lapses, and WMC predicts goal neglect through MW episodes.

Both the resource demand model and executive failure model have been examined in the MW literature and are inconsistent with how working memory capacity plays a role in the frequency of MW. The inconsistency in findings could be due to the tasks used when assessing MW. According to Robison and Unsworth (2017), most of the literature utilized "high demanding" tasks that tax attention and cognitive processes (e.g. SART, STOOP, antisaccade, flanker tasks, reading comprehension) to draw conclusions on how WMC can predict the propensity to MW. However, there are also some inconsistencies with using "low demanding" tasks (e.g. choice reaction time and digit reaction time task). For example, Robison and Unsworth (2017) measured WMC with CST, while using the choice reaction time and digit reaction time task as low-demanding tasks and thought probes. Though the purpose of this study was to determine if individuals with high WMC would mind wander more with thought contents in future oriented thinking, it demonstrated that people with higher WMC showed less mind wandering when a task was less demanding. In support, Miere (2019) attempted to replicate the positive relationship between WMC and MW using the Breath-awareness task (BAT). The BAT had three separate sections: 1) the baseline section: participants were instructed to be aware of their breathing in and out and were presented with thought probes (i.e. Just now where was your attention and How aware were you of where your attention was?), which were measured on a 6-point Likert scale; 2) the counting section: participants were instructed to count after each exhale and press the letter “A”, followed by pressing the letter “F” on the ninth exhale and the control key when they lost count, this section lasted 18 minutes with 12 thought probes; 3) the awareness section: participants were instructed to press the “L” key for every exhale and to press control when they noticed they were off task, this section lasted 9 minutes with 6 pairs of thought probes. Their results showed no relationship between WMC and MW. Contrary to these null finings, there is evidence to support a positive relationship between WMC and MW (Levinson, Smallwood, & Davidson, 2012; Rummel & Boywitt, 2014). A more recent model (Smallwood & Schooler, 2015) has infused both the resource demand model and executive failure model in terms of how WMC is related to the tendency to mind-wander.

According to the Process-Occurrence Framework (POF) the initiation of MW is due to a failure in executive control while working memory is needed for the continuation of the MW episode (Smallwood & Schooler, 2015). POF distinguishes between the process and occurrence of a MW episode, stating that attentional control can limit MW by the enabling of task dependent thoughts; however, once MW occurs, perception of the external environment is taken over by internal thoughts that are not involved with the primary task, causing impairments in task performance (Smallwood, 2013). The empirical evidence of this model is derived from findings on four different hypotheses on the generation of spontaneous thoughts: 1) the current concerns hypothesis (Smallwood, 2013), 2) executive failure (McVay & Kane, 2009), 3) meta-awareness hypothesis (Smallwood & Schooler, 2006), and 4) resource demand model (Smallwood & Schooler, 2006; Smallwood, 2010). According to current concerns model, MW occurs due to attention biases toward an individual's personal concern (Smallwood, 2013), Additionally, the shift in attention from the task to internal thoughts is facilitated by a higher sense of incentive value relative to the current task. According to the meta-awareness hypothesis, MW occurs when there is no awareness of the shift in thought content and that awareness of thought content returns at the end of an MW episode (Schooler et al., 2011). Each of the models mentioned explains the occurrence of MW; however, the resource demand model emphasizes the role of WMC in the continuation of MW episodes (Smallwood,2013). Furthermore, POF is different from the resource demand and executive failure models of MW, emphasizing that the occurrence and processing of MW can only be understood in the context of the tasks demands. These models have been the focal point of debate in the MW literature. Therefore, there needs to be further distinctions in how MW occurs. Recently there have been a trend into examining MW as either intentional or unintentional (Seli et al., 2016). The distinction between intentionality of MW could provide benefits for practical and theoretical implications for MW.

Intentional and Unintentional Mind-Wandering

In recent years, there has been a resurgence in conceptualizing the difference between intentional and unintentional MW. Smallwood and Schooler (2015) suggested that future research would benefit by making a distinction between the two. A shift in attention can be intentional, which requires an individual to have substantial control in processing information or be motivated (Giambra, 1995). Additionally, shifting attention can be unintentional (from primary task to internal thoughts) which implies an individual to have less control over processing information and not be motivated to remain engaged in a task (Giambra, 1995). According to Seli, Risko, Smilek and Schacter (2016), the differences between intentionality of MW can have different subjective experiences, such that, during unintentional MW there is a lack of consciousness in the initiation of the episode and during intentional MW there is a conscious or deliberate initiation of the episode. Individual differences could also play a role in distinguishing how intentional and unintentional MW draw on different cognitive systems; for example, there is evidence that unintentional MW is associated with attention-deficit/hyperactivity disorder (ADHD) and obsessive compulsive disorder (OCD), while there is no relationship between intentional MW and ADHD/OCD (Seli et al 2015, 2016). This implies that intentional and unintentional episodes could be uniquely associated with individual differences.

The Executive failure model posits that MW occur due to a lack of executive control contrary to the idea that working memory resources are needed to initiate and engage in MW (i.e. Resource demand model) and that the process and occurrence of MW are different (i.e. Process-occurrence framework). However, this is under the assumption that MW is unintentional. In laboratory settings, in conjunction to most experimental manipulations, the tendency for unintentional MW was examined though behavioral tasks and probe caught measures. However, when thought probes reflect intentionality, 34% - 41% of MW is deliberate (intentional) (Seli et al., 2016). This suggests that intentional MW stems from a lack in motivation to perform a task or perceive the task to be relatively easy with a belief that performance will not be hindered from MW. The theoretical framework in distinguishing intentionality of MW could be analogous to the cognitive mechanisms in attention that distinguish between exogenous and endogenous control (Seli et al., 2016). Specifically, intentional MW could be compared to endogenous control, reflecting on a willful shift in attention; furthermore, unintentional MW could be related to exogenous control, reflecting processes associated with attentional capture. While exogenous control is associated with external stimuli, in the context of unintentional MW the external stimuli would be the high activation of an individual’s current concerns or primed concepts (Seli et al., 2016). In this framework intentionality of MW could be interpreted as an integration of different attention networks.

According to Seli et al (2016), experimental manipulations that separate unintentional and intentional self-generated thoughts has significant impact on understanding the cognitive mechanism for MW. This study utilized the SART with two difficulty conditions, and a probe-caught method distinguishing between intentional and unintentional MW. The difficult condition was the standard SART. The easy condition was a modified SART, which followed the same procedure as the standard SART with the exception that numbers were not randomized but sequentially presented (i.e. 1, 2, 3

, 4…). Finally, thought probes were presented at the end of every block consisting of 45 trials, totaling 20 probes. One question was presented as the thought probe, “Which of the following responses best characterizes your mental state just prior to the presentation of this screen?”. There were three response options, “On task”, “Intentionally MW” and “Unintentionally MW”. Seli and colleagues found there was no differences in the frequency of MW across easy and hard conditions; however, individuals reported higher intentional MW in the easy SART and higher unintentional MW in the standard SART, suggesting that intentional MW in the easy SART can be due to future oriented thinking based on the assumption that intentional MW can be a strategic process that individuals use for planning or self-reflection (Baird, Smallwood & Schooler, 2012; Smallwood, 2011) . Furthermore, they suggested future research should not only look at the possible interaction between task difficulty and MW, but also evaluate the role of working memory capacity in the relationship between task demand and intentionality of MW.

Task Demands, Mind-Wandering and Working Memory Capacity

Further investigations into how WMC is related to situational demands for benefits and costs of MW have led to context-regulation hypothesis (Smallwood & Andrews-Hama, 2013) and cognitive flexibility hypothesis (Rummel & Boywitt, 2014). According to the context-regulation hypothesis self-generated thoughts are regulated for productivity; specifically, future oriented thoughts allow people to plan their futures (Baird et al., 2011), while past oriented thoughts are associated with distress (Smallwood & O’Conor, 2011). According to Baird et al., (2011), individuals with higher

WMC tend to engage in future oriented thoughts when reporting MW, which benefits the individual in a low demanding task. Baird et al., (2011) also showed that individuals with lower WMC did not report higher rates of future oriented thinking compared to high WMC individuals. However, contrary to expectations, there was not relationship between WMC and past-oriented thought content when they mind wander. The context-regulation hypothesis stems from the resource demand model, such that it expands the expected positive association between MW and WMC by adding a specific type of thought content for individuals with higher WMC.

Like the context-regulation hypothesis, the cognitive flexibility hypothesis emphasizes the role of WMC to be a beneficial factor in understanding how MW occurs based on situational demands. According to Rummel and Boywitt (2014) individuals with higher WMC would be able to adjust self-generated thoughts in context of task demands. "*TUT adjustment*", when individuals adjust the amount of MW based on the situational demands, was the main concern in this study. To examine how task demand facilities a reduction for MW for benefits to task performance, task demand was manipulated as a within-subjects design using 1-back and 3-back task. Additionally, working memory capacity was measured through automated OSPAN. Lastly, participants were asked to estimate their performance in each task at the end of the experiment and the CFQ was administered between tasks. "What were you just thinking about?" was the probe used to measure MW with seven responses: (1) the current task, (2) my performance, (3) everyday stuff, (4) my current state of being, (5) my personal worries, (6) daydreams, and (7) other task-unrelated stuff. MW rates was computed as the frequency of off-task thoughts, with 3-7 being considered episodes of MW, in both conditions. It was found that MW occurred more in the 1-back task than the 3-back task, and that high WMC individuals reported higher rates of MW compared to low WMC individuals in the 1-back condition. Additionally, high WMC individuals reported lower rates of MW compared to low WMC individuals in the 3-back condition. Performance in the 1-back task was higher compared to the 3-back task. Individuals with high WMC had fewer declines in task performance as task demand increases relative to low WMC individuals. In supporting the idea that MW effects task performance, individuals with higher WMC were able to adjust the rates of MW based on situational demands. This is further evidence that there is a positive relationship between WMC and MW in a low demanding task and a negative relationship between WMC and MW in a high demanding task.

The cognitive flexibility hypothesis and the empirical evidence from Rummel and Boywit (2014) show that WMC is a moderating variable in the relationship between task demand and MW, making the linear predictions form the resource demand and executive failure model to be lackluster in understanding the cognitive mechanism of MW. Regarding consistencies with a negative relationship between WMC and MW during a high demanding task, Froster and Lavie (2009) used a visual search task and manipulated perceptual load and found that MW was lower in the high perceptual load task compared to the low perceptual load. Though they did not measure WMC, it was suggested that when attentional capacity is taxed in a demanding task, information processing for MW is reduced. In low demanding tasks there is mixed evidence for how WMC relates to the frequency of MW, some have found a positive relationship between WMC and MW (Levinson et al. 2012, 2014), while most have found a negative relationship (e.g., Meire, 2019; Robinson & Unsworth, 2017; Unsworth & McMillan 2013, 2014). These contradictions indicate that task demands reduce the likelihood for attentional resources to be allocated towards internal distractors. Contrary to this evidence, there have been studies showing no difference in the frequency of MW by task demands and WMC (Seli, Risko & Smilek, 2016; Meire, 2019).

Due to the inconsistency with how task demand influences rates of MW, it has been suggested that multiple predictors contribute to cognitive mechanisms of MW (Randall et al 2019). While the executive failure model and resource demand model account for most data in the last decade, there are findings that do not support one model better than the other. Randall and colleagues (2019) attempted to predict MW from individual characteristics and the task difficulty. This study focused on resource theories (Kanfer & Ackerman, 1989), which combine individual difference variables with task characteristics to determine how attention plays a role in performance; additionally, the resource allocation framework states that self-regulatory strategies are used to allocate attentional resources to different activities or thoughts. When tasks are extremely high or low in demands they are referred to as “resource insensitive”, meaning that any effort put forward to the task will not make a difference in task performance. Therefore, only resource sensitive tasks, in which task demands are within an individual’s capability, will capture any variation in effort and attention for performing a task (Randall et al., 2019). In Randall et al. (2019), task difficulty was manipulated through use of math questions: Easy problems were 155 5th grade math questions, moderate condition included 42 SAT questions, and the difficult problems were 23 GRE quantitative questions. MW was assessed using a post-hoc scale, Attention Regulation Scale (ARS) (Randall & Beier, 2017). ARS is a 7-item scale, in which participants are provided with a Likert scale (i.e. “I thought about other activities”, “I daydreamed while doing the task”,” I let my mind wander while doing the task”). In the first experiment, task difficulty was a between subject factor. The second experiment adopted a within subject manipulation of task difficulty; and, the third experiment added a “very low” condition which had participants complete 924 simple addition problems. MW was found to be more frequent in the easy and hard condition (experiment 1). Additionally, working memory-capacity modulated the relationship between MW and task difficulty. Individuals with higher WMC engaged in more MW in the easy condition and as task-demand increased MW decreased, while lower WM individuals showed a positive association between task demand and MW. Lastly, Randall et al. (2019), found that task demand modulated the relationship between MW and task performance, showing that more MW resulted in lower performance in the high demand condition but not in the low demand condition. WMC did not moderate the relationship between MW and task performance. These findings provide support for resource theoretical frameworks and show that WMC modulates the relationship between task demand and MW.

Randall et al (2019), was able to demonstrate that WMC modulates the relationship between task demand and MW; however, the study did not evaluate the role of intentionality in MW. Ju and Lien (2018), assessed intentionality with WMC and task demand. They manipulated task demand with use of a modified n-back task. For the easy condition, a 0-back task was used, for the hard condition a 2-back task was used. The N-back task was modified by having participants respond to color digits (i.e.

red digits were targets) and not responding to the non-targets which were white numbers. Specifically, participants were instructed to determine if the digit displayed before the present target was odd or even when the item is red by pressing keys on a keyboard for the 0-back task. For the 2-back task, participants were instructed to determine whether the digit presented two digits before was odd or even when the present digit is red. Thought probes were used to assess MW, and they were presented at the end of each block for both n-back tasks. There was a total of 8 blocks in each task, each having a different number of trails (i.e. 12, 15, 18, 21, 24, 30, 33, or 36 trials), totaling 189 trails per n-back task. At the end of each block for each N-back task three thought probes were presented, the first asked what they were doing at the moment. There were eight separate options: (1) concentrating on the numbers without thinking about anything else, (2) thinking about their performance or about the task, (3) having a mind blank, (4) noticing some feelings in their body, (5) recalling the past, (6) planning something, (7) thinking other thoughts that did not fit into the other categories, and (8) could not judge what was being done. The second probe asked, “Were you aware of what you were doing just then?” with two responses. Lastly, “Did you intend to do that?”, with two response options. Additionally, working memory capacity was measured using a Chinese version of OSPAN. Working memory capacity was measured first by the modified n-back tasks. Results showed that WMC modulated the relationship between task demand and MW. It was found that MW occurred more often in the 0-back task, though there was no relationship between working memory capacity and performance in the 0-back task. However, the low working memory capacity group mind-wandered more than high working memory capacity group in the 2-back task compared to the 0-

back task. For intentionality of MW, there was lower instances of intentional and unintentional MW in the 2-back task compared to the 0-back task. WMC did not influence the amount of intentional MW in either conditions. For unintentional MW, individuals with lower working memory capacity reported higher unintentional MW in the 2-back task compared to individuals with higher working memory capacity but no differences between WMC groups for unintentional MW in the 0-back task. For task performance, WMC and MW did not predict performance in the 0-back task; however, there was a positive relationship between working memory capacity and performance in the 2-back task and no relationship with MW.

In summary, Ju and Lien (2018) found that working memory capacity was negatively related to unintentional MW in the 2-back task, working memory capacity does not influence the tendency to intentionally mind-wander in either conditions, unintentional MW occurs more often as task demand increases for low working memory individuals. These findings suggest working memory capacity only plays a role in the tendency to mind-wander when top-down regulation (i.e. deliberate attention) is needed for a task. While this is one of the first studies to incorporate different types of MW in the relationship with WMC, it shows that there could be separate mechanisms for types of MW when looking at WMC, task demand and performance.

CHAPTER TWO

CURRENT STUDY

Recently, literature in MW has shifted to incorporate an operational definition that includes the possibility that MW can be an intentional mental state. When empirically tested, there are differences between intentional and unintentional MW; however, the role of WMC and other inter-individual differences could have further theoretical implications. According to Robison, Miller and Unsworth (2020), MW is a multi-faceted phenomenon that includes more than one distinct predictor for evaluating the occurrence of intentional and unintentional MW. They measured WMC and attention control (AC) through a variety of tasks (e.g., complex span tasks, antisaccade, Stroop, and N-back task) which were labeled “cognitive variables”. They measured state variables with use of questionnaires and labeled them “contextual variables” (e.g., motivation, mood, and alertness) and trait variables (e.g., personality and mindfulness traits) and called them “dispositional variables”. Lastly, MW was assessed during the WMC and AC tasks with “Please characterize your current conscious experience”; furthermore, there were 6 different responses. Regarding the predictive ability of individual differences in cognitive ability, they found evidence that supports resource demand models, such that in high demanding task cognitive ability was negatively associated with MW. In the low demanding task, there was no relationship between cognitive ability and MW. However, cognitive ability was positively associated with intentional MW in low demanding tasks. The results suggest that individuals with better cognitive ability are likely to intentionally MW during a low demanding task. The dispositional and contextual variables also played a role in the occurrence and maintenance of MW episodes, further suggesting that people mind-wander for several reasons.

The current study aims to further evaluate MW as a multi-faceted phenomenon while also integrating the resource demand model (e.g.,Smallwood & Schooler, 2015; Randall et al., 2019) and the executive failure model (McVay & Kane,2009). It was hypothesized that individuals with higher working memory will show more intentional MW, compared to low working memory in the low demanding task as predicted from the resource demand model, and MW would not be related to performance decline. However, low working memory individuals will show more unintentional MW in the high demanding task as predicted by the executive failure model, and there would be a negative relationship between MW and task performance for low working memory individuals.

Methods

Participants

Ninety-three undergraduate students (N_{Female} = 86, M_{Age} = 28) were recruited via SONA for this study. Among the participants, 52.3% were Seniors, 45.3% were Juniors and 2.3% were Sophomores. For English fluency, 80.2% were native speakers. Additionally, 90.7% of the participants were right-handed, 8.1 % were left-handed and 1.2% were ambidextrous. Students signed an informed consent approved by the university's institutional review board (see APPENDIX B).

Materials

All materials/instructions were sent via email to students' accounts (See Appendix). For the Complex SPAN tasks and N-back tasks, Google Drive was used for students to download on to their computers. Students were required to have a Windows desktop or laptop for the programs to be downloaded and used. Specifically, the computerized tasks were administered through E-Prime Go (Psychology Software Tools, Pittsburgh, PA). Consent forms, debriefing statement, and questionnaires were sent separately as Word documents via email.

Complex SPAN tasks. The shortened versions of the Operation span task (OSPAN), Reading span task (RSPAN) and Symmetry span (SSPAN) task were utilized to assess individual differences in WMC (Oswald et al., 2015). During OSPAN participants were presented with arithmetic operations then asked to determine if the solution provided was true or false. A letter was presented after each judgment, in which participants were instructed to recall after the completion of a set (set sizes 4-6). During RSPAN participants were presented with sentences then asked to determine if the sentence was sensible. A letter was presented after each judgment, in which participants were instructed to recall after completion of each set (set sizes 4-6). During SSPAN participants were presented with a set of 8 x 8 matrices and a few squares were filled with black to form a pattern, then they were instructed to judge if the patterns were symmetrical along the vertical midline. Participants were then instructed to recall letters that appeared after each judgment (set sizes 3-5). The final WMC scores were computed by taking the average of all Total Span scores.

N-back tasks. To manipulate task demands, two versions of the verbal N-back task were used (1-back and 3-back tasks) (see Figure 1). Twenty letters (i.e., the entire alphabet excluding U, V, W, X, Y, and Z) were used for the presentation of stimuli, which were 38 in font size and in Consolas style. A letter was presented for 1500 ms against a grey background, followed by a 1-s intertrial interval. In the 1-back version, participants were instructed to press A with their left index finger if the presented letter matched the previous one and L with their right index finger if it did not match. The same key assignments were used in the 3-back version to indicate whether the letter matched the letter presented 3 letters earlier. A letter sequence consisted of 36 or 48 letters, and the target appeared 6 times.

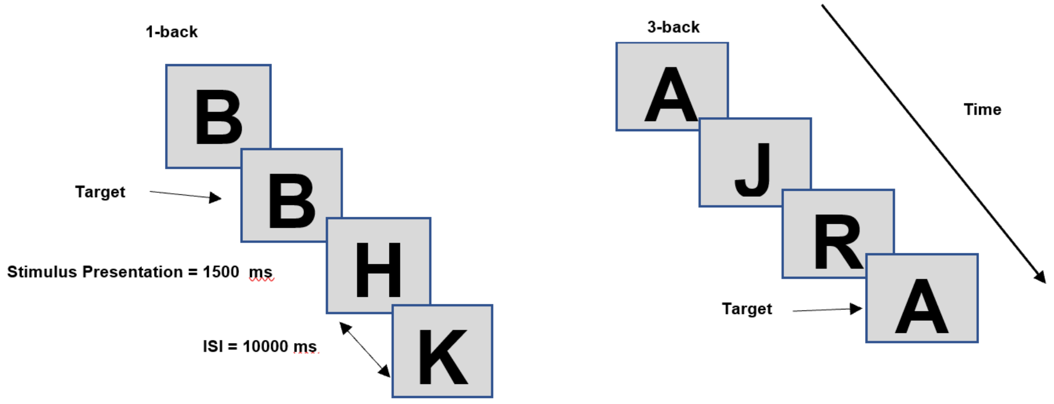

Figure 1: Stimulus display for verbal 1-back and 3-back tasks.

<u>Thought Probes.</u> A Probe-caught method was used to assess MW and was presented at the end of each block of the n-back task. Following Seli et al (2015), participants were instructed to respond to the question: “Which of the following responses best characterize your mental state during the recent task?” The following response options were provided: “(1) on task”, “(2) intentionally MW” and “(3) unintentionally MW”. Participants were instructed to press the corresponding numbers

to represent their type of MW (i.e., “1” for on task, “2” for intentional, and “3” for unintentional).

Questionnaires. A demographic sheet was used to collect participants’ age, gender, class standing, ethnicity, handedness, English fluency, and history of psychological/neurological conditions. Additionally, two questions were utilized to assess participants’ motivation during the task (i.e., “How motivated were you to do well on the task” and “How much did your overall motivation influence your performance on the task”) (Robinson & Unsworth, 2015). A Likert scale was used for ratings, ranging for 1 (*not at all*) to 6 (*very much*). Lastly the Mindfulness Attention Awareness Scale (MAAS) (Brown & Ryan, 2003), a 15-item survey assessing core characteristics of dispositional mindfulness, was given.

Procedure

Data were collected via E-Prime Go, and participants were given instructions via email, which included google link drives for the computerized tasks (see Appendix A). Participants were sent the consent form, debriefing statement and questionnaires as Word and/or PDF files. The consent form was sent with instructions, and the experimenter received the signed consent form via email. WMC was measured using the shortened complex WM tasks (OSPAN, RSPAN and SSPAN in that order), which participants downloaded on to their computers. Upon completing the complex WM tasks, the n-back tasks followed, which were presented randomly. Participants were given specific instructions for each n-back task to indicate whether they were doing the 1-back or 3-back task. Participants were also instructed on the response for thought probes. First, participants completed practice blocks for both the 1-back and 3-back task. There were 24 trials per block with thought probes presented at the end of each block. Participants completed eight blocks for each n-back condition after the practice blocks. There were two types of blocks varying in number of trials (i.e., 36 and 48 trials per block). Additionally, the target appeared 6 times in each block. After completing all computerized tasks, the demographics and MAAS were sent and collected. It is important to note that this experiment was self-paced because it was administered online.

Design and Data Analysis

A 3 x 2 mixed design was utilized in the current study. The following independent variables (IV) were manipulated: task demand was a within-subject factor (High [3-back] vs Low [1-back]) following Rummel & Boywitt (2014) and WMC was a between-subject factor, created with a tercile split. The dependent variables (DV) were the proportions of intentional and unintentional MW and accuracy in both 1-back and 3-back tasks. Additionally, bivariate correlations were computed between WMC groups for all task performance variables (i.e., accuracy and RT), MW, motivation and MASS.

Results

Of the 93 participants, 13 were excluded from the analyses. These exclusions were determined based on performance measures in the n-back tasks. Initially, individuals with 0 % accuracy in either the 1-back or 3-back condition and having an average RT less than 200 ms were removed from the sample. Subsequently, the mean (M) and standard deviations (SD) were computed for accuracy and reaction time for each n-back task. Participants who had RT or error rate outside of M ± (2.5 x SD) for each performance measure were identified as outliers and were excluded. The final sample size for the current study was 72; furthermore, when split by WMC, 25 were grouped into the low WMC group, 26 into the middle WMC group and 21 into the high WMC group. The n-back task performance, MW rates, MAAS, and Motivation are shown in Table 1 for the three groups.

Table 1
Means and Standard Deviations

		N-back		**MW**				
	Condition	RT	ACC	OT	INT	UIN	MAAS	Motivation
High WMC							3.91 (.85)	5.71 (.56)
(M = .88)	1-back	634 (95)	.87 (.08)	.52 (.26)	.17 (.24)	.30 (.20)		
	3-back	707 (99)	.68 (.16)	.48 (.32)	.18 (.23)	.33 (.24)		
Middle WMC							3.90 (.81)	5.38 (.90)
(M = .77)	1-back	626 (77)	.83 (.10)	.45 (.27)	.11 (.14)	.46 (.24)		
	3-back	667 (111)	.48 (.18)	.29 (.24)	.30 (.25)	.41 (.25)		
Low WMC							3.72 (.91)	4.96 (.98)
(M = .57)	1-back	606 (93)	.76 (.13)	.40 (.24)	.20 (.20)	.40 (.20)		
	3-back	686 (126)	.47 (.18)	.37 (.31)	.25 (.20)	.39 (.25)		

Note: Mean (M), reaction time (RT, in ms), accuracy (ACC), and type of mind-wandering (MW) for each WMC group. OT: on task, INT: intentional mind wandering, and UIN: unintentional mind wandering.

Accuracy was computed by taking the average for correct target trials. For accuracy, there was a main effect of task demand, *F (1,69) = 193.025, p < .001,* $\eta_p^2 = .737$; showing that participants performed better in the 1-back condition compared to the 3-back condition. There was also a significant main effect of WMC, *F (2,69) = 11.765, p < .001,* $\eta_p^2 = .152$, showing differences among WMC groups. There was a significant interaction between WMC and task demand, *F (2,69) = 6.187, p =.003,* $\eta_p^2 = .152$, as shown in Figure 2. In the 1-back condition, high WMC group had higher accuracy compared to the low MWC group, *t (44) = 3.475, p = .001, d = .531*, and the middle WMC group showed higher accuracy than the low WMC group, *t (49) = 2.371, p = .022, d = .346*, but there was no difference between the high and middle WMC groups, t (45) = 1.421, *p =.162*. In the 3-back condition, the high WMC had higher accuracy compared to the low WMC group, *t (44) = 4.214, p < .001, d = .621*, and the middle WMC group, *t (45) = 4.141, p < .001, d = .604*. There was no difference between the low and middle WMC groups in the 3-back condition, *t (49) = .144, p = .886*. Altogether, the high WMC group had better performance relative to the low WMC group in both conditions.

RT was computed by averaging across trial types for each n-back task for the correct target trials. There was a main effect of task demand, *F (1,69) = 28.747, p < .001,* $\eta_p^2 = .294$. Therefore, participants had shorter RT in the 1-back task relative to the 3-back task. There was no effect of WMC, F (2,69) = .561, p = .573, $\eta_p^2 = .016$. There was no significant interaction, *F (2,69) = 1.101, p = .338,* $\eta_p^2 = .031$. Altogether, the current study showed that task demand affected RT but that WMC did not affect RT.

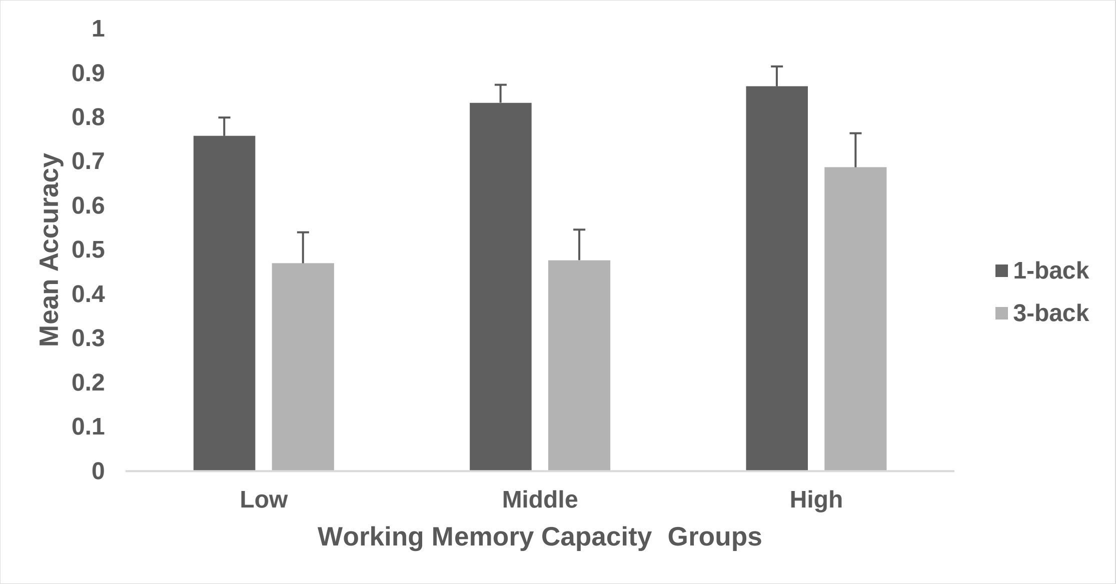

Figure 2: Accuracy in N-back Tasks

Mind-wandering

In the current study, MW was an ipsative measure; specifically, participants chose between intentional and unintentional MW when reporting their state of mind during the n-back task. Since the current study aimed to examine the variances in MW based on intentionality, the proportions of intentional and unintentional MW were utilized. There were 8 thought probes for each n-back task. The proportions were computed by taking the total frequency of MW and dividing by the total number of thought probes for each n-back task (Seli et al., 2016), and they are shown in Table 1 and Figure 3. First a 3 (WMC) x 2 (task demand) mixed ANOVA was used with the overall MW (i.e., the sum of intentional and unintentional MW proportions). There was a significant main effect of task demand, $F\ (1,69) = 4.351,\ p = .041,\ \eta_p^2 = .059$, showing more MW in the 3-back condition compared to the 1-back condition. Secondly, there was a no significant main effect of WMC, $F\ (2,69) = 2.469,\ p = .092,\ \eta_p^2 = .067$. Lastly, there was no significant interaction between WMC and task demand*, F (2, 69) = 1.005, p =.371,* η_p^2 *= .067.* However, post-hoc t tests revealed that in the 1-back condition, there was no difference between the high and middle WMC groups, *t (45) = 1.114, p = .271,* middle and low WMC groups, *t* (49) = .513, *p* = .61, and the high and low WMC, *t (44) = 1.665, p = .103*. In the 3-back condition, the high WMC group showed less MW than the middle WMC, *t (45) = 2.316, p = .025, d = .337,* but there was no difference between the middle and low WMC*, t (49) = 1.005, p = .32,* and between high and low WMC, *t (44) = 1.211, p = .232*. Collapsing across n-back tasks, post hoc t tests determined that MW occurred more in the 3-back task compared to the 1-back task only for the middle WMC group, *t* (25) = 2.418, *p* = .023, d = .48.

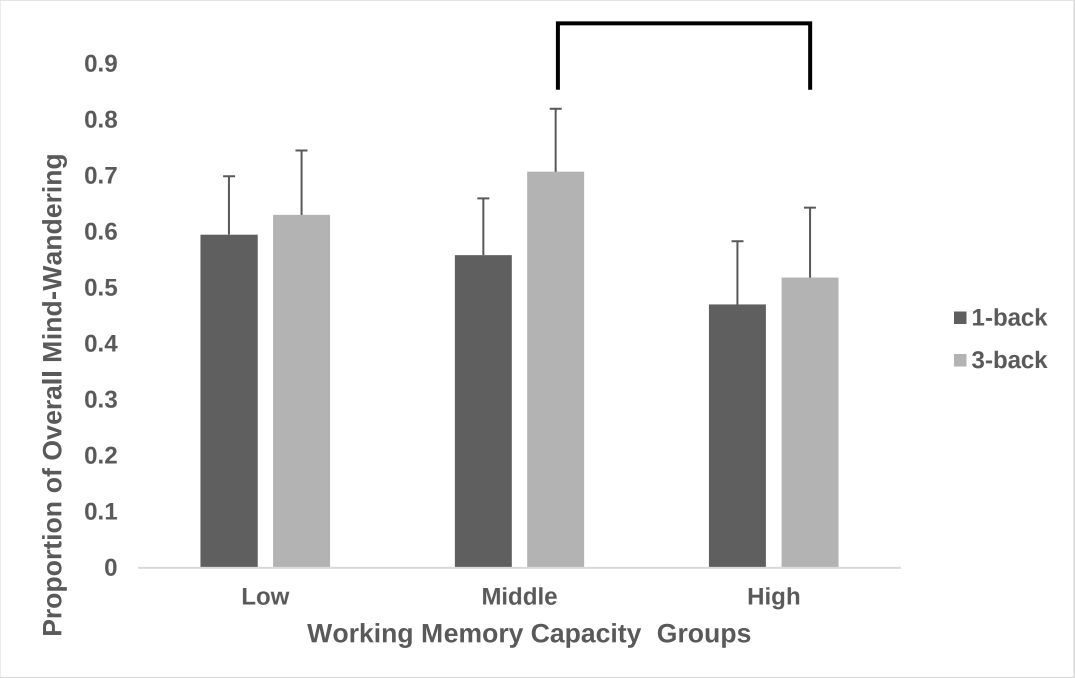

Figure 3: Overall Mind-Wandering

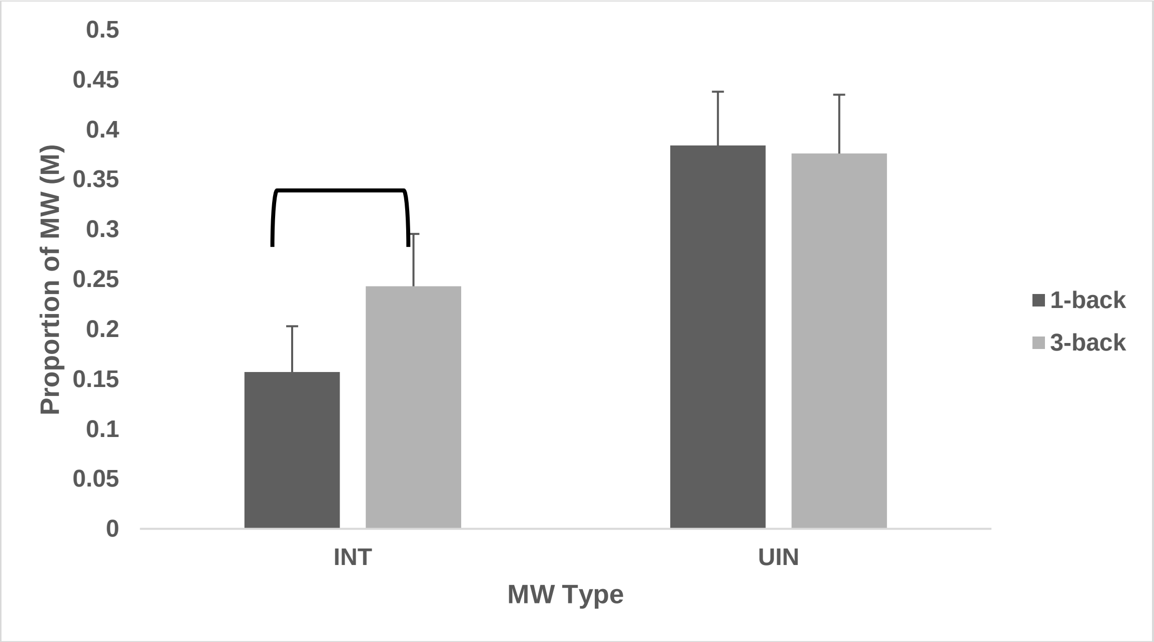

Figure 4: Intentional and Unintentional Mind-Wandering

To further examine the hypotheses on the intentionality of MW and WMC, the proportions of intentional and unintentional MW were separated and treated as a within-subjects variables (e.g., Seli et al 2016). So, a 3 (WMC) x 2 (Task Demand) x 2 (MW type) ANOVA was performed on the proportion of MW (intentional and unintentional). There was a marginally significant main effect of WMC, *F* (2,69) = 2.469, p = .092, η_p^2 *= .067,* showing that rates of MW were different among the WMC groups. There was a main effect of task demand, *F (1,69) = 4.351, p = .041,* η_p^2 *= .059,* showing that MW occurred more often in the 3-back condition compared to the 1-back condition. There was a significant main effect of MW type, *F (1,69) = 27.771, p < .001,* η_p^2 *= .287*, showing more reports of unintentional MW relative to intentional MW. There was a marginally significant interaction between task demand and MW type, *F (1,69) = 3.505, p = .065,* η_p^2 *= .048 (See Figure 4)*. A paired sample t-test revealed higher rates of intentional MW in the 3-back condition compared to the 1-back condition, *t (71) = 3.03,*

$p = .004$, $d = .354$ whereas there were no differences in the rates of unintentional MW between the 1-back and 3-back conditions, $t\ (71) = .321$, $p = .749$, $d = .038$. There was no significant interaction between WMC and task demand, $F\ (2,69) = 1.00$, $p = .371$, $\eta_p^2 = .028$. There was also no significant interaction between WMC and MW type, $F\ (2,69) = .478$, $p = .622$, $\eta_p^2 = .014$. Lastly, there was no significant 3-way interaction, $F\ (2,69) = 2.004$, $p =.143$, $\eta_p^2 = .055$ *(See Figure 5).* A post-hoc t-test revealed that the middle WMC group showed higher rates of unintentional MW than the high WMC group in the 1-back condition, $t\ (45) = 2.017$, $p = .05$, $d = .294$. Additionally, there were higher rates of intentional MW in the 3-back condition compared to the 1-back condition for the middle WMC group=, $t\ (25) = 3.427$, $p = .002$, $d = .685$. Lastly there were no significant differences among WMC groups in intentional MW for either task demand ($p > .05$). Altogether, there were more rates of intentional MW in the 3-back task compared to the 1-back task, there were no differences for the rates of unintentional MW between the n-back tasks. Lastly, individuals with middle WMC engaged in more unintentional MW in the 1-back task compared to high WMC individuals and showed more intentional MW in the 3-back compared to the 1-back condition.

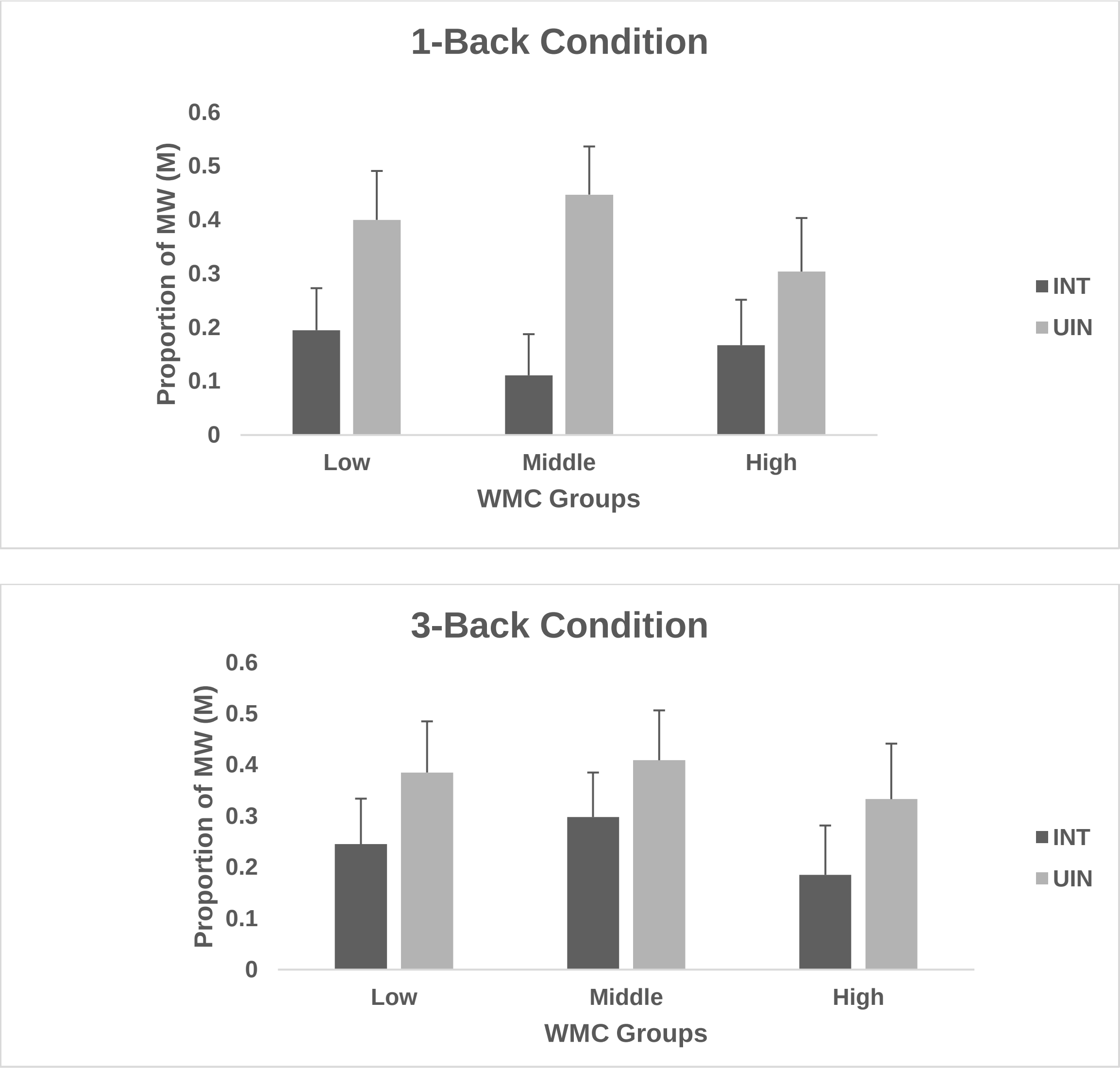

Figure 5: Intentional and Unintentional Mind-Wandering for Working Memory Capacity Groups

Correlations

The Pearson's correlation coefficients (r) were computed to evaluate relationships among accuracy and RT in n-back tasks, MW (Intentional, Unintentional and Overall), On-task, WMC, motivation and MAAS, and they are shown in Table 2. There were significant positive associations between accuracy and RT in the 3-back task, *r (70) = .44, p < .01*, indicating a speed-accuracy-trade-off; however, this relationship was not observed in the 1-back task. Accuracy in the 1-back condition was positively associated with on task, *r (70) = .24, p* < *.05*; subsequently, it was negatively associated with off-task, *r (70) = -.24, p < .05*. In the 3-back condition, accuracy was also positively associated with on-task, *r (70) = .35, p < .05,* negatively associated with off-task, *r (70) = -.35, p* < *.05* and with intentional MW, *r (70) = -.28, p* < *.05*. WMC was associated with accuracy in the 3-back condition, *r (70) = .33, p < .01* and in the 1-back condition, *r (70) = .31, p* < *.01*. WMC was also positively associated with motivation, *r (70) = .31, p < .01*. Lastly, motivation was positively associated with on-task in the 3-back condition, *r* (70) = .25, *p* < .05 and MAAS, *r* (70) = .241, *p* < .05.

Table 2
Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Accuracy in 1-back															
2. Reaction Time in 1-back	.23														
3. Accuracy in 3-back	__.45**__	-.02													
4. Reaction Time in 3-back	__.33**__	__.51**__	__.44**__												
5. On-Task in 1-back	__.24*__	-.16	.17	-.048											
6. Intentional in 1-back	-.15	__.24*__	.03	.22	__-.51**__										
7. Unintentional in 1-back	-.14	-.02	-.22	-.13	__-.69**__	__-.27*__									
8. Off-Task in 1-back	__-.24*__	.16	-.17	.05	__-1**__	__.51**__	__.69**__								
9. On-Task in 3-back	.04	-.01	__.35**__	.03	__.37**__	-.10	__-.33**__	__-.37**__							
10. Intentional in 3-back	-.02	__-.23*__	__-.28*__	-.14	__-.24*__	__.28*__	.04	__.24*__	__-.57**__						
11. Unintentional in 3-back	-.02	.23	-.16	.08	-.22	-.13	__.35**__	.22	__-.67**__	-.23					
12. Off-Task in 3-back	-.04	.01	__-.35**__	-.03	__-.37**__	.10	__.33**__	__.37**__	__-1**__	__.57**__	__.67**__				
13. WMC	__.31**__	.13	__.33**__	-.01	.16	-.03	-.16	-.16	.10	-.05	-.08	-.10			
14. Motivation	.19	.16	.17	.09	.05	-.02	-.04	-.05	-.01	-.01	.01	.01	__.31**__		
15. Motivation 2	.08	.11	.21	.12	.14	-.02	-.14	-.14	__.25*__	-.18	-.13	__-.25*__	.18	__.67**__	
16. MAAS	.15	.22	.16	.11	.07	-.06	-.03	-.07	.11	-.05	-.09	-.11	.13	__.24*__	__.26*__

Note: The correlation tables are bi-variate Pearson Rs; __* p < .05, ** p < .01__

Correlation coefficients are also computed for each WMC group to examine the relationships between each MW type and accuracy in the 1-back and 3-back task. The first hypothesis predicted that the high WMC group would show more intentional MW in the 1-back condition, and their rate of MW would not be correlated with task performance. The second hypothesis predicted that the low WMC group would show more unintentional

MW in the 3-back condition, and their rate of MW would be negatively correlated with task performance. The results of the previous analyses showed that the high WMC group did not show more intentional MW in the 1-back condition. Their accuracy in the 1-back task did not correlate with unintentional MW, *r (19) = .14, p > .05* or intentional MW*, r (19) = -.15, p > .05*. However, their accuracy was negatively correlated with unintentional MW in the 3-back condition, r (19) = -.57, p < .01, which is opposite to the hypothesis. For the low WMC group, the previous analyses showed that the rate of unintentional MW in the 3-back condition was not higher than that in the 1-back condition. Their accuracy in the 1-back task did not correlate with unintentional MW, *r (23) = -.25, p > .05* or intentional MW, *r (23) = -.04, p > .05* . Additionally, accuracy in the 3-back task did not correlate with unintentional MW, *r (23) = -.03, p > .05* or intentional MW, *r (23) = -.23, p > .05*. For the middle WMC group, the previous analyses showed that the rate of intentional MW was higher in the 3-back task relative to the 1-back task. Their accuracy was negatively correlated with intentional MW in the 1-back task, *r (24) = -.58, p < .01* and in the 3-back task, *r (24) = -.52, p < .01*.

Regarding other relationships not associated with the hypotheses, there was a positive relationship between motivation and MAAS for the low WMC group, *r (23) = .41, p < .05*. For the high WMC group, there were positive relationships between being on-task in the 3-back condition and motivation, *r (19) = .44, p < .05* and MAAS*, r (19) = .51, p < .05*. Lastly there was a negative relationship between motivation and MAAS, *r (19) = -.51, p < .01*.

Table 3

Correlation Matrix by Group

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Low WMC														
1. Accuracy in 1-back														
2. Reaction Time in 1-back	.14													
3. Accuracy in 3-back	**.43***	.03												
4. Reaction Time in 3-back	**.40***	**.64****	**.53****											
5. On-Task in 1-back	.23	-.15	-.07	.06										
6. Intentional in 1-back	-.04	.31	.27	.37	**-.60****									
7. Unintentional in 1-back	-.25	-.12	-.18	**-.43***	**-.62****	-.25								
8. Off-Task in 1-back	-.23	.15	.07	-.06	**-1****	**.60****	**.62****							
9. On-Task in 3-back	.00	.04	.17	.04	.25	.09	-.39	-.25						
10. Intentional in 3-back	-.04	-.09	-.23	-.01	-.20	.29	-.05	.20	**-.56****					
11. Unintentional in 3-back	.03	.02	-.03	-.05	-.15	-.33	**.50***	.15	**-.78****	-.08				
12. Off-Task in 3-back	.00	-.04	-.17	-.04	-.25	-.09	.39	.25	**-1****	**.56****	**.78****			
13. Motivation	.27	.27	.03	.18	-.19	.07	.16	.19	-.26	.11	.23	.26		
14. Motivation 2	.25	.15	.12	.08	-.08	.00	.10	.08	.03	-.03	-.02	-.03	**.74****	
15. MAAS	.02	.25	.32	.21	-.10	.04	.08	.10	-.04	.10	-.02	.04	**.41***	**.42***
Middle WMC														
2. Reaction Time in 1-back	.15													
3. Accuracy in 3-back	.29	-.10												
4. Reaction Time in 3-back	**.44***	.29	**.60****											
5. On-Task in 1-back	.25	-.14	.22	-.05										
6. Intentional in 1-back	**-.58****	.08	-.38	-.28	-.22									
7. Unintentional in 1-back	.04	.10	-.03	.19	**-.87****	-.28								
8. Off-Task in 1-back	-.25	.14	-.22	.05	**-1****	.22	**.87****							
9. On-Task in 3-back	-.06	-.06	**.44***	.09	.25	.00	-.25	-.25						
10. Intentional in 3-back	.06	**-.43***	**-.52****	-.34	-.10	.04	.08	.10	**-.46***					
11. Unintentional in 3-back	.00	**.48***	.09	.25	-.14	-.04	.16	.14	**-.50****	**-.54****				
12. Off-Task in 3-back	.06	.06	**-.44***	-.09	-.25	.00	.25	.25	**-1****	**.46***	**.50****			
13. Motivation	-.18	.07	.00	-.14	.23	-.03	-.21	-.23	.17	-.02	-.14	-.17		
14. Motivation 2	-.29	-.15	.14	-.14	.27	-.19	-.17	-.27	.25	-.15	-.09	-.25	**.67****	
15. MAAS	.34	.20	.12	.30	.07	-.23	.05	-.07	-.14	.02	.12	.14	.35	.11
High WMC														
2. Reaction Time in 1-back	.34													
3. Accuracy in 3-back	.42	-.20												
4. Reaction Time in 3-back	.03	**.59****	.05											
5. On-Task in 1-back	-.02	-.30	.13	-.27										
6. Intentional in 1-back	.14	.33	.08	.42	**-.70****									
7. Unintentional in 1-back	-.15	-.01	-.27	-.17	**-.46***	-.32								
8. Off-Task in 1-back	.02	.30	-.13	.27	**-1****	**.70****	**.46***							
9. On-Task in 3-back	.02	-.08	.26	-.17	**.58****	-.42	-.26	**-.58****						
10. Intentional in 3-back	.00	-.17	.24	.10	**-.44***	**.58****	-.14	**.436***	**-.66****					
11. Unintentional in 3-back	-.03	.26	**-.57****	.13	-.37	.02	**.47***	.37	**-.71****	-.05				
12. Off-Task in 3-back	-.02	.08	-.26	.17	**-.58****	.42	.26	**.58****	**-1****	**.66****	**.71****			
13. Motivation	-.09	-.07	.11	.32	-.21	.00	.28	.21	.01	-.01	.00	-.01		
14. Motivation 2	.00	.30	.10	**.56****	.08	.12	-.25	-.08	**.44***	-.33	-.28	**-.44***	**.45***	
15. MAAS	.01	.18	-.09	-.32	.22	-.01	-.28	-.22	**.51***	-.29	-.42	**-.51***	**-.46***	.11

Note: The correlation tables are bi-variate Pearson Rs; *** p < .05, ** p < .01**

CHAPTER THREE

DISCUSSION

The current study aimed to integrate two predominant theoretical frameworks (i.e., executive failure model and resource demand model) for MW, while considering task demand and intentionality of MW. It was hypothesized that individuals with higher WMC would show higher rates of intentional MW in the low demanding condition relative to individuals with lower WMC and that performance would not be impacted. However, this hypothesis was not supported. Secondly, it was hypothesized that individuals with lower WMC would show higher rates of unintentional MW in the high-demanding condition compared to individuals with higher WMC and that performance would be impacted. The current findings did not support the hypothesis; however, there were additional findings that provide further insight or speculation when differentiating between intentional and unintentional MW with different attentional demands to a task.

The current study found that (1) individuals with higher WMC had better accuracy in both the low and high demanding conditions, relative to individuals with lower WMC, (2) there was more MW in the high demand condition, relative to the low demanding condition, (3) there were higher rates of intentional MW in the high demand condition relative to the low demand condition , (4) in the high demand condition, the middle WMC showed a negative correlation between intentional MW and task performance, (5) individuals with higher WMC were more likely to decline in accuracy when they unintentionally mind-wandered in the high demand condition.

As expected, WMC was associated with task performance. The n-back task has been associated with other working memory tasks (e.g., OSPAN) (Shelton, Metzger &

Elliot, 2007). Specifically, the n-back tasks and working memory tasks used in the current study both rely on an individual's ability to manipulate information in working memory. This further demonstrates a domain-general perspective when empirically assessing working memory. In turn, the task demand manipulation was successful. There were performance differences between the two conditions, such that accuracy was better in the low demanding condition compared to the high demanding condition. Secondly, RT was influenced by task demand, such that participants had shorter RT in the low demanding task relative to the high demanding task. This is consistent with previous studies (e.g., Miller et al., 2009; Schmidt et al., 2009) that showed increasing memory load in the n-back task would cause RT to increase and accuracy to decrease. Another important observation from the current study was the speed-accuracy-trade-off in the 3-back condition, suggesting that when individuals were completing the 3-back task, they took longer in accurately responding to target trials. Specifically, this pattern was only observed in individuals with low and middle WMC, suggesting that individuals with higher executive functions were able to be accurate without the need to take longer to process and retrieve information from working memory.

Robison, Miller and Unsworth (2020), labeled MW as a complex and multifaceted occurrence. The current study showed multiple factors that contribute to the occurrence of overall, intentional, and unintentional MW in tasks that vary in attentional demands. Past studies have shown that when tasks are easy (e.g., low on attentional demands), MW would occur more often (e.g., Forster & Lavie, 2009; Rummel & Boywitt; Seli et al., 2016). However, this finding was not replicated in the current study. In n-back tasks, there were more instances of MW in the high demanding condition, suggesting that MW occurred due to a failure in executive control. There are two possible explanations: (1) the high demanding task taxed attentional resources resulting in a failure in goal maintenance (i.e., perform the task), or (2) due to the complexity of the task, which would facilitate the occurrence of MW. This was further supported with the negative relationship between task performance and overall MW. So, when people mind-wandered, there was a negative impact in task performance for both n-back conditions.

The current hypothesis on different rates between intentional and unintentional MW in the low demanding task was not supported. Past research has found that intentional MW is more likely to occur in a low demanding task (e.g., Ju & Lein, 2018; Robison, Miller & Unsworth 2020; and Seli et al., 2016). There were higher rates of intentional MW in high demand task compared to the low demand task, while there were no differences in the rate of unintentional MW between conditions in the current study. This is inconsistent with the idea that intentional MW occurs in a low demanding task because subjects are aware that the task requires less resources, so they engage in MW (e.g.,Seli, Carriere, Wammes et al., 2018). It is possible that intentional MW in a high demanding task is endogenous and an individual has given up instead of them being bored. Another explanation could be intentional MW is an incoherent category (Murray & Krasich, 2019); furthermore, it was discussed that intentional MW could be indistinguishable from other intentional mental activities (e.g., focused daydreaming, motivated task-switching, personal goal processing). In the assumption that an individual could focus on different tasks in a given moment, attention among tasks could shift due to intent, while not being categorized as an episode of MW (Murry & Krasich, 2019). This assumption would make motivated tasks switching different from internal

MW because they are reorganizing thought content based on relevance. Therefore, in the high demanding condition, participants were more likely to shift attention to more “relevant” tasks and categorized the mental state as “intentional” due to the experimental manipulation in the current study. Subsequently, the motivated task switching caused performance decline in the high demanding task.

The current study also showed that WMC impacted the relationship between unintentional MW and accuracy in the high demanding task; such that for individuals with higher WMC, as unintentional MW increased, accuracy was likely to decrease. However, this was not observed for other WMC groups. This is contrary to the current hypothesis, as it was expected that the negative association between unintentional MW and accuracy in the high demand condition would be present with individuals with lower WMC. Another important observation was that high WMC individuals that were more motivated, had higher rates of on-task in the high demanding condition. This suggests that individuals with higher cognitive abilities are more motivated to stay on task, so when MW occurred, it was unintentional and had a negative impact on accuracy.

Motivation and trait mindfulness also had some indirect influence on accuracy and individual difference in WMC in the current study. MW affected accuracy in both the low and high demanding conditions; additionally, WMC was related to performance in both conditions and motivation. Motivation was also associated with WMC and trait mindfulness. Altogether, individuals with higher WMC were more motivated to complete all tasks in the experiment, and mind-wandered less. While the relationship between mindfulness traits and WMC was not observed in the study, observing the relationship between mindfulness and motivation could imply that individual differences in executive functions play a role in individuals’ intrinsic motivation to be aware of task performance or that motivation plays a role in executive functions. These connections are not conclusive due to the lack of statistical significance among all three variables, but still posits an interesting question on how motivation and WMC is related. However, this is not consistent with the findings that showed no relationship between the WMC and motivation (e.g., Robison & Unsworth, 2018; Robison, Miller & Unsworth, 2020). Future research should elaborate more on these findings to determine theoretical importance.

The current study was able to provide partial evidence for the executive failure model, showing that individuals with relatively lower cognitive abilities were more likely to engage in MW; additionally, this relationship was independent of task demand. In terms of differentiating between intentional and unintentional MW, the current study failed to elaborate on past findings investigating the difference. However, unintentional MW could be different from intentional MW, as indicated by WMC impacting the relationship between unintentional MW and accuracy only in the high demanding task. Additionally, other intrinsic individual differences (i.e., motivation and trait mindfulness) contribute to an individual’s ability to sustain attention while performing tasks.

Limitations in the current study and Future research

Most of the hypotheses were not supported in the current study. The current experiment only measured the occurrence of MW, without evaluating individual differences in self-awareness of the MW episodes. Additionally, motivation was only assessed at the end of the experiment instead of at the end of each task; therefore, directly inferring on the relationship between task performance, WMC, or MW on motivation is not feasible. Lastly, the change in procedures for data collection could be an additional contribution for most of the results in the current study. Specifically, the study was conducted remotely via Eprime Go, instead of a controlled setting in the lab.

The current study adopted a within subject manipulation for task demand. Previous studies that investigated MW and manipulated task demand used the same procedures when testing their hypotheses (e.g., Ju & Yuu-Wen, 2018; Rummel & Boywitt, 2014). However, there are past studies (e.g., Seli et al., 2016) that utilized a between subject manipulation regarding task demand. While a within subject manipulation has advantages in experimental designs, it is possible that the use of 1 and 3 back tasks were difficult for participant to differentiate, even though there were appropriate instruction cues. Regarding the recording of MW, self-reported methods have some limitations. Furthermore, it seems that the literature is relying heavily on the participants' ability to distinguish among on-task, intentionally MW, and unintentionally MW. In other words, they assume that people are capable of cognitively monitoring their mental state while performing a task, then accurately identify that mental representation as attention has shifted from the task. Using self-caught methodology could improve or fix this issue for future research.

In the future, to further investigate MW with a multifaceted approach, other measures could be added. For example, Randall et al., (2019) and Xu and Metcalfe (2016) argued that the relationship between task demand and MW are curvilinear. In theory, in extremely low demanding tasks, individuals could be bored and able to entertain off-task thoughts while having no influence on performance. Subsequently, in high demanding tasks, MW would occur because the task is too difficult for them to keep their attention on the task. The current study did not address this curvilinear relationship, but future research could investigate by adding multiple levels of difficulty (i.e., 0-back, 1-back, 2-back, and 3-back). Additionally, measuring differences in State and Trait Anxiety, mood, or depression could have been beneficial. It is evident that when differentiating between intentional and unintentional there are different impact on task performance and rates depending on WMC. Using a very low demanding task could further test the idea that intentional MW occurs when a task is mundane and requires no attentional resources.

APPENDIX A

INSTUCTIONS

Thank you Participant ###

This study requires a working computer, running on Windows, with internet access. You most use the email that this message was sent to, to participate in the current study. These emails should be affiliated with XXX.

Thank you for signing up and participating in the study! This study will include several programs to be downloaded and completed. The suggested time for completing is 75-90 minutes. **Please find a nice quiet environment before starting and complete all tasks at once! It is vital that you take no breaks throughout series of tasks**. Following are the steps to complete this study is the suggested time frame mentioned above

1. For each program you will click on the link provided below, there should be an option to download the file.
2. Once downloaded click the arrow and option “keep”, do not “discard”. A window will pop up, click “more info” then “run anyway”.
3. E-prime Go will then open asking for your participant number. Please use the provided participant number for all experiments.
4. For the session number, put “1” for **ALL** tasks.
5. Read the consent form attached
6. Mark an X where there is a signature line and place the date of completion

Task One: https://drive.google.com/file/d/1Up4c7iusMZtcYIrS5XqdEC65AA0Ie22K/view?usp=sharing

Task Two:

https://drive.google.com/file/d/1x0jDads6nNeipxMcHICiI9q7uRe_mNuV/view?usp=sharing

Task Three:

https://drive.google.com/file/d/1LDvrXZfoCEOXnSQdQoIFFyCVzh1YVXmz/view?usp=sharing

Task Four A:

https://drive.google.com/open?id=1OAcx35m1cIBp_h7cOjSYZNVp5Ei0qP5O

7. Once all tasks are complete, **reply to this email** with the zipped files that will be found in a folder labeled “E-Prime Go” on your desktop.
8. Once I have received the data files, I will be sending the debriefing statement, and a few questionnaires.
9. Complete the forms and reply in the **same email thread**

APPENDIX B

IRB APPROVAL

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

March 9, 2020

CSUSB INSTITUTIONAL REVIEW BOARD

Administrative/Exempt Review Determination Status: Determined Exempt

IRB-FY2020-206

and Hideya Koshino

Department of CSBS - Psychology California State University, San Bernardino 5500 University Parkway

San Bernardino, California 92407

Dear Hideya Koshino :

Your application to use human subjects, titled “Does working memory capacity modulate the relationship between task demand and intentional mind-wandering?” has been reviewed and approved by the Chair of the Institutional Review Board (IRB) of California State University, San Bernardino has determined that your application meets the requirements for exemption from IRB review Federal requirements under 45 CFR 46. As the researcher under the exempt category you do not have to follow the requirements under 45 CFR 46 which requires annual renewal and documentation of written informed consent which are not required for the exempt category. However, exempt statusstill requires you to attain consent from participants before conducting your research as needed. Please ensure yourCITI Human Subjects Training is kept up-to-date and current throughout the study.

Your IRB proposal ([FY2020-206]) is approved. You are permitted to collect information from [200] participants for [5 SONA credits or $10 Amazon credit] from [SONA/CSUSB]. This approval is valid from [3/9/2020] to [3/8/2021].

The CSUSB IRB has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval notice does not replace any departmental or additional approvals which may be required.

Your responsibilities as the researcher/investigator include reporting to the IRB Committee the following three requirements highlighted below. Please note failure of the investigator to notify the IRB of the below requirements may result in disciplinary action.

Submit a protocol modification (change) form if any changes (no matter how minor) are proposed in yourstudy for review and approval by the IRB before implemented in your study to ensure the risk level to participants has not increased,

If any unanticipated/adverse events are experienced by subjects during your research, and Submit a study closure through the Cayuse IRB submission system when your study has ended.

The protocol modification, adverse/unanticipated event, and closure forms are located in the Cayuse IRB System. If you have any questions regarding the IRB decision, please contact Michael Gillespie, the Research Compliance Officer. Mr. Michael Gillespie can be reached by phone at (909) 537-7588, by fax at (909) 537-7028, or by email at mgillesp@csusb.edu. Please include your application approval identification number (listed at the top) in all correspondence.

If you have any questions regarding the IRB decision, please contact Dr. Jacob Jones, Assistant Professor ofPsychology. Dr. Jones can be reached by email at Jacob.Jones@csusb.edu. Please include your applicationapproval identification number (listed at the top) in all correspondence.

Best of luck with your research.

Sincerely,

Donna Garcia

Donna Garcia, Ph.D., IRB Chair CSUSB Institutional Review Board

DG/

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