12-18-2013

The Role of Spontaneous Retrieval, Monitoring and Sustained Attention in Prospective Memory

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by

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ABSTRACT

According to the Multiprocess Theory (Einstein and McDaniel, 1990), prospective memory is supported by two separate cognitive processes: monitoring and spontaneous retrieval. Successful monitoring during prospective memory tasks requires attention to be divided between separate stimuli and the attention needs to be sustained throughout the course of the task. However, this theoretical account also allows for prospective memory in the absence of monitoring, as in cases where memory is retrieved spontaneously in response to some cue. In the course of this study, support for the Multiprocess Theory has been found. Using a dual-task paradigm, prospective memory targets were displayed during a lexical decision task where participants were required to make a word/nonword decision to letter strings. Prospective memory targets were found using both monitoring and spontaneous retrieval, although displaying the target in the focus of attention or not did not differentially induce monitoring. A small increase from 2% target presentation rates (Experiments 1 through 3) to 3% target presentation rates (Experiment 4) did produce evidence of task interference that reflects monitoring; however, increasing target presentation rates to 5% did not increase reaction times above those found with 3% target presentation rates. Focal prospective memory targets (words) had higher accuracy rates than nonfocal prospective memory targets (words starting with letter "g"). Inhibiting responses to the lexical decision task to respond to prospective memory targets encouraged priorities to shift attention to the lexical decision task and increased the speed of lexical decision responding across the extended task. No evidence was found to support the hypothesis that sustained attention is identical to, or even a significant component of, monitoring. Sustained attention was not necessary to accomplish the prospective memory action, as variables affecting vigilance were not found to influence prospective-memory performance in the extended version of the dual-task paradigm used in this experiment. In Experiment 3, draining attention resources did negatively affect lexical decision reaction times and prospective memory performance with focal targets, but not with nonfocal targets. The strength of the lexical decision task routine was manipulated by varying the number of lexical decision practice trials given before the dual-task in Experiment 5. The strength of the routine did not affect task interference for focal or nonfocal targets. Overall, monitoring did not follow the sustained-attention pattern observed in vigilance. Prospective memory can be performed utilizing both cognitive mechanisms of monitoring and spontaneous retrieval.

INDEX WORDS: Prospective memory, Attention, Vigilance, Sustained attention, Monitoring

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

in the College of Arts and Sciences

Georgia State University

2013

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December 2013

ACKNOWLEDGMENTS

Thank you to the undergrads who helped run participants, you made my life easier. Thank you to the committee for being a part of this and David for reading draft after draft after draft. Most of all, thank you to my friends, family and, especially, my children for accepting that Mommy is upstairs writing. Above everyone else, thank you to my husband for putting up with me while I finished this and for his unerring devotion to helping me achieve this goal. If it wasn't for him, I would have never finished.

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1: INTRODUCTION

Overview

Prospective memory has been defined as the cognitive task of remembering to perform an action at a specific point in the future (Einstein & McDaniel, 1990). In this way, prospective memory is a unique kind of memory. Rather than reporting recent or distant past events, prospective memory involves remembering to do something in the near or distant future. There have been thousands of studies of episodic memory, working memory, autobiographical memory, declarative memory, procedural memory, and the other varieties of retrospective memory; conversely, there have been relatively few studies of prospective memory. The recent surge in interest in prospective memory has largely been motivated by Einstein and McDaniel's (1990) Multiprocess Theory.

According to the Multiprocess Theory, prospective memory is supported by two separate cognitive processes, monitoring and spontaneous retrieval. Monitoring is an attention-demanding process that consumes resources by storing and maintaining an intention in memory. In contrast, spontaneous retrieval is the process by which the intention is automatically retrieved when the prospective memory cue is given. Accordingly, spontaneous retrieval does not require attention resources in the same way as is seen with monitoring. Prospective memory tasks can be manipulated to encourage use of one cognitive process over the other cognitive process. Focal prospective memory tasks present the prospective memory cue in the focus of attention of the concurrent task which encourages the use of spontaneous retrieval. Nonfocal prospective memory tasks present the prospective memory cue outside the focus of attention to encourage the use of monitoring (McDaniel & Einstein, 2007). Successful monitoring during nonfocal tasks requires attention to be divided between separate stimuli (the prospective-memory intention and the primary task stimuli) and attention presumably needs to be sustained throughout the course of the task.

In prospective memory research, researchers have often concentrated on attention limits that cause a reduction in performance on the tasks that are being performed concurrently. Thus, attention capacity affects performance by limiting how much information can be focused on concurrently. This line of research has helped to support the Multiprocess theory by providing findings that display both monitoring and spontaneous retrieval being utilized to accomplish prospective memory. Attention limits do not exist solely for determining how many tasks or items can be focused on concurrently (although this is what “attention capacity” is typically used to denote), but attention limits exist also for the length of time that attention can be sustained. According to Kahneman's (1973) model, attention is a limited resource that can be allocated or exhausted to the point where one has no remaining attention capacity (i.e., over and above the attention that is already allocated to other tasks). Current prospective memory research has yet to address how these attention limits affect prospective memory abilities.

Vigilance, or sustained attention, is the maintenance of attention on a region or activity of interest for a prolonged period of time (See, Howe, Warm & Dember, 1995). Vigilance research typically requires participants to observe a display and to search for an infrequent target stimulus for an extended amount of time. The vigilance decrement is the change in performance on the task across time and is characterized by decreases in the number of critical targets that are detected, and increases in response time to critical targets that are detected (Mackworth, 1961). The vigilance decrement is due to attention being limited but sustained and thus exhausted throughout the task. Sustained attention in vigilance research may be able to inform the mechanism for successful monitoring in nonfocal prospective memory tasks. Support for the premise that both vigilance and prospective memory utilize sustained attention would allow researchers to start learning more about how limited attention and exhaustion of attention affect performance during prospective memory tasks. This is the purpose for the present line of studies. Manipulations that are known to affect performance in vigilance will be tested in prospective memory paradigms to provide further support for the hypothesis that monitoring requires the cognitive process of sustained attention.

Background and Significance

Prospective memory is required in daily life, as is other types of retrospective memory. Although prospective memory does include elements of retrospective memory, there is a clear distinction between the types of memory. Retrospective memory is recalling past actions or events when prompted to recall that information whereas prospective memory requires self-initiation of a requested action in response to an external stimulus. Self-initiation of an action means that the intention is retrieved without direction that the action must be completed. For example, prospective memory would be required when a plan is made in the morning to stop at the store on the way home after work to pick up milk whereas retrospective memory would be remembering that bread was also on the grocery list. Other examples of prospective memory are remembering to give a message to a colleague, to buy a birthday gift, to take medication, to go to a doctor appointment, or to attach an intended attachment to an email message. With the wide range of behaviors that require prospective memory in daily life, it comes as no surprise that this field of research has broad range of implications and has become an emerging area of study.

Prospective memory cues can either be time-based or event-based. Time-based prospective memory is performing an action at a specific time predetermined in the intention. For example, a time-based prospective memory task would be remembering to watch a favorite show at 8 pm tonight. Conversely, event-based prospective memory tasks require remembering to perform an action when the specific scenario in the environment presents the ability to complete the intended action. For instance, the grocery store on the way home can serve as the target cue where the action of stopping and picking up the milk can be performed.

McDaniel and Einstein (2007) defined parameters that help to classify prospective memory tasks. In order to test prospective memory in the laboratory, tasks would have to be characterized by these defining parameters; otherwise, performance might be attributable to another component of memory. The parameters specified by McDaniel and Einstein enable researchers to develop tasks that examine the prospective memory demands that are manifest in the behavior. McDaniel and Einstein (2007) proposed five parameters to function as the defining criteria of prospective memory tasks. Parameter 1 stipulates that the intended action cannot take place immediately after the intention has been formed. Immediate performance of the intention would either not require memory or remove the self-initiation of the intention and could be retrospective memory. Parameter 2 specifies that another task or activity has to be performed concurrently with the prospective memory task. In daily behavior, when an intention is formed to perform an activity in the future, individuals do not typically sit and wait to perform that action while rehearsing that intention—except in instances in which the action will be performed just seconds or perhaps minutes in the future, in which case the task can be performed by working memory with support from rehearsal. Requiring participants to perform concurrent tasks postpones the intended action and removes the ability to rehearse the intention. With the prospective memory task embedded within a concurrent task, it enables the prospective memory cue to appear as a stimulus within the concurrent task and not as an explicit and unambiguous signal to perform intention (Einstein, Smith, McDaniel & Shaw, 1997). Thus, the memory cue has an alternate purpose and is not a directive to recall. Without the intention developed before the concurrent task, the memory cue requires no additional action and the concurrent task could continue uninterrupted. Presentation in the concurrent task enables the prospective memory cue to appear naturally, which is necessary to simulate real life scenarios (Graf & Uttl, 2001) and reproduces how prospective memory interrupts activities within a daily routine.

Cue presentation is not the only part of the intention that needs to be limited to satisfy the parameters of prospective memory. Parameter 3 requires the response initiation to be constrained to a specific window of opportunity (McDaniel and Einstein, 2007). For example, the time to remember to pick up the milk is when passing the grocery store, not when sitting down for dinner. The window of remembering to perform the prospective memory intention has passed in this case and would be considered a failure to remember to perform the action. The action of stopping at the store had to be started when the window of opportunity was presented. Thus, the response to the prospective memory cue needs to have a defined occasion to be performed. Additionally, in Parameter 4 the performance of the intention needs to be executed during a limited time period. One might intend to read a particular book, but this would not be considered a prospective memory because the action would require too long a period of time to perform. Finally in Parameter 5, a conscious intention has to be formed to be classified as a prospective memory task (McDaniel and Einstein, 2007). Without the intention to perform the action, performance of the action could be considered timely retrospective memory.

For event-based prospective memory, different paradigms have been used to test whether individuals remember to perform an intention in the future. However, a majority of the studies in event-based prospective memory have used the paradigm developed by Einstein and McDaniel (1990). This paradigm enables researchers to do laboratory testing of prospective memory in a controlled setting over relatively short amounts of time and adheres to the parameters proposed by McDaniel and Einstein, (2007). In this paradigm, the instructions and prospective memory target are given near the beginning of the session, before a filler task. After performing the filler task, participants are required to perform a lexical decision task while concurrently performing the previously indicated prospective memory task. The lexical decision task paradigm requires participants to respond to a string of letters presented on the screen by indicating whether that letter string is a word or nonword. Responses are required for every letter string and vary depending upon whether a word or nonword was presented.

The prospective memory task requires participants to remember to make a different response when a particular event happens (e.g., a target word appears). For this paradigm, the target words for the prospective memory task can be embedded within lexical decision task by presenting the prospective memory target words (cues) as a letter string. Responses to prospective memory targets are required in addition to the button-presses to words and nonwords. For example, the required response to a word might be *f* on the computer keyboard and to a nonword might be *j* on the keyboard. The response to the prospective target cue might be the F1 key. This paradigm allows many types of manipulation to the stimuli and tasks which enables researchers to learn more about prospective memory.

With this paradigm, researchers have shown that encoding of the prospective memory target cues is important. In everyday life, tools, devices or strategies can be used to increase the chances of accomplishing the prospective memory action. Some common tools individuals could use include post-it notes, alarms, reminders and lists. Other external aids utilized at the time of encoding can also increase performance. Directions to support memory by using an external encoding aid, such as items found on the desk (stapler, tape), increased performance in the prospective memory task above the performance in the condition with no memory aids (Einstein & McDaniel, 1990). Similarly, Smith and Bayden (2004) manipulated encoding difficulty by giving participants either a short encoding time of 5 seconds or a long encoding time of 20 seconds to learn the stimuli. With more time to learn the target words, prospective memory performance increased. Alternately, prospective memory performance can be reduced when the difficulty of encoding the targets is increased. For example, encoding was made more difficult by requiring participants to perform a digit monitoring task while encoding the target (Einstein et al., 1997).

Another encoding tool is implementation intention. Implementation intention is planning for a specific situation, such as when and where, and then linking that situation to the intended prospective memory action. For example, the intention would be to pick up a present for a friend, stopping at the store is the prospective memory action and the specific situation is after work that evening to stop at the store and pick up the present. When implementation intention as a planning technique is added to a prospective memory task, prospective memory performance was increased, regardless of whether one or two concurrent tasks were performed (McDaniel, Howard & Butler, 2008).

Preparatory Attentional and Memory Processes (PAM) Theory

Multiprocess Theory is not the only framework proposed to explain how prospective memory is used to accomplish the intention. The Preparatory Attentional and Memory Processes (PAM) theory states that the intention developed in a prospective memory task can be retrieved only when preparatory processes such as attentional monitoring are engaged at the time of cue presentation (Smith, 2003; Smith & Bayen, 2004). Monitoring processes observe the environment for the presentation of a prospective memory target. Then, a recognition check on different stimuli is performed to evaluate whether a given stimulus matches the target and, if there's a match, to elicit the intended action. Thus, prospective memory is never automatic according to the PAM theory, but rather depends on monitoring that consumes attention resources. Participants have to engage resource-demanding processes by actively watching for the target to ensure successful completion of the intention that exists within prospective memory. The lexical decision and prospective memory paradigm allows researchers to look at the performance on the prospective memory task and to measure the cost of the addition of the prospective memory to reaction times in the lexical decision task.

Three arguments support the findings of the PAM theory of prospective memory (Loft & Yeo, 2007). These arguments are based on the premise of the PAM theory that prospective memory requires attentional monitoring to be engaged in order to accomplish the prospective memory. If monitoring is not done, then the prospective memory intention will not be completed. First, secondary tasks have been found to reduce prospective memory performance (Marsh, Hancock & Hicks, 2002; Marsh & Hicks, 1998) presumably because the secondary task consumed attention resources needed for prospective memory monitoring. Second, adding the prospective memory task to a concurrent task adversely affected performance on the concurrent task (Marsh, Hicks & Cook, 2005; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003; Smith & Bayen, 2004). Because attention is a limited resource, diverting attention to monitoring will have negative effects on performance of concurrent tasks—at least, for concurrent tasks that require attention resources. Third, reaction times in the concurrent task have been shown to be correlated with performance in the prospective memory task (Smith, 2003; Smith & Bayen, 2004). That is, Smith and colleagues found that performance on the prospective memory task increased as reaction times on the lexical decision task slowed, and vice versa.

According to the PAM theory, intention retrieval is not possible without preparatory attentional processes that require nonautomatic monitoring. Concurrent tasks using attention would leave fewer available attention resources to support monitoring. Consequently, performance on the prospective memory tasks would be reduced. Thus, when working memory resources were absorbed by highly demanding concurrent tasks prospective memory performance was decreased (Marsh & Hicks, 1998; Marsh, Hancock & Hicks, 2002). For example, prospective memory was detrimentally affected when the concurrent task required the participant to switch randomly between two different decisions about the stimuli presented (Marsh, Hancock & Hicks, 2002). The decisions were either a yes-or-no determination of whether the word presented contained the long-e sound or whether or not it was a living item. However, these judgments in the concurrent task did not focus attention on the information of the stimuli that was necessary to determine whether it was a prospective memory target. Thus, it could be argued that this study only revealed that increasing working memory load in the concurrent task negatively affects performance in a prospective memory task when the task does not focus on the prospective memory targets.

The second prediction from the PAM theory is that addition of the prospective memory requires attention resources and would slow reaction times in the concurrent task. If prospective memory requires preparatory attention (monitoring) to recognize the target stimulus, then lexical decision times would be increased due to the cognitive cost to the concurrent activity. The increased speed on noncue trials in the lexical decision task was termed task interference (Hicks, Marsh & Cook, 2005). Use of task interference as a way to measure attention demand has become increasing popular within prospective memory research. In the PAM theory, task interference is indicative of the degree of monitoring which is theorized to mediate prospective memory. Task interference has been found to be increased by adding prospective memory in multiple studies (Einstein et al., 2005; Marsh et al., 2003; Marsh, Hicks, Cook, 2005; Scullin, McDaniel, Shelton & Lee, 2010; Smith, 2003; Smith & Bayen, 2004; Smith, Hunt, McVay & McConnell, 2007; Smith, 2010). Thus, larger amounts of cost lead to increased performance on the prospective memory task. For example, task emphasis in the instructions caused reaction times in the lexical decision task to decrease, leaving prospective memory unaffected (Einstein et al., 2005; Kliegel, Martin, McDaniel & Einstein, 2004; Loft & Yeo, 2007). Prospective memory required preparatory attentional resources even on trials when the target was not presented, signifying that preparatory attentional resources were engaged throughout the task (Marsh, Hicks & Cook, 2005; Marsh, et al., 2003; Smith, 2003; Smith & Bayen, 2004).

However, adding the prospective memory task does not lead always to task interference. Task interference was decreased when expected targets were not presented, regardless of whether the instructions focused on the lexical decision task or the prospective memory task (Loft, Kearney & Remington, 2008). In addition to increasing prospective memory performance, implementation intention removed task interference for the two concurrent tasks (McDaniel, Howard & Butler, 2008). Lack of task interference suggests that enough attention resources were available to accomplish the prospective memory task in addition to the concurrent tasks. Thus, when implementation intention was used, prospective memory had no effect on the concurrent tasks and required no attention resources.

The PAM theory is also supported by research in which task interference positively correlated with prospective memory performance (Smith, 2003; Smith & Bayen, 2004). Smith (2003) mean split participants into above average and below average performers on the prospective memory task. Participants with above average prospective memory performance had slower reaction times on the lexical decision task than participants with below average prospective memory performance. Additional support for the PAM theory was found when better prospective memory performance was found with poorer performance on the concurrent task (Smith, 2003). Yet, this effect is not consistently demonstrated (Meiser & Schult, 2008). Scullin, McDaniel, Shelton and Lee (2010) did not find task interference, averaged across the block of lexical decision trials, to predict differences in prospective memory performance as measured by hits. There may be multiple reasons that some researchers have found statistically significant correlations whereas others do not. The correlation between prospective memory performance and the concurrent task interference may depend on task focus. Prospective memory performance was found to correlate significantly with task interference only when the prospective memory target was in the focus of attention and under instructions to have the accuracy of concurrent lexical decision task responses be more important than speed on the task (Meiser & Schult, 2008). Prospective memory performance was correlated with the task interference only in the condition with instructions to focus on accuracy and with task inappropriate processing. However, the correlation between task appropriate processing conditions and task interference was not significant. Thus, prospective memory performance is not always a function of resource allocation.

The evidence for PAM theory has also been challenged in other ways. Looking at task interference across the complete task can be misleading. Attention waxes and wanes across trials (Davies & Parasuraman, 1982). Task interference on trials immediately before the target presentation correlated with nonfocal prospective memory performance (Scullin, McDaniel & Einstein, 2010). Thus, in nonfocal tasks, prospective memory performance increased as reaction time on the lexical decision task decreased. In other words, attention was needed in the nonfocal task correctly to detect the prospective memory cue. Task interference on pre-target trials did not predict differences in prospective memory performance during focal tasks. Additionally, task interference was found to only emerge after the first target cue was presented, but not before that presentation (Scullin, McDaniel, Shelton & Lee, 2010). Indeed, task interference was not found before the first target presentation, even after 500 trials had been completed. These results are contrary to predictions by the PAM theory. Additionally, a median split according to task interference was conducted (Einstein & McDaniel, 2010), allowing for subsequent comparison between performance-based groups. Because PAM theory predicts that preparatory attention requires resources and would be correlated with prospective memory performance, the group with faster reaction times to the concurrent task should show lower prospective memory performance, whereas participants with slower reaction times on the concurrent task should produce relatively high prospective memory performance. However, this prediction was not reflected in the data. There was no significant difference in prospective memory performance between groups of participants with slow and fast reaction times. According to Einstein and McDaniel, this failure of the PAM theory reflects the fact that participants were satisfying the prospective memory task using spontaneous retrieval, a process that is absent from the PAM framework.

Thus, the studies discussed previously are evidence that the PAM theory does not tell the whole story about the cognitive resources that are utilized to support prospective memory. Attention demanding processes are not necessary to complete a prospective memory task, and thus are not consistent with the tenets of PAM theory. Prospective memory performance in the absence of concurrent task disruption suggests that some target stimuli are processed automatically, without active monitoring. When targets were focally processed, automatic mechanisms do not vary with resource allocation. The findings that prospective memory tasks can be completed with no added cost to concurrent tasks (Marsh, Hicks & Cook, 2005), that prospective memory performance was not affected by addition of resource demanding concurrent tasks (McDaniel, Howard & Butler, 2008) and prospective memory did not correlate consistently with task interference (Scullin, McDaniel & Einstein, 2010) show that the PAM theory can explain some research findings, but not all and not consistently.

Multiprocess Theory

Marsh, Hicks and Cook (2005) theorized that prospective memory does not require attention resources when the concurrent task requires attention to be focused on relevant features of the prospective memory target. Attention resources would be required when the concurrent task requires attention to be focused on cues irrelevant to the prospective memory task instead of cues relevant to the concurrent task. This prediction was supported using semantic and orthographic targets and manipulating the concurrent task. Semantic intentions were animal words whereas orthographic intentions were palindromes. In this study, two types of tasks were included, focal tasks and nonfocal tasks. Focal tasks required task-appropriate processing where the lexical decision task included word/nonword decisions and the prospective memory task an animal-name as the target word (semantic intention). Thus, attention in the lexical decision task focused on relevant features of the stimuli and the prospective memory cues. Nonfocal tasks contained task inappropriate processing where the lexical decision task focused on word/nonword decisions and the prospective memory task was focused on finding palindromes (e.g., civic) or orthographic intentions. Thus, the lexical decision task and the prospective memory target were not processed similarly and required attention to be split between responding to stimuli and monitoring for the prospective memory cue.

Marsh and collaborators (2005) found increased prospective memory performance when the task required task-appropriate processing. In focal tasks, resources to perform the lexical decision task and the prospective memory task are the same and this increases performance by removing effortful attention; thus, focal tasks use spontaneous retrieval. Cue detection increased and task interference decreased when task-appropriate processing was required. When task processing was different for the lexical decision task and the prospective memory, then cue detections decreased and task interference increased. Monitoring was found in nonfocal tasks where attention was not focused on the same intention for both the prospective memory task and the lexical decision task. Marsh and colleagues found evidence that monitoring is not necessary for prospective memory to be accomplished. This study also provided a basis for prospective memory researchers to manipulate tasks.

The Multiprocess theory, proposed by Einstein and McDaniel (2007; McDaniel & Einstein, 2000; Einstein et al., 2005) states that prospective memory utilizes more than one cognitive process (attention-demanding monitoring) to accomplish intentions stored in prospective memory. McDaniel and Einstein theorized that in order to perform prospective memory retrievals in daily life, it is adaptive to incorporate multiple, different processes that can accomplish the prospective memory tasks. The two processes theorized to support prospective memory are monitoring and spontaneous retrieval.

Spontaneous retrieval is the cognitive process that supports prospective memory in focal tasks where task-appropriate processing was utilized (Marsh, Hicks & Cook, 2005). Spontaneous retrieval was consistent with the intuitive experience of an intention “popping” into one’s mind (Meier, Zimmermann & Perrig, 2006). It does not require attention resources to be focused on cue monitoring in order to process and to respond to a target presentation (McDaniel & Einstein, 2000, 2007). Spontaneous retrieval was theorized to be a cognitive process where intentions are retrieved automatically when a cue appeared and do not require preparatory attentional processes (McDaniel & Einstein, 2000, 2007).

Thus, the existence of spontaneous retrieval as a mechanism to support prospective memory is the difference between the PAM theory and the Multiprocess theory. Multiprocess Theory does not deny that prospective memory tasks can be designed to encourage or to require sustained attention for monitoring. However, monitoring is not required to accomplish all prospective memory tasks, because spontaneous retrieval can be used instead. The process that an individual will utilize is dependent upon the characteristics of the prospective memory task, such as the task demands and activities, and the individual's assessment of the task difficulty. The task variables influence whether the individual will choose the automatic process of spontaneous retrieval or the effortful process of monitoring. McDaniel and Einstein (2007) discussed that individuals have a tendency to rely on spontaneous retrieval for prospective memory tasks to be more efficient in their daily activities.

The divide between supporters for the PAM theory and the Multiprocess theory has caused researchers to concentrate on two main areas of testing. First, researchers have studied how the manipulations of task demands could affect prospective memory performance and task interference, because manipulations of task demand are theorized to affect which cognitive process is utilized to accomplish the prospective memory (McDaniel & Einstein, 2007). Task interference can be used as a tool to reflect which process, monitoring or spontaneous retrieval, is being used during the task by measuring changes in reaction time in the concurrent task, usually a lexical decision task (Hicks, Marsh & Cook, 2005).

Second, researchers have designed their studies to use different cognitive processes. Each study was designed to determine which task variables encouraged an individual to choose monitoring versus relying on spontaneous retrieval during the prospective memory task. As was suggested earlier, the task variables that have been manipulated include target stimuli for both the prospective memory task and the concurrent task, and the focus of attention through physical location of stimuli, task directions, and task processing.

Stimuli have been manipulated in multiple different ways to cause a prospective memory task to become a focal or nonfocal task. Prospective memory targets can be varied dependent upon the characteristics of the target. As previously discussed, semantic intentions would be focal when the concurrent task is a word/nonword lexical decision task, whereas orthographic intentions (e.g., requiring decisions about word structure) would be nonfocal in the same concurrent task (Marsh, Hicks & Cook, 2005). The distinction of focal and nonfocal are not limited to having semantic focal targets. When the target is a palindrome (orthographic) and the concurrent task is orthographic in nature, this is a focal task. Focal targets can also be a specific word (cat) where the nonfocal target was any word that fit in the animal category (Marsh et al., 2003). Additionally, a focal target could be a specific word (e.g., “tortoise”) whereas the nonfocal target would be a syllable (e.g., “tor”; Einstein et al., 2005). Focal targets have to be using the same resources that are used in the concurrent task whereas nonfocal targets have the target use different resources or are outside the focus of attention.

In what McDaniel, Guynn, Einstein, and Breneiser (2004) termed the reflexive-associative hypothesis, the more strongly the cue and response are associated during intention planning, the more likely the intended action will be automatically and rapidly brought to awareness with few cognitive resources. The cue and response association are made at encoding, but use previously developed associations developed through learning. The reflexive-associative hypothesis is supported by increased prospective memory performance with strong associations between the target word and the response word (McDaniel et al., 2004; Loft & Yeo, 2007). Strong associations were targets like "spaghetti and sauce" compared to weak associations like “spaghetti and church” (McDaniel et al., 2004). Following this finding, the authors added another element by varying the level of cognitive demand. With high attention demand of an additional monitoring task, performance on the prospective memory task was not significantly different than without the additional task; however, this was found only in the high-association condition. The low-association condition had lower prospective memory performance with the addition of the monitoring task. Thus, with high-association targets, spontaneous retrieval was the cognitive process that enabled performance to stay at high levels. Similarly, when the prospective memory target was a category of items, manipulation of the target typicality in the category affected task performance (Penningroth, 2005). According to the reflexive-associative hypothesis, more typical category members should have stronger associations with the category. Typical targets of the categories had better prospective memory performance than atypical targets, and this was true regardless of the category of targets. Automatic processing theorized by the reflexive-associative hypothesis supported the Multiprocess theory. Performance of prospective memory can happen without effortful monitoring, by using spontaneous retrieval.

Prospective memory target characteristics are not limited to the type of target that they fall into, but the properties of the word itself can also be manipulated. Researchers have used different numbers of prospective memory targets, and this has been found to have an impact on which cognitive process is utilized. Searching for one target allows the person to use the spontaneous retrieval process as the prospective memory task caused no task interference (Einstein et al., 2005). However, when the prospective memory task includes six targets, task interference to the lexical decision task was found, suggesting that monitoring processes must be used. Another manipulation to the target was to have the target be familiar or distinctive (Einstein & McDaniel, 1990). Prospective memory performance was increased with distinctive targets over familiar targets, regardless of the age of the individual. Distinctive targets are not just targets that are rare or unique and uncommon words, but can also be distinctive because of a difference from the concurrent task. For example, visual changes can make targets distinctive. Displaying a target word in capital letters when the concurrent task was displayed in lower case increases prospective memory performance (Einstein et al., 2000). Changes in the target cue that caused a dissimilar visual display will increase prospective memory performance.

Another design manipulation that encourages use of one cognitive process over the other is directing the focus of attention. Changing the focus of attention can be done in multiple ways. One way already discussed is manipulation of task-processing. A more simple manipulation of attention can be done through physical location of stimuli. Directing attention through physical location on screen towards the target also causes the task to rely on spontaneous retrieval versus monitoring (Einstein & McDaniel, 2005). A concurrent task of pleasantness ratings of words was displayed in the upper left corner of the monitor. Lower task interference was found when the targets were presented closer to this location than targets presented in the opposite corner of the screen. The opposite corner of the screen represented the physical, nonfocal location. Thus, a task can be focal or nonfocal dependent upon the physical presentation of the stimuli. Physical presentation can encourage spontaneous retrieval or monitoring.

The dual-task nature of the prospective memory paradigm allows researchers to manipulate which task is the task to be concentrated on primarily. Directions for the task can are manipulated to change the focus of attention to either the concurrent task or the prospective memory task. Task emphasis in the instructions causes different performance on the prospective memory task and the lexical decision task (Einstein et al., 2005; Kliegel, Martin, McDaniel & Einstein, 2004; Loft & Yeo, 2007). Effort is manipulated by instructing the focus of attention. Directed effort was high, medium and low with high attending to the concurrent task (lexical decision), medium dividing effort equally between both tasks and low was to have a relaxed pace on the lexical decisions. Effort was directed using high, medium and low tones (Marsh, Hicks & Cook, 2005). Lexical decision speed increased and prospective memory was decreased as the attention was directed towards the lexical decision task. When the lexical decision task was highlighted as more important, reaction times in the lexical decision task were faster and prospective memory was not affected. Thus, spontaneous retrieval was the process that individuals used when the task was focal and the lexical decision task was emphasized. The same results were found when the task instructions encouraged the participants to maximize performance on speed or accuracy during the lexical decision task (Meiser & Schult, 2008). Directions on task emphasis caused the use of monitoring or reliance on spontaneous retrieval. Directions to concentrate on the prospective memory task or accuracy in the lexical decision task encouraged monitoring for prospective memory targets and only affected performance when targets were nonfocal. Subsequently, directing attention to the prospective memory task to encourage monitoring only increased prospective memory performance when spontaneous retrieval was not a beneficial cognitive process.

Not all focal and nonfocal targets have the same level of difficulty for cue detection. Recently, it was shown that monitoring for syllables is more difficult than monitoring for words in a cue detection task (Scullin, McDaniel, Shelton & Lee, 2010). Scullin and colleagues found that there was no difference in difficulty in the cue detection task between the starting letter of the word compared to the entire word. Once a similar difficulty level between stimuli was found, the authors tested whether the effects of focal and nonfocal targets still caused differences in performance. In the third experiment, the prospective memory task used the focal target of a word compared to a nonfocal target of the first letter of the word. Greater task interference was found in the nonfocal (initial letter of word) condition than in the focal (word) condition. These findings supported the Multiprocess theory and the use of focal and nonfocal targets as a way to encourage which cognitive process the participant would employ.

As discussed above, changing elements of the experimental design can encourage the use of different cognitive processes to accomplish prospective memory. Use of these task manipulations has been used to lend support for the Multiprocess theory. The previously discussed research supports the claim in the Multiprocess theory that both monitoring and spontaneous retrieval are the processes that support prospective memory and that the process utilized depends upon the task demands and stimuli. In summary, the manipulations that encourage spontaneous retrieval are strongly associated cues, typical cues, targets in the focus of attention either through physical location or use of the same cognitive resources, task emphasis in the instructions, and number of target cues.

Different cognitive constructs also can be used to test the theories of prospective memory. Working memory capacity is defined as the ability to keep task-relevant representations active in the face of distractions (Engle & Kane, 2004). Variations in working memory are individual differences in cognitive control (Conway & Kane, 2001). Thus, an individual differences approach with working memory capacity was utilized to test the predictions of the Multiprocess theory. High working memory capacity individuals can actively maintain a goal in primary memory and control retrieval from secondary memory (Unsworth, 2007). When working memory capacity is measured in relation to prospective memory performance, the Multiprocess theory was supported (Brewer, Knight, Marsh & Unsworth, 2010). An interaction between working memory capacity and the type of target cue was found. When the target cue was focal, no difference was found in task interference between high and low working memory capacity individuals. However, when the target cue was nonfocal, high working memory capacity individuals had lower task interference than low working memory individuals. This interaction reflects the cognitive processes used. Thus, no difference was found between the groups when prospective memory could be accomplished by spontaneous retrieval. However, when prospective memory required monitoring, participants with high working memory capacity outperformed participants with low working memory capacity.

The discussed findings all support the view that prospective memory performance is increased when the prospective memory target is in the focus of attention and decreased when the target is not in the attention focus of the concurrent task. Consistent with this, task interference is decreased or not found when the prospective memory task is focal, and task interference is found when the prospective memory task is nonfocal. This supports the Multiprocess theory of prospective memory because the absence of task interference in focal tasks suggests that spontaneous retrieval is the cognitive process used to accomplish the task.

Vigilance

As can be seen from this review, the concentration in the literature has been on whether prospective memory performance ever reflects spontaneous retrieval. However, no one has denied that monitoring can be utilized when faced with prospective memory tasks. Einstein and McDaniel (2010) stated that the Multiprocess theory and the PAM theory only differ in their predictions when tasks are focal and have no costs. Both the PAM theory and the Multiprocess theory agree that monitoring is supported by the cognitive process of attention, or perhaps attention control as reflected in individual differences in working memory capacity (Smith 2003; Smith et al., 2007; McDaniel & Einstein, 2007). The findings discussed above support that attention is necessary, at least when the prospective memory task is nonfocal in nature (McDaniel & Einstein, 2007). Attention resources have broad implications and are used in a variety of different tasks. For example, there is a broad line of research that is unrelated to prospective memory, but that investigates the ability to monitor for an event. This literature is not typically cited in the prospective memory field, just as prospective memory is not typically discussed in this literature. The research area includes many studies of sustained attention or vigilance.

The purpose for the current research was to discuss the connections between these literatures, to explore the nature of monitoring in prospective memory, and to understand the cognitive processes that underlie monitoring in prospective memory performance. If monitoring is more deeply understood, it is more likely that prospective memory performance can be positively affected by increasing the likelihood of performing the intention or decreasing the likelihood of missing the opportunity to perform the action. One possible path to understanding monitoring is to determine whether it requires continuously sustained attention.

Vigilance or sustained attention is the maintenance of attention on a region of interest for a prolonged period of time (See et al., 1995). Vigilance tasks require participants to identify infrequent, unpredictable signals that are distributed across the watchperiod (Davies & Parasuraman, 1982). Staying vigilant is required in a broad range of tasks, usually when the task is considered to be boring because of repetitive stimuli but infrequent target presentations. For example, many different jobs require the worker to stay vigilant over long periods under difficult circumstances. Some jobs that require vigilance have automated human-machine systems, including military surveillance, air traffic controllers, industrial process/quality control, and long distance driving (Warm, Parasuraman, & Matthews, 2008). Simple vigilance tasks are designed to mimic these real-world operator demands by requiring the participants to watch a display with occasional, sporadic responses to targets.

One example of a classic vigilance task is the Clock Test developed by Mackworth (1961). Mackworth designed a simulated radar task similar to radars utilized for air traffic monitoring. The Clock Test had a black pointer that traveled in small jumps around the circumference of a clock face without markings. Participants were required to monitor the black pointer and watch for the critical target of the pointer making a larger, double jump. This task lasted for 2 hours. Critical targets required a response from the individual, but otherwise, no response was made to nontarget stimuli. As expected, attention during the vigil did not stay at an optimum level of performance for the whole length of the task (Mackworth, 1961). The change in performance across time is referred to as the vigilance decrement. The vigilance decrement is characterized by decreases in the number of critical targets that are detected, and increases in response time to critical targets that are detected. Indeed, performance on vigilance tasks has been found to decrease in the first 5 to 10 minutes of the watchperiod (Helton, Dember, Warm, & Matthews, 1999). New vigilance tasks have been developed where the vigilance decrement for a 12-minute watchperiod was comparable to that obtained with much longer vigilance tasks (Temple, Warm, Dember, Jones, LaGrange & Matthews, 2000; Helton et al., 2007). For example, the Temple task (Temple et al., 2000) rapidly displays the letters O, D or a backwards D on a computer screen, each for 40 milliseconds. Participants completed 57.5 go/no-go trials a minute where the target was the letter O for a total of 690 trials in a 12-minute vigil. Nontarget trials did not require any response. Performance in the abbreviated Temple task replicated the vigilance decrement found in longer vigilance tasks.

Any vigilance task requires that mental effort is applied to the maintenance of attention for the duration of the task, thus sustained attention. Additionally, vigilance tasks that incorporate the need for observers to hold the critical target in working memory for comparison to the presented stimuli are more resource demanding (Helton et al., 2007). Note that this task requirement is similar to the need of individuals to maintain the prospective memory target within their working memory in order to accomplish the prospective memory task. Most importantly, vigilance tasks have been found to be resource demanding (Helton et al., 2007). Prospective memory tasks that require monitoring are also found to be resource demanding (Marsh, Hicks & Cook, 2005; Smith, 2003). It seems reasonable to suggest that prospective memory tasks that require monitoring are resource-demanding due to the same mental effort to sustain attention as in vigilance tasks.

Vigilance has been addressed previously within the prospective memory literature, although briefly. Graf and Uttl (2001) theorized an additional parameter that should be a requirement for a prospective memory task. The parameter was that prospective memory only takes place when the formed intention is not maintained in the focus of attention throughout the task. Thus, the formed intention cannot be something that the individual was rehearsing or thinking about. The authors suggested that if the intention is active constantly in working memory, then the task is no longer a prospective memory task and transforms into a vigilance task. The issue at stake here is not whether the prospective memory task is a vigilance task, but whether prospective memory intention can be in the focus of attention throughout the task and still be defined as a prospective memory task. McDaniel and Einstein (2007) suggested that a majority of researchers do not ascribe to the additional limitation that the intention cannot be held in the focus of attention on prospective memory tasks. Thus, a majority of the research published under event-based prospective memory does not address the issue of the intention being sustained over time.

Vigilance tasks do not typically meet the parameters (McDaniel & Einstein, 2007) that are defined to prospective memory tasks. Vigilance tasks do not have a delay between formation of the intended action and starting the vigil. Plus, throughout the task, the intention is the focus of the task. Both of these facts violate the parameters of prospective memory tasks. Prospective memory tasks are required to have a delay between the development of the intention and the task where the intention can be implemented. In vigilance tasks, the goal is sustained in working memory and the display is monitored for the target. Responses are only performed in response to target presentation. Conversely, in prospective memory tasks, responses are required for the concurrent task in addition to the prospective memory targets. Prospective memory tasks have to be embedded in another task so that the presentation of the prospective memory target does not serve as reminder of the intention. Reminding the participant of the intention does not matter in vigilance research as the focus is on the fatigue caused by sustaining the attention.

The two types of tasks do overlap with the qualities necessary to make a response. Vigilance tasks and prospective memory tasks both require that an intention must be developed and that the response of that developed intention has to be initiated in specific window of time and executed in a limited time frame. Most importantly, Graf and Uttl (2001) stated that vigilance and prospective memory differ in the way that cognitive resources are utilized. Prospective memory tasks require resources to be divided between multiple tasks and purposes whereas vigilance tasks allow resources to be allocated solely upon the vigilance task.

Within prospective memory, nonfocal tasks have been found to be a drain on attention resources during the task. The cognitive process that has been labeled monitoring in the prospective memory literature is supported by attention, but attention is also being sustained throughout the nonfocal task. Already, variables manipulated in prospective memory studies contain similar findings to findings in the vigilance research.

Previous findings already suggest that sustained attention might produce similar findings in both prospective memory and vigilance research. For example, cues can be used to increase performance in both vigilance and prospective memory tasks. Different variables have been found that increased the vigilance decrement in vigilance tasks (See et al., 1995). Vigilance researchers have looked at the effect of cues on performance. In a computer generated air traffic controller program, participants were required to watch the screen and response only when two "aircrafts" were on a direct path to collide

(Hitchcock, Dember, Warm, Moroney, & See, 1999). Cued participants were informed that a critical trial was approaching with a verbal command. This cue was a perfect predictor of critical trials. As expected, performance in the cued condition compared to a control condition was improved and showed no sign of the vigilance decrement.

Using semantic lures in a prospective memory task, Scullin, McDaniel and Einstein (2010) manipulated whether the lures were presented close to the target trial or further from the target trial. Task interference was measured on the trial before the target trial was presented. Semantic lures caused monitoring as semantic lures increased task interference when displayed. Experiment 2 of this study compared focal and nonfocal tasks, and displayed a cued background or noncue. Cue condition had no effect on task interference or reaction times. Prospective memory performance was significantly higher with the help of a cued background in the nonfocal condition, but was unaffected in the focal condition. The cost on attention resources was manipulated by using semantic lures and cuing, and cueing increased prospective memory performance. The finding with the nonfocal prospective memory task was the same as with the cuing study in vigilance. Cuing allowed participants to stop monitoring during trials that were not cued and to monitor only during the cued trials. Thus, sustained attention was affected similarly in both vigilance and nonfocal prospective memory tasks.

With these similarities and differences in findings, tasks and purposes between vigilance and prospective memory, it is unclear whether sustained attention is used to accomplish both tasks or if sustaining attention is not necessary in prospective memory. Sustained attention has been studied extensively in the vigilance research and the findings could be used further to inform prospective memory literature. However, before findings from the vigilance literature lead prospective memory researchers, it must be established that sustained attention is the common cognitive mechanism between the two constructs. This is the purpose for the current study. The intent was to discover whether sustained attention affects prospective memory, as evidenced by the appearance of known phenomena from vigilance research in data from prospective memory paradigms.

Each experiment utilized the McDaniel-Einstein paradigm of a prospective memory task to find evidence of prospective memory. Any evidence of completion of the prospective memory task without task interference would be evidence that the task was completed using spontaneous retrieval; thus, support for the Multiprocess theory. Evidence of task interference would be evidence for monitoring during the prospective memory task and this was expected for nonfocal targets and not for focal targets. In addition to ensuring that the prospective memory task was completed and that monitoring existed during the task, the study was designed to test whether evidence for sustained attention could also be found using a prospective memory task. Accordingly, manipulations to the prospective memory task were tested in the experiments to look for vigilance effects.

2: EXPERIMENT 1

In the this study, I examined the time-course of prospective memory, so as to determine whether there was a decline in monitoring that mirrors the vigilance decrement, and that subsequently results in a reliance on spontaneous retrieval for prospective memory. Evidence of a vigilance decrement found during a prospective memory task would lend support to the prediction that sustained attention was used to accomplish the prospective memory task. I also investigated whether the presentation schedule of prospective memory targets would positively affect prospective memory performance during the nonfocal task by enabling the participant to anticipate the target and begin monitoring.

As described above, vigilance tasks reveal a systematic variation in attention across the task that has been labeled the vigilance decrement. In vigilance literature, the vigilance decrement is a well documented phenomenon and is the decline of detecting target cues presented across the course of time (Warm, Matthews & Finomore, 2008). A vigilance task itself can cause stress and fatigue for a person performing the task, effects that are shown in subjective self observations as well as in objective psychophysiological indicators.

Like sustained attention in vigilance, monitoring during prospective memory tasks waxes and wanes over the course of trials (Loft, Kearney & Remington, 2008; Marsh, Hicks, & Cook, 2005; McDaniel, Einstein & Rendell, 2008; Scullin, McDaniel, Shelton & Lee, 2010). However, even though prospective memory studies have demonstrated a decrease in performance across the task, researchers have not been particularly interested in this decrease. Loft and collaborators (2008, Experiment 3) examined how task interference changed over the course of trials and found increased reaction times for lexical decisions in Block 3 compared to Block 1. In that experiment, targets were presented every 40 trials during block 2 containing 540 trials and more importantly, blocks 1 and 3 with 100 trials each did not contain any targets. Thus, the increased reaction times could have been caused by a vigilance decrement or by shifts in resource allocation as the authors assumed. They also saw a reduction in lexical decision accuracy with time on task which the researchers attributed to fatigue; however, Loft and collaborators did not specifically discuss vigilance decrements. Rather, they concluded that this change in lexical decision reaction times was due to changes in attention allocation due to not presenting targets. A study discussed earlier showed that task interference did not begin until the first target presentation (Scullin, McDaniel, Shelton & Lee, 2010). There is the alternate explanation that some of the change in reaction times was caused by the vigilance decrement due to the length of the task. The prospective memory condition was compared to the control condition and showed significantly greater task interference. This analysis did support that attention allocation to prospective memory tasks decreased over the course of concurrent task. However, the authors did not distinguish between tasks that might use monitoring versus spontaneous retrieval.

The present experiment was designed to remedy the ambiguity in how prospective memory performance varies across a task. If sustained attention was used to complete the prospective memory task, it was expected that a vigilance decrement would be found. An extended trial allowed the tracking of how performance waxes and wanes over time to determine whether a vigilance decrement would be found within prospective memory tasks. This extended prospective memory task was similar to vigilance tasks in that the task was long by extending the task to include 900 trials. As the Multiprocess theory would predict different performance for focal and nonfocal prospective memory tasks, both were included. By including both focal and nonfocal tasks, the experiment may lend further support to the use of different cognitive processes in prospective memory tasks. Additionally, the results could suggest that in nonfocal tasks, monitoring included (or perhaps consisted of) sustained attention, similar to that of vigilance tasks. The task was effortful in the nonfocal condition as sustained attention was required for an extended length of time as in vigilance studies. Thus, if the nonfocal condition utilizes sustained attention similarly in prospective memory as in vigilance tasks, then extended prospective memory task would display a vigilance decrement. In other words, a vigilance decrement would be considered evidence for sustained attention in nonfocal prospective memory performance. As the focal condition typically relies on spontaneous retrieval and not sustained attention, one would not expect any vigilance decrement during the focal prospective memory task. If no vigilance decrement was found when there was evidence of monitoring, this would suggest that sustained attention was not used to accomplish the prospective memory task.

In addition to the effects of time-on-task on performance, research has shown that signal presentation can affect sustained attention during a vigilance task. Past experience in attention demanding tasks can be used by individuals to form expectations about future demand and allow the participant to anticipate and prepare for the event (Coren, Ward & Enns, 2004). In vigilance research, this phenomenon has been labeled the “signal regularity effect” which occurs when targets were presented in a regular and predictable temporal pattern (Helton et al., 2005). Performance in the vigilance task was increased by the signal regularity effect (Warm, Dember, Murphy, & Dittmar, 1992). Target signals were presented at scheduled intervals of every 30 seconds and irregular intervals varying from 12 to 60 seconds with a mean of 30 seconds (Helton et al., 2005). As expected, patterns in target presentation were observed and utilized by participants in order to predict when targets would appear. Participants increased their performance by predicting and preparing for the target when the target was expected compared to relaxing and not remaining vigilant when the target was not expected.

As prospective memory was hypothesized to use attention in nonfocal tasks, one would expect that the signal regularity effect would be observed and tasks should incorporate irregular target presentations. However, a majority of the studies in the prospective memory literature present the targets at regularly scheduled intervals. For example, targets were presented every 40 trials and approximately 1.5 minutes apart by Smith (2003), every 25 trials by Marsh, Hicks, Hancock and Munsayac (2002), and every 40 trials by Einstein and collaborators (2005). The scheduled target presentation in these studies could be boosting performance by allowing participants to form expectations of the target and only monitor at times when the target was expected.

In this experiment, signal regularity was manipulated to determine how it would affect prospective memory performance. Additionally, if the signal regularity effect was found in a prospective memory task, this would lend support to the prediction that sustained attention was used during monitoring. The present experiment included both focal and nonfocal tasks with regularly scheduled and random presentation conditions to test whether the signal regularity effect would be found in nonfocal tasks and whether regular signals in focal tasks encouraged monitoring. It was expected that the signal regularity effect would be found in the nonfocal condition. However, the signal regularity effect should not be displayed in a focal prospective memory task. According to the Multiprocess theory, the cognitive process typically utilized in focal tasks is spontaneous retrieval and monitoring was not the process that would be utilized in that task. It could be that studies with monitoring effects of task interference during focal tasks (e.g. Smith et al., 2007) actually caused periodic monitoring through use of regularly scheduled target presentation. The formation of the expectation may have encouraged participants to increase their performance by monitoring even though usually they would not monitor in focal tasks.

Experiment 1 Method

Participants. A total of 125 participants (79 females and 42 males, plus 4 participants who preferred not to answer) participated in Experiment 1, with 12 participants dropped due to computer error. All participants received one credit hour to use in their introductory Psychology class to satisfy a course requirement. The 17 participants who stated in the exit questions that they did not know the prospective memory cue were not included in the analysis. Thus, 96 participants (61 females, 32 males) were included in the analyses. Age ranged from 18 to 58 years old, with an average age of 20.78 years.

Apparatus and Tasks. All tasks were administered using individual PC computers. Stimuli were displayed on standard 15” monitors, and participants responded by pressing keys on the keyboard. Additionally, participants completed paper-and-pencil mazes as a filler task.

Lexical Decision Task. Participants were given the instructions for the lexical decision task and performed the task initially without a concurrent task (i.e., with no additional instructions to remember prospective memory items). Participants were instructed to determine whether each string of letters presented on the screen was a word or was a not a word. Participants were asked to make the lexical determination as quickly and as accurately as possible. Response keys were the "F" key when the letter string was a nonword and the "J" key when the letter string was a word. The lexical decision task included 200 trials, with half the letter strings being words and the other half the trials being nonwords. Words and nonwords were randomly presented and were not repeated. A fixation cue appeared on the screen prior to the presentation of the letter string. The fixation duration randomly varied between 425 and 900 ms to ensure that the participant could not anticipate the exact presentation of the letter string. The letter string was displayed until the decision response was made. Responses latencies were recorded by the program.

All the words were medium-frequency words from the Balota et al. (2007) English lexicon database. Medium frequency words were defined as having a log-transformed Hyperspace Analogue to Language (HAL) frequency within one standard deviation of the mean, from 3.76 to 8.56. Each word included 4 to 10 letters and had 2 to 4 syllables. Pronounceable nonwords were taken from the Balota et al. (2007) list of norms. All nonwords were 4 to 10 letters long.

Prospective Memory Task**.** The prospective memory task was embedded within a lexical decision task, as is typical using the Einstein and McDaniel paradigm (2007). Participants in the prospective memory conditions were instructed to also respond to a specific given target (prospective memory target) that was presented as a letter string within the lexical decision task. This was in addition to the lexical decision task of responding word or nonword to the letter strings. Participants performed one of three prospective memory load conditions: a no-load condition with no prospective memory targets, the nonfocal memory load condition (hereafter referred to as nonfocal load) or the focal memory load condition (focal load). Both tasks were preceded by instructions, which included the information that the prospective memory targets would only appear as words and would not appear as nonwords.

The no-load condition had no prospective memory instructions and functioned as a control for the prospective memory load conditions. In the prospective memory loaded conditions, participants were instructed to press the spacebar when the prospective memory target was presented on the screen. Any word beginning with the letter *G* or the specific word *governs* was the critical prospective memory target (nonfocal and focal loads, respectively). Instructions in the nonfocal condition were to press the spacebar when any word that started with the letter *G* was presented. The focal condition had the prospective memory target of *governs.* Instructions stressed the priority of the lexical decision task.

After the instructions were read, the participant completed 10 minutes of a filler task. The filler task was a paper-and-pencil maze task where the objective was to complete as many as mazes as possible. As many mazes as needed were supplied. After finishing the timed maze task, participants performed the prospective memory task. Both conditions presented the critical prospective memory target on 2% of the 900 lexical decision trials for a total of 18 critical targets. The prospective memory task had the target presentation schedule manipulated. The target presentation conditions were random target presentations or a regular schedule of target presentations. In the random target presentation condition, the prospective memory targets were pseudo-randomly presented throughout the 900 trials with the target presented on average of every 50 trials. Target presentations ranged from 16 trials to 114 trials apart. In the random condition, no targets were presented in the trials 845 to 855. The scheduled condition had presentations of the target every 50 trials (i.e., on trials 50, 100, 150, 200, 250, 300, 350, and so on). In the scheduled condition, Trial 850 was a probe trial to look at reaction time when a target was expected and not presented. Trial 875 was a probe trial when a target was presented but not expected.

After the task was completed, the participants responded to questions displayed on the screen by typing in the letter or word that they believed was their target and the response that they were required to make to the critical target. This ensured that the participant correctly remembered the target. Additionally, participants were asked whether they knew when the target would be presented and if the targets were presented on a schedule.

Procedure. Participants were tested in a small group setting, with each subject using an individual computer console. All tasks were presented on the computer screen of the participant's personal computer. The tasks were presented on the computer screen of each individual computer, and participants also were given a pen and paper mazes. The experiment lasted less than 1 hour in which participants performed the lexical decision task, the mazes and the dual-task. All participants began their session by completing the lexical decision task without any dual-task instructions. Prospective memory instructions were given before the 10-minute filler task. Once the timed maze task was completed, participants performed the dual-task, which was the prospective memory task embedded in a lexical decision task. That was, in addition to performing the lexical decision task for a second time, participants were instructed to also respond to a specific target that was presented within the lexical decision task (or not, in the no-load condition). Participants were randomly assigned to perform one of the three prospective memory load conditions: the no-load condition, the nonfocal condition or the focal condition. Additionally, participants in the focal or nonfocal conditions were randomly assigned to have targets presented in the regular presentation condition or the random presentation condition. After the task was completed, participants were asked the series of questions listed in Post-task Survey

1 (see Appendix A). Questions included the perceived difficulty of the task, and the perception of their performance. After the questions were completed, the participant were debriefed and excused.

Experiment 1 Results

Multiple one-way ANOVA analyses were conducted to determine whether age, gender, or race affected performance. None of the effects were significant, $p > 0.05$. Experiment 1 was a 3 x 3 x 4 mixed design, with PM load (No PM load, focal, nonfocal) and presentation (no PM load, scheduled, random) as between-groups variables, and task quarters (1 to 4) as the within-subject variable. The session was divided into 4 equal quarters of 225 trials each. Because there was only one control (no PM load/schedule) group, the data were analyzed in two separate mixed ANOVAs (PM load X quarters; schedule X quarters) for each dependent variable (lexical decision accuracy and reaction time). Responses to prospective memory targets were analyzed using a 2 (focal, nonfocal) X 2 (scheduled, random) X 4 (quarters) mixed ANOVA. An alpha level of $p < .05$ was used for all statistical tests in this and all subsequent experiments.

PM Target Accuracy. An ANOVA was conducted for the dependent variable of accuracy for the prospective memory trials. All means in the analysis were figured as percentages of correct PM trials compared to all PM target presentations. Target accuracy varied significantly dependent upon the presentation condition, $F(1, 59) = 4.30$, $p = 0.043$, $\eta^2 = 0.068$. The random presentations (mean = 67%, SE = 4.1%) had significantly higher PM target accuracy compared to the scheduled presentations (mean = 55%, SE = 4.1%).

Participants in the focal condition (mean = 80%, SE = 3.6%) were significantly more accurate in their performance on PM target detection than were participants in the nonfocal condition (mean = 41%, SE = 4.5%), $F(1, 59) = 45.38$, $p < 0.001$, $\eta^2 = 0.435$. This main effect was qualified by a significant interaction of PM load and quarters, $F(3, 177) = 3.28$, $p = 0.03$, $\eta^2 = 0.053$. The data were split according to PM load and a mixed measure ANOVA was repeated to delve into the interaction. In the focal condition, time-on-task significantly affected PM accuracy, $F(3, 111) = 8.40$, $p < 0.001$, $\eta^2 = 0.185$. Pairwise comparisons showed that PM accuracy was significantly lower on PM trials in Q1 than Q2, Q3 or Q4 (see Figure 1). There were no significant differences between Q2, Q3 or Q4. However, PM accuracy in the nonfocal condition was not significantly different between quarters, $p > 0.05$.

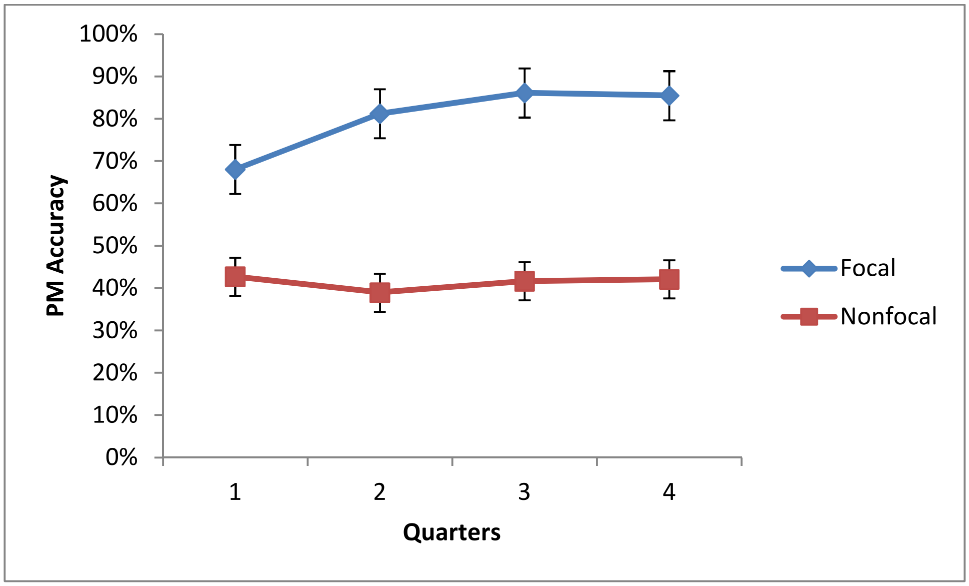

Figure 1 - Prospective Memory Accuracy across Quarters and Prospective Memory Conditions: Mean prospective memory accuracy (percent correct) for focal and nonfocal targets across the task, which was divided into quarters. PM Accuracy for focal targets in Q1 was significantly lower than all other quarters while PM accuracy did not vary for nonfocal targets. Bars represent standard errors.

Target Reaction Times. A mixed ANOVA was conducted to examine PM target reaction times to each target presentation. In this analysis, quarters were the repeated-measure and the dependent measure was reaction times to correctly report PM targets. After calculating the overall means, any trials greater than 3 standard deviations from the mean were removed before the ANOVA was conducted. No significant main effects or interactions were observed, $F < 1$. Thus, there was no significant difference between reaction times on PM trials where targets were focal (mean = 853.21 ms) compared to when targets were nonfocal (mean = 940.05 ms). Additionally, the length of time on task did not affect performance, $F < 1$. Trial 850 (mean = 739.45 ms) was a trial that would have been an expected target in the schedule condition whereas trial 875 (mean = 794.42 ms) was a trial where the target would have been unexpected. These two trials were compared in a mixed ANOVA and no significant main effects or interactions were observed for the dependent variable of trial reaction times, $F < 1$.

Lexical Decision Accuracy. Multiple ANOVAs were completed for the dependent variable of lexical decision accuracy. Separate ANOVAs were conducted for PM load and Schedule. Lexical decision accuracy included trials that were responses to the lexical decision task with reaction times within 3 standard deviations of the overall mean and excluded trials that displayed PM targets. Reported means were percentages of correct trials to total trials. Lexical decision accuracy decreased significantly across the task, $F(3, 279) = 18.00$, $p < 0.001$, $\eta^2 = 0.162$. Pairwise comparisons showed that lexical decision accuracy was significantly higher in the first quarter than in all other quarters (see Figure 2). Accuracy in Q2 was significantly higher than the Q3 and Q4. There were no significant differences in accuracy between Q3 and Q4. No other significant main effects or interactions were observed.

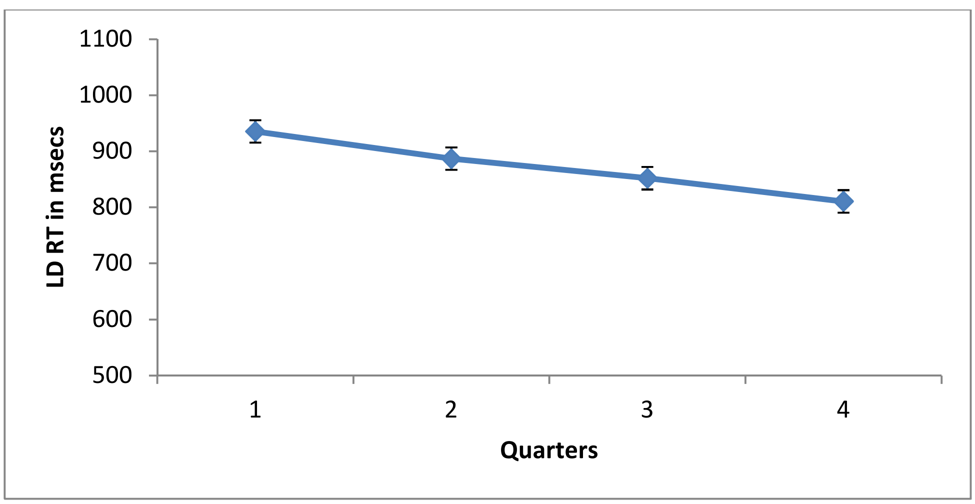

Figure 2 - Mean Lexical Decision Accuracy across Quarters: Lexical decision accuracy (percent correct) across the task, which was divided into quarters. LD accuracy in Q1 was significantly higher than all other quarters, dropped in Q2 and significantly dropped to plateau for Q3 and Q4. Bars represent standard errors of the mean.

Lexical Decision Reaction Times. Multiple ANOVAs were completed for the dependent variable of lexical decision reaction times. Separate ANOVAs were conducted for PM load and Schedule.

Lexical decision reaction times included reactions times for correct responses that were within 3 standard deviations from the overall mean. Lexical decision reaction times were significantly higher with a focal load (mean = 898.69 ms, SE = 24.74 ms) and nonfocal load (mean = 911.27 ms, SE = 31.95 ms) compared to the no PM load condition (mean = 734.68 ms, SE = 27.67 ms), $F(3, 93) = 12.47$, $p < 0.001$, $\eta^2 = 0.211$. Pairwise comparisons revealed no significant differences between the focal and nonfocal loads. Reaction times deceased significantly as the time on task increased, $F(3, 279) = 39.55$, $p < 0.001$, $\eta^2 = 0.298$. Across the task, pairwise comparisons showed that reaction times improved significantly across each quarter, as is shown in Figure 3.

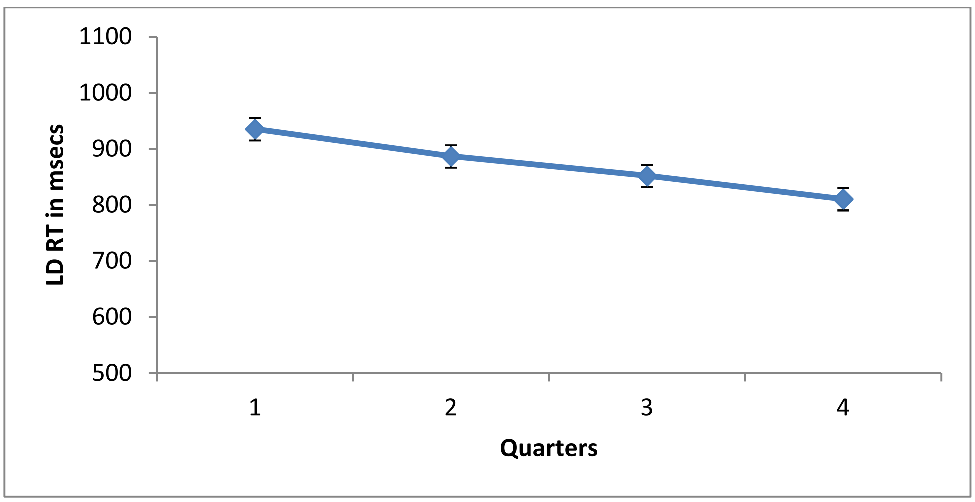

Figure 3 - Mean Lexical Decision Reaction Times across Quarters (Correct Trials Only): Lexical decision reaction times (LD RT) in milliseconds across the task, which was divided into quarters. LD RTs sped up significantly for each quarter across the task. Bars represent standard errors of the mean.

Response times also significantly differed between presentation conditions, $F(2, 93) = 15.01$, $p < 0.001$, $\eta^2 = 0.244$. The no-load (control) condition with no prospective memory demand had significantly faster reaction times (mean = 734.68 ms, SE = 27.09 ms) compared to the scheduled condition (mean = 864.78ms, SE = 27.09 ms) and random presentations (mean = 947.17 ms, SE = 27.09 ms). Scheduled and random presentations were not significantly different from each other. Reaction times deceased significantly as the time on task increased as reported in Figure 3. There was no other significant main effect or any interactions between the variables.

Pre-target Reaction Times. A mixed ANOVA was conducted to examine lexical decision reaction times to the two stimuli that preceded each target presentation (pre-target reaction times). This analysis was used to find task interference for the trials directly preceding the display of the prospective memory target compared to task interference during the whole task. In this analysis, quarters were combined and the repeated-measures variable was target performance such that pre-target reaction times before PM hits were compared to pre-target reaction times before PM misses (target hits vs. target misses). Trials that were accurate responses to the lexical decision task and had response times within 3 standard deviations from the overall mean were included. Lexical decision reaction times were significantly faster in the Scheduled presentations (mean = 800.54 ms, SE = 38.32 ms) than in the Random presentations (mean = 923.13 ms, SE = 33.97), $F(1, 44) = 5.73$, $p = 0.02$, $\eta^2 = 0.115$. No other comparisons revealed significant differences, $p > 0.05$. Target hits had mean pre-target lexical decision reaction times of 876.98 ms (SE =26.92 ms) that were not significantly different from pre-target reaction times of 846.68 ms (SE =32.26 ms) for misses.

Self-Report Measures. Levels of self-report perceived difficulty and performance were taken after the task was completed. Difficulty ratings were Likert scales from 1 to 7, with 1 being that the task was very difficult to 7 being that the task was very easy. Performance ratings were also completed on the Likert scale from 1 to 7, with 1 being very poor performance to 7 being very good performance. Frequency counts (see Figures 4 and 5) show a positive skew. Further analyses using a 2 x 3 ANOVA with PM Load and Presentation conditions were completed on both difficulty (mean =4.12, SE = 0.16) and performance ratings (mean =4.32, SE = 0.11). No significant main effects or interactions were found for either difficulty or performance ratings ($p > .05$).

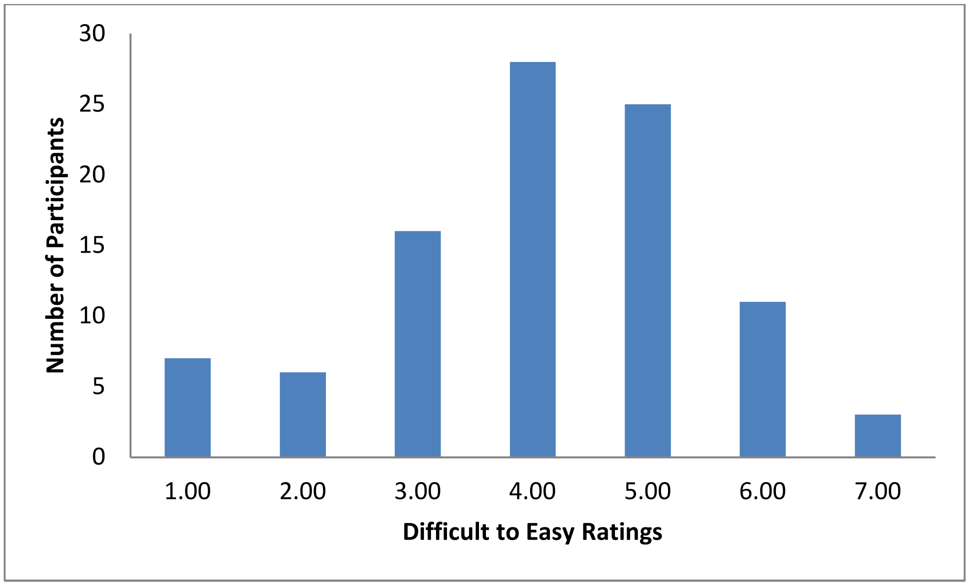

Figure 4 - Frequency of Difficulty Ratings in Post-task Survey: Number of participants who responded on a Likert scale of difficulty with ratings of 1 to 7, with 1 being the hardest and 7 being the easiest. Ratings displayed a positive skew.

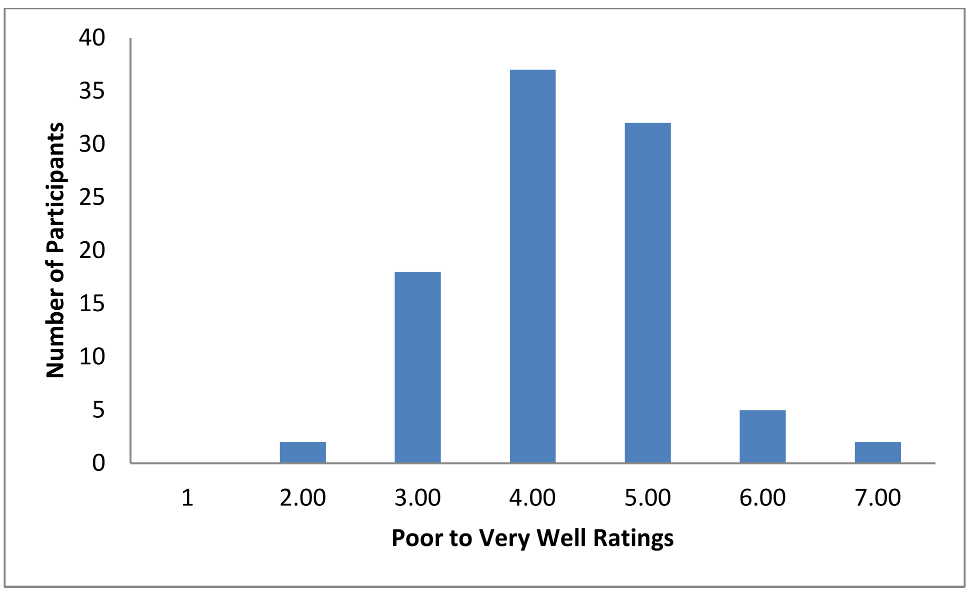

Figure 5 - Frequency of Performance Ratings in Post-task Survey: Number of participants that responded on a Likert scale of 1 to 7, with 1 being the performed extremely poorly and 7 being performed very well. Ratings displayed a positive skew.

Experiment 1 Discussion

In the current study, there was clear evidence for monitoring, but no support for the hypothesis that sustained attention was utilized for this monitoring. It was surprising that the lexical decision component of the prospective memory task did not display any vigilance decrement across trials. In fact, the opposite was true: Reaction times in the lexical decision task got significantly faster across the task. This continued speeding up of performance on the lexical decision task did not appear to plateau during the 900 trials included in this task. This finding did not match previous findings of slowing in reaction times in vigilance (sustained attention) tasks, and the increased speed across task quarters displayed here overrode any vigilance decrement that could have been produced. However, a slight but significant vigilance decrement was seen in accuracy for lexical decision trials, suggesting a speed-accuracy trade-off in lexical-decision performance: across the 900 trials, participants became motivated to respond faster, with less concern for accuracy.

A vigilance decrement was also not produced in prospective memory performance on the task. Prospective memory performance did not change across the task in the nonfocal condition. In the focal condition, prospective memory was low in the first quarter and improved to an asymptote for the rest of the task. Thus, the strong vigilance decrement that was predicted for the extended prospective memory task was not observed. This suggests either that the demands of the task were insufficient to drain the attention resources of the individual and cause cognitive fatigue (leading to the vigilance decrement) like that which is typically found in other vigilance research, or that sustained attention is not required for the prospective memory task. It may also have been that the lexical decision task, which required a response on every trial, prevented a vigilance decrement. However, this is unlikely as a vigilance decrement was found when responses are required to nontargets and responses had to be withheld for the target (Helton et. al., 2005)

Task interference was found for the prospective memory loads in the lexical decision task. That is, lexical decision reaction times were longer with a prospective memory load (regardless of the type of load) than in the control condition with no prospective memory load. The task interference suggests that participants did use monitoring to detect prospective memory targets and did not rely completely on spontaneous retrieval. Spontaneous retrieval does not require preparatory attention processes and thus leads to no interference (divided attention) costs. Additionally, the data regarding presentation condition supported the use of monitoring. Task interference was seen for both the random and scheduled presentation groups, regardless of the type of prospective memory load. Including a prospective memory load in any way caused lexical decision reaction times to be slower than without the load. This task interference implies that there was monitoring being used during the dual-task. However, pre-target reaction times failed to show a difference between target hits versus target misses, suggesting that attention was not continuously divided between lexical decision judgments and monitoring for prospective memory targets (or if it was, that attention was not effective in improving target detection). Rather, it appears that prospective memory targets produced an increase of attention demands, but higher task interference did not lead to an increased likelihood of accomplishing the prospective memory.

Performance in the present prospective memory task was comparable to performance found in previous research (Einstein et al., 2005). Higher focal performance for prospective memory compared to nonfocal performance was expected, as nonfocal loads are more challenging prospective memory events, regardless of the cognitive mechanism supporting the task. It is interesting that both the focal load and the nonfocal load had similar lexical decision reaction times even though prospective memory accuracy was significantly different. Prospective memory performance in this task varied dependent upon the type of prospective memory and the length of time on task. In the first quarter, performance was lowest overall across all quarters of the focal condition, but that performance improved in the second quarter and then reached a plateau for the last 450 trials. This initial increase from Quarter 1 to Quarter 2 in performance could have been caused by the repeated presentation of the focal target. That is, repetition priming would have facilitated PM responses to the repeated target stimulus. However, performance did not improve continuously across the task as would have been expected with a repetition priming effect. Thus, repetition priming effect was not found here in the prospective memory task. Nonfocal targets varied across the task and did not repeat, to keep them from becoming focal targets.

The Signal Regularity effect (Helton et al., 2005) was not demonstrated here. Prospective memory performance was not significantly more accurate or faster on target trials in the scheduled than the random condition, and prospective memory performance did not increase across the task, as might be expected if participants were routinely learning the schedule. In fact, only one participant correctly stated in the debriefing responses that a pattern existed of a regularly scheduled number of words and nonwords between the targets. Indeed, contrary to expectations, accuracy was higher on prospective memory targets for random presentation compared to scheduled presentation. Perhaps the participants were looking for a pattern in the targets regardless of the prospective memory load or presentation condition and this activity was draining resources more to keep track of the trials and thus caused more errors. Nevertheless, there was no difference in pre-target trials reaction times between scheduled and random presentation of the prospective memory targets. Additionally, there were no differences between expected and unexpected target presentations. It seems that the presentation of only 2% targets with targets averaging every 50 trials (ranging from 16 to 114 trials) was too infrequent for the schedule to be perceived.

The findings suggest that target presentation encouraged different strategies in the use of monitoring compared to spontaneous retrieval, regardless of whether prospective memory targets were focal or nonfocal. Compared to the scheduled condition, accuracy for the targets was significantly higher for random presentations, with slower lexical decision reaction times. However, reaction times did not differ as a function of whether the target was correctly hit or missed. Thus, the schedule may have encouraged different strategies between speed and accuracy, but these strategies did not affect whether reaction times could predict when a target could be correctly detected. Looking at the performance on pre-target trials, the scheduled presentations had significantly slower pre-target reaction times than the random presentations. Perhaps these differences reflect the early stages of implicit learning of the schedule, but it seems clear that the presentation of targets was too infrequent for the pattern to be learned as prospective memory performance did not increase in the scheduled presentations nor was the pattern identified. The absence of significant schedule effects was unexpected. One might expect to see no schedule effects if the task was too hard, even when participants were monitoring. However, this is unlikely in the present case, as the difficulty ratings of the task do not reflect a high level of self-reported difficulty with the task. Additionally, lexical decision accuracy and prospective memory performance were similar to levels found previously in the literature.

A possible explanation for the evidence of monitoring with both the focal and nonfocal loads found here was a unique methodology used in the current experiment, in which the participants were required to respond to the prospective memory cue before any lexical decision had been made. In fact, a lexical decision was not necessary at all on prospective memory trials. However, participants were instructed to make the lexical decision task their overall primary goal. Thus, there was a conflict between the priority of the lexical decision task and the requirement to suspend lexical decision in favor of a prospective memory response on target trials. Inhibition of this primary goal in order to perform the prospective memory decision could have been the reason that the prospective memory task interfered with lexical decision. That is, attention may have been diverted from the lexical decision not by monitoring per se, but rather as a cognitive cost of the requirement to inhibit a word/nonword response on trials in which the prospective-memory target appeared.

Another issue in this study may have been the instructions themselves. We had an unusually high number of participants (N = 17) that were excluded from the final analyses due to their lack of knowledge evidenced in the post-task survey about the prospective memory component of the task. These participants seem to have missed completely that they were supposed to looking for a specific target word. It seems reasonable to suggest that instructions that promoted better memory of the task demands might produce patterns of data that were more consistent with expectations. This suggests that it might be necessary to require confirmation of the target to ensure participants read and understood the instructions.

3: EXPERIMENT 2

As was discussed above, Experiment 1 required that responses to the concurrent task be inhibited in order to respond to the prospective memory target. In many prospective memory tasks, the ongoing task is a lexical decision task in which participants are required to respond to the cue as being a word or nonword (McDaniel & Einstein, 2007). There is freedom to respond to the cue as a prospective memory target after the word/nonword decision has been made. However, in many real life scenarios that require prospective memory, one must stop the current activity to perform the prospective memory action. Air traffic controllers do not have the freedom of clearing a flight path altitude and then requiring the plane to alter its course or altitude to avoid collisions. Controllers have to focus instead on clearing the plane only after it is determined that atypical actions are not required. Loft and colleagues (Loft & Remington, 2010; Loft, Finnerty & Remington, 2011) applied prospective memory theories to air traffic control (ATC) simulations in which participants had to monitor air traffic patterns. Performance on these tasks was lowered when an additional goal of performing a prospective memory task was added. Additionally, the prospective memory task was not completed in the course of the task; thus, performance was not as high as in other studies. In these studies, performance of the prospective memory action was required in special circumstances where the action was conducted instead of the normal action. This method of responding could be producing differential costs on sustained attention. This is caused by the addition of inhibition to the prospective memory task. Inhibitory control helps explain the age differences within prospective memory, and thus is a key cognitive component of performance in prospective memory tasks (Kliegel, Mackinlay & Jager, 2008).

In the vigilance literature, tasks have used overt responding by button pushing to targets, or alternatively overt responding to nontargets and inhibiting this response to signify a target. The detection rate of vigilance targets was significantly higher in conditions with responses to targets compared to responses being withheld to targets (Helton et al., 2005). The authors took these findings as support for the explanation that vigilance costs are caused by the mental burden of sustained attention. Thus, it is reasonable to suppose that any sustained attention utilized in prospective memory tasks would also be subject to additional costs caused by inhibiting responses.

Prospective memory tasks can vary widely, and methods do not always stipulate whether prospective memory responses are required as the only response to a cue or can be made after an initial response to another attribute of the cue. The current study was designed to test performance on both the lexical decision task and the prospective memory task when the pattern of responding is manipulated. Prospective memory is not limited to performance of an action immediately after the cue, but it can be necessary to stop the current activity to perform the action. The costs of stopping the current activity to perform a prospective memory action are currently unknown. In this current experiment, I investigated how different rules for responding to prospective memory targets affected performance. Experiment 1 required inhibition of the current activity to perform the prospective memory task while the current experiment allowed responses to occur within a specified time. I predicted that prospective memory performance would be negatively affected by requiring that the lexical decision response be inhibited to perform the prospective memory response, as was done in Experiment 1. That is, I expected that performance would be higher if participants were allowed to respond whenever they recognized prospective memory targets, whether before or after making a lexical decision response, or even within the next few trials following the prospective memory target.

Experiment 2 Method

Participants. A total of 141 participants (98 females and 34 males, plus 9 participants that preferred not to answer) were recruited using Sona Systems at Georgia State University, with 13 dropped due to computer issues. Participants received one credit hour to use in their introductory Psychology class to satisfy a course requirement. Participants who stated in the exit questions that they did not know the prospective memory cue were not included in the analysis. Thus, 34 participants were excluded, leaving 94 participants (67 females, 21 males) included in the mixed ANOVA. The demographic characteristics and assignment rules were like those in Experiment 1. Age ranged from 18 to 39 years old, with an average age of 18.40 years. Unless otherwise indicated, the apparatus and tasks were those of Experiment 1.

Procedure. The procedure was the same as in Experiment 1, with two notable exceptions. In Experiment 1, participants were required to inhibit responding whether the letter string (PM target) was a word or nonword in order to press the spacebar. Thus, they had to inhibit their current actions to perform the prospective memory action. For Experiment 2, participants were instructed that as soon as they realized that they saw a prospective memory cue, the spacebar should be pressed, whether or not they had already responded word/nonword, and even whether or not another lexical decision stimulus had appeared on the screen. Thus, these new instructions allowed response to the PM target to occur after the lexical decision had been made. Second, a confirmation of target was added directly after the prospective memory instructions. Following the instructions for the prospective memory task, participants were required to confirm knowledge of the prospective memory target by typing the target into the program. Following target verification was a response verification screen. Participants were asked to press the key that they were supposed to press when they saw the prospective memory target. They were once again given the prospective memory target in these instructions. The correct response was the spacebar. Feedback was given to reinforce that participants had correctly remembered their target response (spacebar), or, if incorrect, instructions again appeared to press the spacebar to the target. This change was done to encourage participant to remember the prospective memory element of the task, with the goal of lowering the number of participants who were dropped from the analysis due to inability to remember the target.

As in Experiment 1, the prospective memory task was embedded in a lexical decision task with 900 trials. There were three prospective memory load conditions, manipulated as between-groups variables: no prospective memory load (control), the nonfocal condition (*g*-words) or the focal condition (*governs)*. For the latter two conditions, targets were presented on 2% of the 900 lexical decision trials (18 critical targets) in either random presentations or regularly scheduled presentations. As in the previous experiment, presentation condition (random or scheduled) was also a between-groups manipulation.

Experiment 2 Results

Multiple one-way ANOVAs were conducted to determine whether age, gender, or race affected performance. None of the effects were significant, $p > 0.10$. Experiment 2 was a 3 x 3 x 4 mixed design, with PM load (no PM load, focal, nonfocal) and schedule (no PM load, scheduled, random) as between-groups variables and task quarters (1 to 4) as the within-subject variable. The analysis strategy was identical to that of Experiment 1.

PM Target Accuracy. A mixed ANOVA was conducted for the dependent variable of accuracy for the prospective memory trials. All means in the analysis were figured as percentages of correct PM trials compared to all PM target presentations. The focal condition (mean = 93%, SE = 5.4%) had significantly more accurate performance on PM target detection compared to the nonfocal condition (mean = 41%, SE= 5.1%), $F(1, 74) = 49.12$, $p < 0.001$, $\eta^2 = 0.402$. PM Accuracy varied significantly across the quarters, $F(3, 222) = 3.56$, $p = 0.044$, $\eta^2 = 0.040$. Pairwise comparisons show that Q1 and Q2 were significantly lower accuracy on PM trials than Q4 (see Figure 6). There were no significant differences between Q3 and Q4. PM Accuracy did not interact with other variables.

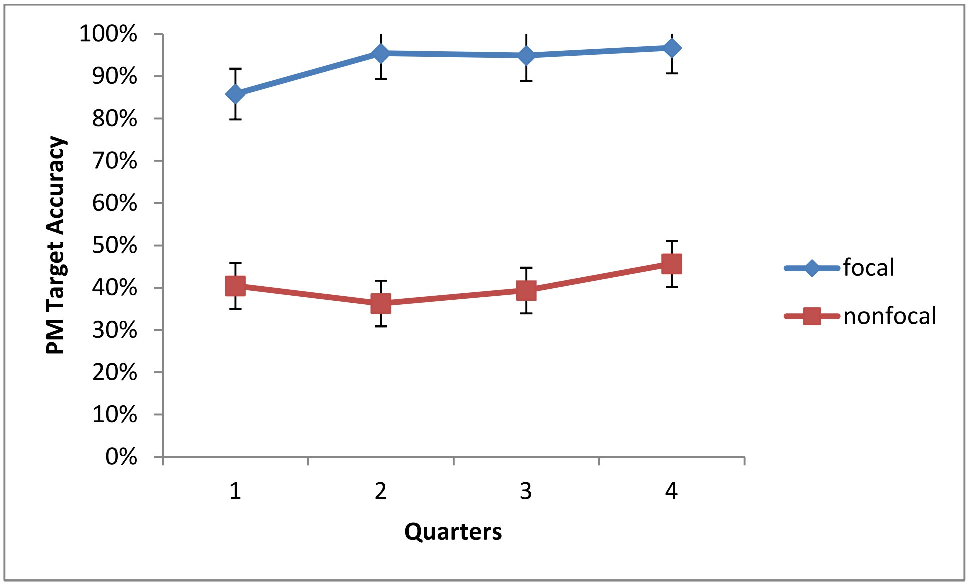

Figure 6: Prospective Memory Accuracy across Quarters for PM loads: Mean prospective memory accuracy (percent correct) for focal and nonfocal targets across the task, which was divided into quarters. PM Accuracy in Q1 and Q2 was significantly lower than Q4, but there was no significant interaction between PM Accuracy and target load type. Bars represent standard errors.

Lexical Decision Accuracy. Multiple ANOVAs were completed for the dependent variable of lexical decision accuracy. Separate ANOVAs were conducted for PM load and Schedule. Lexical decision accuracy included trials that were accurate responses to the lexical decision with reaction times within 3 standard deviations and excluded trials that displayed PM targets. Accuracy varied significantly across quarters, $F(3, 273) = 7.09$, $p < 0.001$, $\eta^2 = 0.071$. In the pairwise comparisons, lexical decision accuracy was significantly higher in Q1 than in Q2 and Q3 with no difference from Q4. There were no significant differences in accuracy between Q2, Q3 and Q4. Accuracy in Q1 was 83% correct, SE = 1.2%, Q2 was 81% correct, SE = 1.2%, Q3 was 82% correct, SE = 1.1% and Q4 was 82% correct, SE = 1.2%. This main effect was qualified by an interaction of length of time on task and Schedule, $F(6, 273) = 2.25$, $p = 0.048$, $\eta^2 = 0.047$ and an interaction of length of time on task and PM Load, $F(6, 273) = 2.27$, $p = 0.046$, $\eta^2 = 0.048$. When divided by Presentation condition, accuracy varied significantly across the task quarters both for Scheduled, $F(3, 108) = 6.08$, $p = 0.004$, $\eta^2 = 0.144$ and also for Random, $F(3, 123) = 7.09$, $p < 0.001$, $\eta^2 = 0.233$. For scheduled targets, performance in Q1 was significantly more accurate than Q3.

With random targets, accuracy was significantly higher in the first quarter than all others. The control condition did not vary significantly across the task. The interaction can be seen in Figure 7.

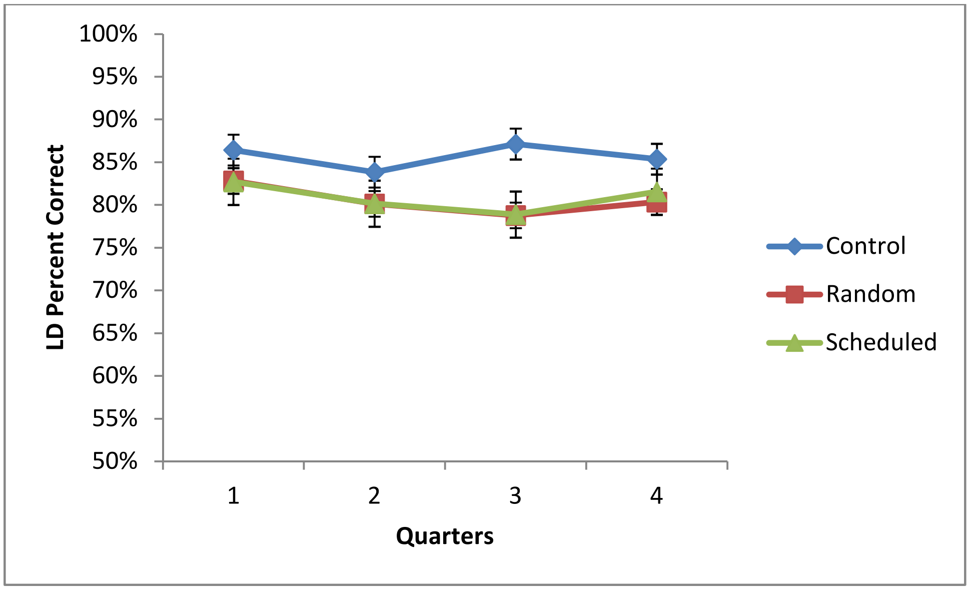

Figure 7: Lexical Decision Accuracy across Quarters for Presentation Conditions: Mean lexical decision accuracy (percent correct) for different target schedules across the task, which was divided into quarters. In the scheduled target condition, lexical decision accuracy was significantly higher than in Q3. Lexical decision accuracy in the random target condition was significantly higher in Q1 than the rest of the task. Performance on the control condition did not vary across the task. Bars represent standard errors.

When divided by type of PM load, lexical decision accuracy varied significantly across the task for focal load, $F(3, 105) = 10.43$, $p < 0.001$, $\eta^2 = 0.230$ and nonfocal load, $F(3, 123) = 6.46$, $p = 0.001$, $\eta^2 = 0.133$. The No PM load group did not produce significant differences across task quarters. Accuracy with the focal load decreased significantly from Q1 to Q2, stayed similar in Q3 and increased in Q4. With nonfocal targets, accuracy was significantly higher in Q1 than Q2 or Q3. The interaction can be seen in Figure 8. No other significant main effects or interactions were observed.

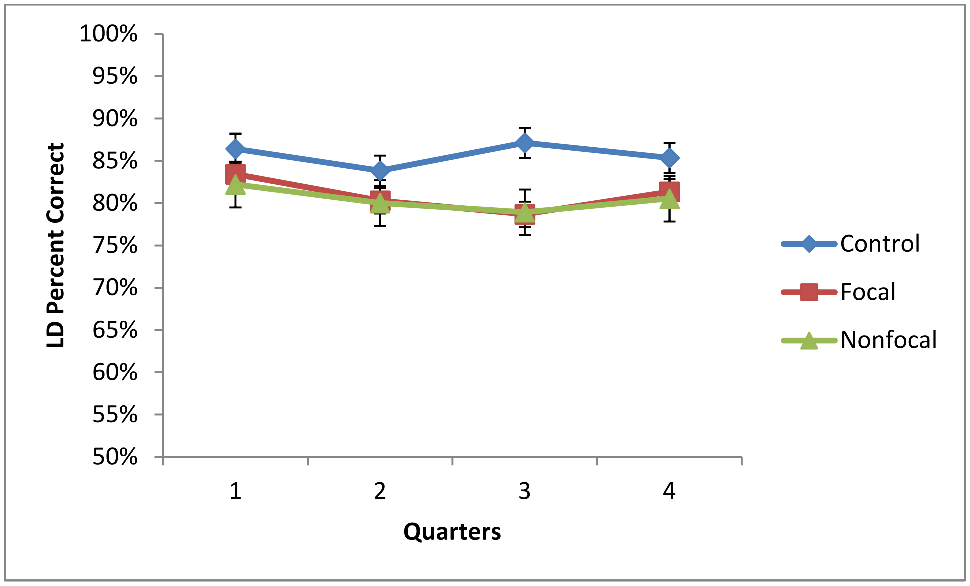

Figure 8: Lexical Decision Accuracy across Quarters for PM Loads: Mean lexical decision accuracy (percent correct) for different prospective memory loads across the task, which was divided into quarters. Accuracy with the focal load decreased significantly from Q1 to Q2, stayed similar in Q3 and increased in Q4. With nonfocal targets, accuracy was significantly higher in Q1 than Q2 or Q3. Performance on the control condition did not vary across the task. Bars represent standard errors.

Lexical Decision Reaction Times. Multiple ANOVAs were completed for the dependent variable of lexical decision reaction times. Separate ANOVAs were conducted for PM load and Schedule. The analyses of lexical decision reaction times included trials in which responses were correct and latencies were within 3 standard deviations from the mean. Unlike in Experiment 1, there was no significant effect of length of time on task (quarters). There was no significant main effect for PM Load, Schedule or any interactions between the variables. Mean lexical decision response times were statically similar for focal-scheduled (920.14 ms), focal-random (1000.24 ms), nonfocal-scheduled (1000.91 ms), nonfocal-random (958.42 ms), and no-load control (876.68 ms), $p > .10$.

Pre-target Reaction Times. A mixed ANOVA was conducted to examine lexical decision reaction times to the two stimuli that preceded each target presentation (pre-target reaction times). In this analysis, quarters were combined and the repeated-measures variable was target performance such that pre-target reaction times before PM hits versus PM misses (target hits vs. target misses). Trials that were accurate responses to the lexical decision and with response times within 3 standard deviations from the mean were included. No significant main effects or interactions were observed. Thus, there was no significant difference between reaction times before PM trials where targets were hit compared to when targets where missed.

Self-Report Measures. Levels of perceived difficulty and performance were taken after the task was completed. Difficulty ratings were Likert scales from 1 to 7, with 1 being that the task was very difficult to 7 being that the task was very easy. Performance ratings were also completed on the Likert scale from 1 to 7, with 1 being very poor performance to 7 being very good performance. Further analyses using 2 x 2 ANOVAs with PM Load and Target Schedule were completed on both difficulty and performance ratings. PM Load had a significant main effect on difficulty ratings, $F(1, 89) = 4.95$, $p = 0.029$, $\eta^2 = 0.053$. Pairwise comparisons showed that focal load was higher in difficulty ratings (mean = 5.07, SE = 0.24) compared to nonfocal load (mean = 4.33, SE = 0.23), but not different from no-load (mean = 4.53, SE = 0.37). There was no significant difference in performance ratings between no-load and nonfocal.

Performance ratings differed significantly across PM loads, $F(1, 89) = 12.51$, $p = 0.001$, $\eta^2 = 0.123$. Pairwise comparisons showed that focal load was significantly higher in performance ratings (mean = 4.99, SE = 0.24) compared to nonfocal load (mean = 3.83, SE = 0.23), but not different from no-load (mean = 4.20, SE = 0.36). There was no significant difference in performance ratings between no-load and nonfocal.

Comparison with Experiment 1. Data from Experiment 2 were compared to those from Experiment 1 using a mixed design ANOVA. Prospective memory target accuracy was examined to determine whether accuracy varied dependent upon the type of responding. Lexical decision reaction times were compared to determine whether monitoring or spontaneous retrieval was utilized differently between the experiments. For the dependent variable of prospective memory target accuracy, no significant main effects or interactions between the two experiments were observed.

For the dependent variable of lexical decision reaction times, reaction times differed significantly dependent upon the target presentation, $F(3, 552) = 18.84$, $p < 0.001$, $\eta^2 = 0.093$. The No-load (control) condition with no prospective memory demand had significantly faster reaction times (mean = 805.68 ms, SE = 27.34 ms) compared to the scheduled condition (mean = 908.83 ms, SE = 21.09 ms) and random presentations (mean = 957.67 ms, SE = 20.50 ms). Scheduled and random presentations were not significantly different from each other. Lexical decision reaction times were significantly higher with a focal load (mean = 924.99 ms, SE = 20.24 ms) and nonfocal load (mean = 942.48 ms, SE = 22.46 ms) compared to the no PM load condition (mean = 805.68 ms, SE = 27.56 ms), $F(2, 184) = 8.37$, $p < 0.001$, $\eta^2 = 0.083$. Pairwise comparisons revealed no significant differences between the focal and nonfocal loads. None of these main effects were qualified by an interaction with experiments, consequently the data displayed in Figure 9 are collapsed across experiments.

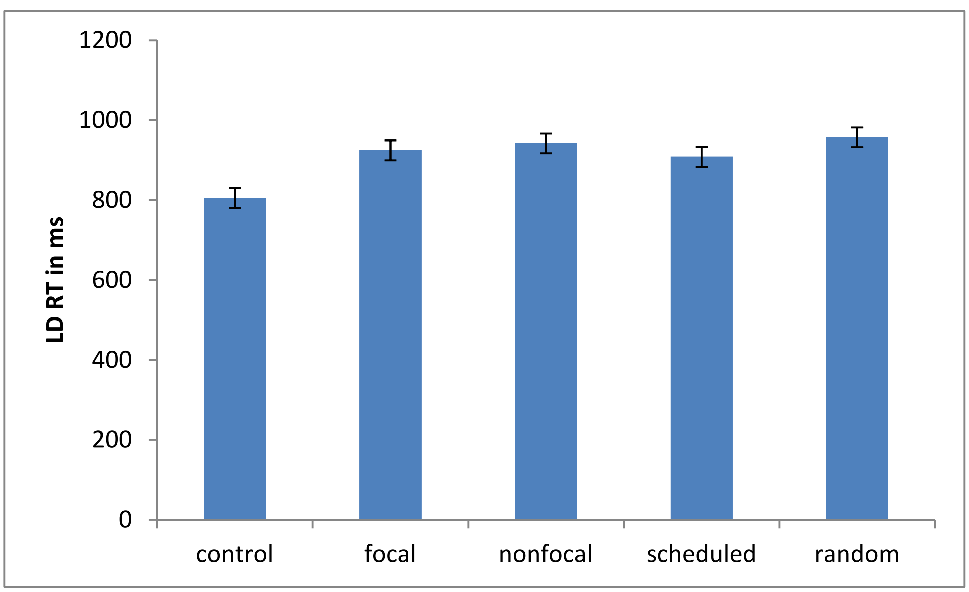

Figure 9: Mean Lexical Decision Reaction Times for Prospective Memory Load and Schedules: Lexical decision reaction times combined across Experiment 1 and 2 divided by PM load and target schedules. The control condition was significantly faster than any condition that contained a prospective memory

load. There were no significant differences in LD RT between the type of PM load. Bars represent standard errors.

Responses were significantly faster in the inhibition-response conditions of Experiment 1 (mean = 848.36 ms, SE = 18.38 ms) compared to Experiment 2 with freedom to respond within 5 trials of a target (mean = 933.74 ms, SE = 20.15 ms), $F(3, 552) = 10.49$, $p = 0.001$, $\eta^2 = 0.054$. Reaction times varied across the task, $F(3, 552) = 18.84$, $p < 0.001$, $\eta^2 = 0.093$. These main effect was qualified by an interaction between Response Types and Quarters, $F(3, 552) = 5.15$, $p = 0.006$, $\eta^2 = 0.027$ (See Figure 10). The data were split according to Response Type and a mixed measure ANOVA was repeated to delve into the interaction. Response times did not vary significantly across Quarters in the free response condition (Experiment 2). Reaction times for the inhibit response condition (Experiment 1) decreased significantly across the task. No other significant main effects or interactions were observed.

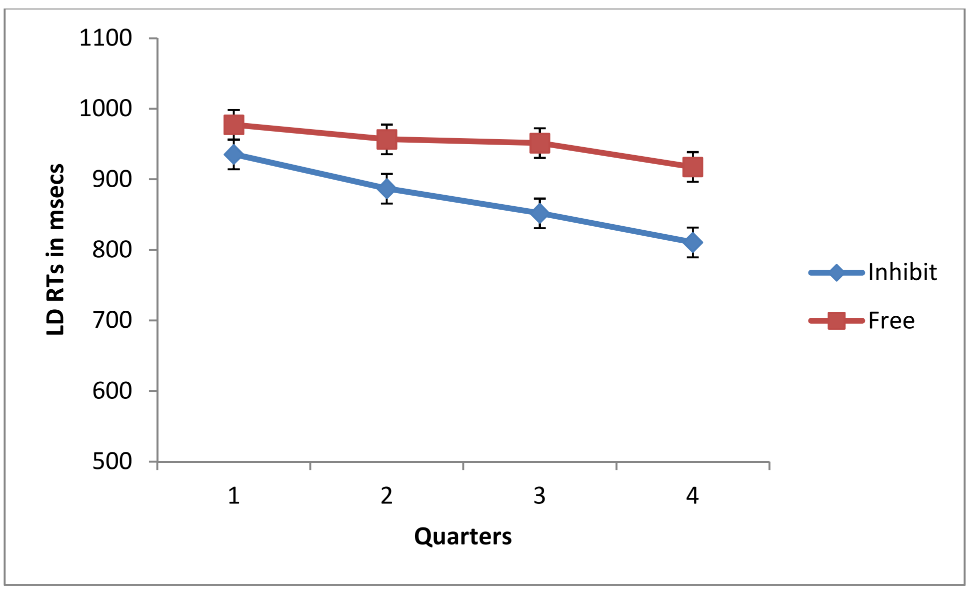

Figure 10: Mean Lexical Decision Reaction Times for Response Types (i.e., Experiment 1 versus Experiment 2) across Quarters: Lexical decision reaction times for response types across the task which was divided into quarters. LD RTs did not vary across the task with Free Responding (Experiment 2) whereas LD RTs were significantly faster in each quarter with Inhibit responding (Experiment 1). Bars represent standard errors.

As task interference was found without an interaction between experiments, further analyses were completed. Controls were compared between the experiments and were found to be significantly slower in the current experiment (mean = 876.68 ms, SE = 35.85 ms) compared to Experiment 1 with inhibition responding (mean = 734.68 ms, SE = 24.55 ms), $F(3, 552) = 10.68$, $p = 0.002$, $\eta^2 = 0.192$. Comparisons without the controls, including only PM loads, were conducted using a 2 x 2 x 2 ANOVA. Free responding reaction times were found to be significantly slower in the current experiment (mean = 969.93 ms, SE = 21.76 ms) compared to Experiment 1 with inhibition responding (mean = 905.21 ms, SE = 24.0 ms), $F(3, 552) = 3.99$, $p = 0.048$, $\eta^2 = 0.029$. No other significant main effects or interactions were observed.

Experiment 2 Discussion

Consistent with the previous findings from Experiment 1, sustained attention appeared not to be necessary to accomplish the prospective memory requirements here, as variables that typically affect vigilance were not found to influence performance in the extended version of the dual-task paradigm used in this experiment. Neither the lexical decision reaction times nor the prospective memory judgments displayed any vigilance decrement across trials. Thus, even with the removal of the demands to inhibit a lexical decision response to a prospective memory probe, no vigilance decrements were found. Lexical decision accuracy may have shown a slight vigilance decrement, as participants were significantly most accurate in the first quarter of trials. This decrement was not found in the control condition (without a prospective memory intention), whereas accuracy decreased across the task with a prospective memory load. Prospective memory accuracy actually increased from the beginning to the end of the task, regardless of whether the target was focal or nonfocal. Although this pattern might be expected if participants were learning the regularity of target presentation, there was again no evidence of the Signal Regularity Effect (i.e., no effects or interactions of presentation schedule or differences in probe trials). More likely, the increase was caused by multiple presentations increasing performance or functioning as a reminder of the prospective memory element of the task. Repetition priming is not a likely explanation in this case, as there was no difference between focal and nonfocal performance. The same focal target (*governs*) was presented multiple times whereas nonfocal targets (*g*- words) also had multiple presentations, but did not repeat. Taken together, this pattern of results suggests that prospective memory monitoring did not follow the sustained attention pattern observed in vigilance, even when some evidence of monitoring was observed.

Contrary to the results in Experiment 1, the findings in the current experiment seem to suggest that spontaneous retrieval was the cognitive mechanism employed to accomplish responding to prospective memory targets. Prospective memory load had no significant effect on lexical decision reaction times or accuracy. Thus, task interference was not found as evidence of any monitoring costs. Without requiring participants to inhibit lexical decision responses in Experiment 2, there was no evidence of monitoring. Not only did the PM load have no effect on lexical decision speed or accuracy, neither did the target presentation conditions. Monitoring was not caused by focal or nonfocal prospective memory targets. The presentation condition, regardless of scheduled or random presentations, did not have significantly different lexical decision reaction times in either analysis of overall reaction times or pre-target reaction times. The task interference due to prospective memory intentions that was found in Experiment 1 was removed when participants had free responding. Thus, the costs previously found were driven by the costs associated with adding inhibition to the dual-task paradigm.

Although clear evidence for monitoring was not found in the current experiment, the discussion of the findings is not as simple as the previous paragraph would lead one to believe. When data from the current experiment and previous experiment were combined, evidence for monitoring was found overall, with no interaction between the type of responding and the prospective memory load. Comparisons of the prospective memory load conditions did not display any significant differences between the two types of responding. These findings suggest that monitoring was being utilized with free responding as well as inhibition responding from the previous experiment. The current experiment had significantly slower lexical decision reaction times even during the no-load condition compared to the no-load condition in the previous experiment. It is unclear why reaction times in the no-load condition were elevated in the current experiment compared to the previous experiment. Other than the switching the response requirements from inhibition responding to free responding (which should not have affected the control condition, because it had no prospective memory demands at all), the only other change was a slight difference in wording of the instructions. Nevertheless, the increase in lexical decision reaction times for the no-load condition in the current experiment appears to have complicated the interpretation of whether participants in the focal and nonfocal groups were monitoring.

The type of prospective memory load did change prospective memory performance. Nonfocal target performance was significantly lower than focal target performance. However, other than prospective memory accuracy, prospective memory load did not otherwise affect performance. The comparison of pre-target lexical decision reaction times were not significantly different between when a target was going to be hit or missed. These findings together lend support to the premise of the Multiprocess theory that spontaneous retrieval can be used reliably to accomplish a prospective memory task.

Free responding to a prospective memory target (i.e., the freedom to respond within 3 trials of a target-word presentation) did not increase performance on the prospective memory task, irrespective of the type of prospective memory load. Accuracy on the prospective memory task was higher for focal load compared to nonfocal load, both with free responding (Experiment 2) and inhibition responding (Experiment 1). Compared to inhibition responding, prospective memory accuracy was higher and closer to a ceiling effect with the focal load compared to no differences in the nonfocal load. This could be caused by free responding allowing spontaneous retrieval more time to activate a response to the focal prospective memory targets. The nonfocal memory load still can utilize spontaneous retrieval, as evidenced by correct responses to the target without evidence of monitoring; but regardless of responding type, monitoring may be necessary to achieve prospective memory accuracy levels above the levels that were reported here for nonfocal targets. However, when monitoring in Experiment 1, prospective memory performance was not higher.

When comparing the data between Experiment 1 and Experiment 2, it is interesting to note that reaction times to the lexical decisions were faster with the inhibition responding compared to free responding. It is important to note that this difference was not simply an artifact of delayed lexical decision responses on trials with a prospective memory probe stimulus. Those trials were always excluded from analyses of lexical decision response time and accuracy. More specifically, the response times were comparable between Experiment 1 and Experiment 2 at the beginning of the task (first quarter). Contrary to the speeding up of reaction times seen in Experiment 1, reaction times in the current experiment did not change significantly across the task quarters. As previously discussed, task interference between the prospective memory demand and the lexical decision judgments was observed when performance was combined across experiments. Consequently, further analyses were conducted to delve into these data. When comparing inhibition responding and free responding for only prospective memory load conditions (i.e., not including the no-load condition), lexical decision reaction times were significantly longer with free responding than inhibition responding. A potential explanation is the inhibition responding encouraged participants to focus on the strength of the routine of lexical decisions. Thus, the strong routine would lead to giving the lexical decision a higher priority than the prospective memory. Free responding could be allowing the focus (thus priority of task) to shift from the strong routine of lexical decisions to shifting attention between the dual-tasks. This suggestion was explored in Experiment 5. However, Experiment 3 was conducted first to explore the relation between resource depletion and monitoring in a prospective memory test.

4: EXPERIMENT 3

The third study was designed to investigate whether taxing attention resources through a demanding task would temporarily interfere with monitoring performance on the subsequent prospective memory task. In the previous experiments, evidence of the vigilance decrement was not found. This did not support the hypothesis that sustained attention is needed during prospective memory. Another premise for looking for evidence of sustained attention during a prospective memory task is to determine whether reduced attention resources adversely affects performance during the dual-task. Resource theory states that attention is a resource, like mental energy, that has a flexible but finite capacity (Kahneman, 1973; Engle, Conway, Tuholski & Shisler, 1995; Helton & Warm, 2008). At any time, an individual has a limited amount of attention that can be divided between tasks or activities. The amount of resources is subject to the level of arousal during the task. Greater arousal produces higher amounts of resources whereas less arousal yields less attention resources. Different tasks can require varying levels of attention resources and individuals allocate attention in ways to optimize performance. Importantly, automatic processes do not utilize attention resources whereas controlled processes do consume attention resources (Shiffrin & Schneider, 1977). Multiple tasks can be completed concurrently so long as the combined tasks do not require more resources than are available. Furthermore, if a task consumes attention resources and there is insufficient time for those resources to be replenished, then performance on subsequent tasks may also be impaired (Engle, Conway, Tuholski & Shisler, 1995).

The resource allocation theory can be used as an explanation for the vigilance decrement (Helton & Warm, 2008). Sustaining attention for an extended amount of time taxes resources and consumes them to the point where too few resources are still available to accomplish the task at an optimal level. Thus, performance on the task decreases as the tasks continues to drain resources until a plateau is reached. Most important, vigilance tasks have been found to be capacity draining and resource demanding (Helton et al., 2007). The vigilance decrement can be increased by increasing the difficulty of the task within the vigil (See et al., 1995).

As both vigilance tasks and nonfocal prospective memory tasks are theorized to rely on sustained attention for successful task completion, one could expect that nonfocal prospective memory tasks would be also subject to the capacity limits set forth in the resource theory because attention must be sustained. Moreover, nonfocal prospective memory tasks require attention shifting in addition to sustained attention. Attention shifting adds an extra drain on attention resources above and beyond the attention demand from sustaining attention on nonfocal information in addition to the concurrent task.

Sustaining attention depletes attention resources and results in a vigilance decrement. Nonfocal prospective memory tasks require sustained attention to monitor for targets. Taken together, these findings suggest that if attention resources were depleted before a nonfocal prospective memory task was begun, then prospective memory performance would suffer. The present experiment was designed to tax a participant's attention resources with the attention demanding task. Then, the resulting effect on monitoring was determined during a subsequent prospective memory task. A resource depletion task known as the Number-Letter task was adapted by Friedman, Miyake and colleges (Friedman, Miyake, Corley, Young, DeFries & Hewitt, 2006) from a task originally developed by Rogers and Monsell (1995). I predicted that when working with grossly depleted resources, participants would be less vigilant monitors. This result would suggest that the variables affecting sustained attention might be similarly affecting monitoring.

The Number-Letter task requires participants to switch attention between the stimuli presented along with continuous switching between which goal needs to be maintained. In order to cause task switching, the Number-Letter task requires participants to respond to either the letter or number, dependent upon the location of the stimulus presentation. A pair of one letter and one number was displayed in one quadrant of a grid on the screen. The rule for responding to either the letter or number is dependent upon presentation location. Thus, constant goal maintenance in this task is vital, similar to the Stroop task (Kane & Engle, 2003). Furthermore, resources are further taxed by switching attention between the stimuli.

As was discussed previously, working memory capacity has been shown to affect prospective memory performance when the task was nonfocal (Brewer et al., 2010). Thus, when sustained attention is necessary to complete the prospective memory task (as in nonfocal tasks), then performance is more reliant on attention control. As attention control is important during nonfocal prospective memory tasks and because resource theory states that attention is limited, then it was expected that depletion of attention resources during the Number-Letter task would be detrimental to performance during the nonfocal task but have no effect on performance in the focal task.

Experiment 3 Method

Participants. A total of 147 participants (114 females and 24 males, plus 9 participants that preferred not to answer) were recruited using Sona Systems at Georgia State University. Participants received one credit hour to use in their introductory Psychology class to satisfy a course requirement. Due to computer problems, 9 participants were not included in the analysis because they did not complete all the tasks. Participants who stated in the exit questions that they did not know the prospective memory cue were not included in the analysis. Thus, 37 participants were excluded, leaving 101 participants (77 females, 19 males) included in the mixed ANOVA. The demographic characteristics were similar those in Experiment 1. The demographic characteristics included age, gender and race. Age ranged from 18 to 40 years old, with the average age of 19.41 years.

Number-Letter Task. The Number-Letter task measured the control necessary to set-switch. A pair of stimuli consisting of one letter and one number was displayed in one quadrant of a grid on the screen (see Figure 11). The Number-Letter task required participants to respond to either the letter or number, depending upon the location of the stimulus presentation. If the pair was displayed in one of the top two quadrants, then the participant should have indicated via button-press whether the number was odd or even. If the number was odd, participants clicked the left mouse button but if even, they clicked the right mouse button. If the Number-Letter pair displayed in one of the bottom two quadrants of the screen, the participant were supposed to indicate whether the letter was a consonant or vowel. If a consonant, participants were instructed to click the left mouse button and if a vowel, to click the right mouse button. Also displayed on the top of the screen above the stimulus display box were reminder instructions. The instructions displayed were "Top = even/odd. Bottom = consonant/vowel" and were displayed after errors in the task. Responses had to be made within a titrated time limit based on performance or participants received a penalty of 3 seconds of buzzing plus time out. When the response was correct, the next trial was presented. If the response was incorrect, a buzz sounded for 3 seconds while the rule that was displayed on the top of the screen was displayed also below the stimulus display box. The intertrial interval was 3 seconds.

Participants were randomly assigned to the one of two possible Number-Letter conditions: one-rule or two-rule. The one response rule (one-rule) was to determine whether the letter in stimulus pair was a consonant or vowel. The one-rule number-Letter task displayed the stimulus pair in only the top two quadrants so as not to require goal switching and thus not to be attention demanding. The two-rule condition included two rules to follow, either letter or number decision based on the location of the stimuli. Each participant completed 200 trials of the task.

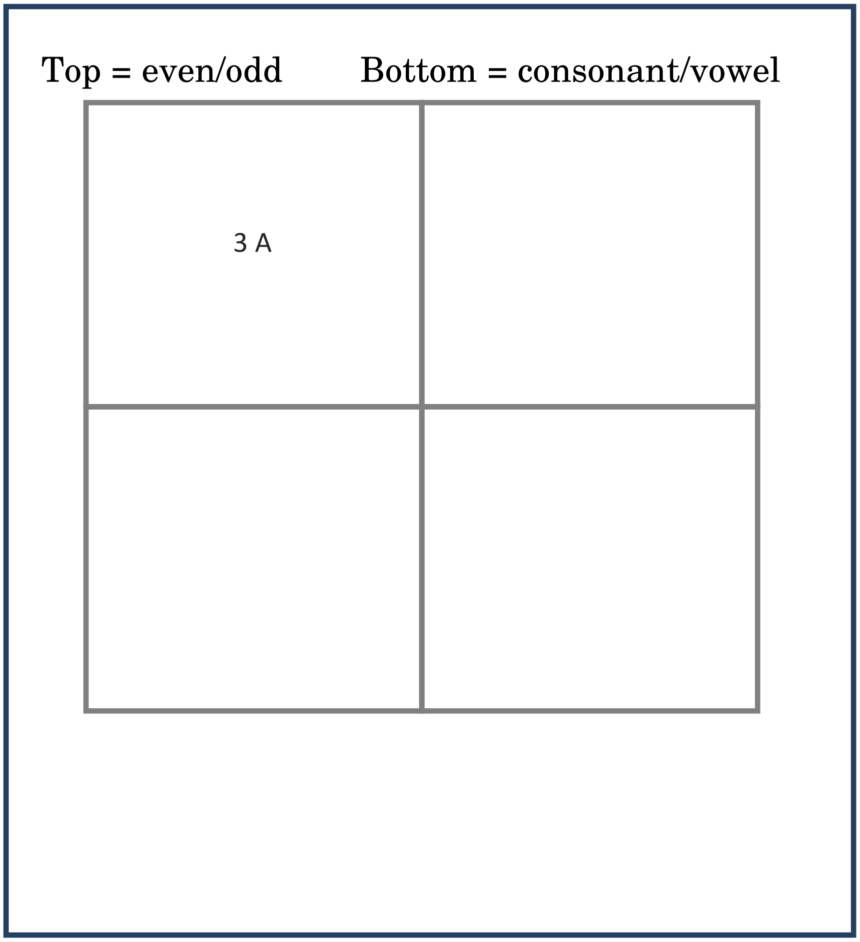

Figure 11 - View of Letter-Number trial on screen: Letter-Number task example trial where the stimulus pair of one number and one letter was presented in one of the 4 quadrants displayed on the screen. Instructions displayed consistently throughout the task.

Procedure. Unless otherwise noted, the apparatus and tasks for this experiment were the same as in Experiment 1. In the previous experiments, the filler task was a pen and paper maze task. However, the Number-Letter task was administered as the filler task instead of mazes. Thus, participants completed the first lexical decision task, received prospective memory instructions, completed the Number-Letter task, and then performed the dual-task. Number-Letter task instructions were displayed on the screen and when the participant was ready to start the task, he or she clicked on the spot below the instructions. The participants were assigned randomly to one of two rule conditions, the control condition (one-rule) or the draining condition (two-rule). In the control condition, the

Number-Letter task had only one rule, which were always congruent trials. The draining condition or attention demanding task of Number-Letter task contained two rules, which required continuous goal switching and updating.

As in Experiment 1 and 2, the dual-task was the prospective memory task was embedded in the second lexical decision task. The prospective memory task included the same prospective memory conditions with no PM load (control) condition, the focal load condition (*governs),* and the nonfocal load condition (*g-words*). In this prospective memory task, only the random schedule of targets was presented. Additionally, the number of trials included in the dual-task was reduced from 900 to 300. Including an extended dual-task of 900 trials to determine whether the task was draining was not necessary in this experiment. The second lexical decision task had 300 trials with half the trials, randomly determined, being words and the other half of the trials being nonwords. The dual-task was shortened in the number of trials due to lack of evidence that the vigilance decrement exists in prolonged prospective memory tasks. The prospective memory task presented 4 targets. Participants were free to respond to targets before or after the lexical decision were made (free responding). No other elements of the lexical decision task varied from Experiment 2.

Experiment 3 Results

Analyses were conducted to determine whether age, gender, or race affected performance. None of the effects were significant, $p > 0.10$. Experiment 3 was a 3 x 2 design, with PM load (no PM load, focal, nonfocal) and rule (one-rule, two-rule) as between groups variables. An alpha level of $p < .05$ was used for all statistical tests.

Number-Letter Performance. For the t-test, response accuracy was measured as percent of trials completed correctly. One-rule response accuracy was significantly higher (mean = 88% correct) compared to two-rule response accuracy (57%), $F(1, 117) = 4.077$, $p < 0.001$. There was no significant difference between mean reaction times in the one-rule condition compared to the two-rule condition (mean RT = 757 ms vs. 743 ms, respectively).

PM Target Accuracy. A 2 x 2 ANOVA was conducted for the dependent variable of accuracy for the prospective memory trials. All means in the analysis were figured as percentages of PM Hits compared to all PM target presentations. Participants in the focal condition responded significantly more accurately (mean = 77%, SE = 6.1%) to PM targets than did participants in the nonfocal condition (mean = 33%, SE = 5.8%), F (1, 68) = 28.31, $p < 0.001$, $\eta^2 = 0.294$. The two-rule group (mean = 64%, SE = 6.2%) had significantly higher accuracy on PM trials than one-rule group (mean = 46%, SE = 5.6%), F(1, 38) = 4.80, $p = 0.032$, $\eta^2 = 0.066$. No significant interaction was observed.

Lexical Decision Accuracy. Lexical decision accuracy included trials with reaction times within 3 standard deviations and excluded trials that displayed PM targets. Reported means were percentage of lexical decision trials that were corrected answered compared to all completed. Accuracy for lexical decision was significantly lower in the two-rule condition (mean = 81%, SE = 1.0%) than the one-rule condition (mean = 84%, SE = 1.1%), F(1, 95) = 5.31, $p = 0.023$, $\eta^2 = 0.053$. No other significant main effects or interactions were observed.

Lexical Decision Reaction Times. For the 3 x 2 ANOVA, reaction times for lexical decision were significantly slower in the one-rule condition (mean = 1078.33 ms, SE = 39.80 ms) than the two-rule condition (mean = 951.77ms, SE = 43.08 ms) , F(1, 95) = 4.66, $p = 0.033$, $\eta^2 = 0.047$. No other significant main effects or interactions were observed. Lexical decision reaction times were not significantly different between the focal load (mean = 1006.71 ms) and nonfocal load (mean = 1057.60 ms) and the no PM load condition (mean = 980.83 ms).

Pre-target Reaction Times. A mixed ANOVA was conducted for the dependent variable of pre-target reaction times. In this analysis, the repeated-measures variable was target performance such that pre-target reaction times for target hits or target misses. Trials that were accurate responses to the lexical decision and with response times within 3 standard deviations from the mean were included. No significant main effects or interactions were observed. Thus, there was no significant difference between reaction times before PM trials where targets were hit compared to when targets where missed.

Self-Report Measures. Levels of perceived difficulty and performance were taken after the task was completed. Difficulty ratings were Likert scales from 1 to 7, with 1 being that the task was very difficult to 7 being that the task was very easy. The grand mean for difficulty was 4.30, SE = 0.13. Performance ratings were also completed on the Likert scale from 1 to 7, with 1 being very poor performance to 7 being very good performance. The grand mean for performance was 4.06, SE = 0.14. Further analyses using a 2 x 3 ANOVAs with PM Load and Presentation conditions were completed on both difficulty and performance ratings. No significant main effects or interactions were found for either difficulty or performance ratings ($p > .05$).

Experiment 3 Discussion

As in the previous experiments, prospective memory accuracy was affected by PM Load. The nonfocal load had significantly lower hit rate than the focal load. Whereas the overall pattern of Experiments 1 and 2 results supports a role of monitoring in PM performance (albeit the evidence is inconsistent in Experiment 2), there is no evidence of monitoring in Experiment 3, where the PM task was administered after the Number-Letter activity. Thus, it appears that spontaneous retrieval was used to complete the prospective memory task in both the focal and nonfocal conditions.

Performance on the dual-task (lexical decision and prospective memory) was affected by the Number-Letter task, albeit in inconsistent directions relative to what was predicted. The one-rule Number-Letter condition produced lower prospective memory performance (and slower but more accurate lexical decision performance) than the two-rule condition. This was contrary to the prediction that the Number-Letter task would drain attention and cause disruptions in the dual-task, particularly when task-switching was required (as in the two-rule condition). One potential explanation of the findings in the current study was to assume that the Number-Letter task was not taxing—that is, that it did not drain attention resources at all. I do not believe that is the case. The grand mean reaction time for lexical decision during this experiment (1015.05 ms) was longer than in previous experiments (848.36 ms and 933.74 ms respectively), and was longer within this experiment for participants in the two-rule condition compared to one-rule condition. Overall prospective memory performance was also lower in the present study than in the previous experiments, even if one limits the comparison the first 300 lexical decision trials of Experiments 1 and 2 (72.28% in the present study versus 82.3% in the previous experiments). Additionally, accuracy in the Number-Letter task was significantly lower in the two-rule than the one-rule condition, even though reaction times were not significantly different between the conditions. Thus, during the Number-Letter task, accuracy was severely limited by the addition of switching attention between the two stimuli that were being attended dependent upon visual cues. Indeed, performance in the two-rule condition was only slightly, albeit significantly ($p < .001$) different than chance. Performance during the Number-Letter task implies that the task was taxing, and more difficult (if not more attention draining) in the two-rule condition than the one-rule condition. Both conditions were taxing, as the titration of the window of time for responding was a function of accuracy. With these findings, I would conclude that the two-rule condition was too difficult, as performance was barely better than chance. Participants worked harder to get the answer right in the one-rule condition, but basically guessed (which does not consume many resources) in the two-rule condition. Thus, both groups show effects of having performed letter-number, but the two-rule group was not unduly drained because they basically gave up when required to accomplish task-switching.

The Number-Letter task included titration in order to keep the task challenging. From the findings, it is likely that the participants completed the Number-Letter task and used the experience with titration to shape how they performed on the dual-task. In the one-rule condition, participants were slow on the lexical decision trials but more accurate on those decisions. It was the opposite in the two-rule condition: lexical decision trials were faster but less accurate. Thus, the focus after the one-rule condition was on correctly accomplishing the task whereas after the two-rule condition, the focus was on completing the trials as quickly as possible even with the sacrifice to accuracy. Performance on the prospective memory task in the concurrent task leads itself to this explanation. The one-rule condition had significant task interference, which may be evidence for monitoring. However, prospective memory accuracy was lower than in the two-rule condition. The two-rule condition was faster but had higher performance on the prospective memory task. Although there is evidence that strategies varied as to how to perform the task at an optimum level, those strategies did not increase prospective memory accuracy. Taking this evidence into consideration, it appears that the task switching in Number-Letter task drained resources enough that spontaneous retrieval was used to support prospective memory. Task interference was not found overall for focal or nonfocal prospective memory loads. However, when resources were not depleted, as in Experiments 1 and (perhaps) 2, monitoring was engaged.

In this case, using the Number-Letter task did affect performance on the dual-task, for both lexical decision task and prospective memory task. Attention resources were depleted to the point where spontaneous retrieval was the primary cognitive mechanism used to complete the prospective memory task. The performance patterns found in this study reflect prospective memory performance when only spontaneous retrieval is used, as resources were unavailable to do consistent monitoring.

5: EXPERIMENT 4

Different target presentation rates bring about different conscious experiences (Graf and Uttl, 2001). For example, relative to the experiments reported here, vigilance tasks tend to have much higher rates of target-to-nontarget presentations, such as 20% target rates (Helton et. al., 2007), which produce problems with participant fatigue. However, prospective memory tasks completed in the previous experiments (with a 2% target presentation rate) did not show signs of fatigue, or any similar type of decrement. Thus, the rate of target presentation may have caused participants to utilize a different cognitive mechanism depending on which task was given the priority. The previous experiments have produced evidence of the use of both monitoring (with or without inhibition is unclear) and spontaneous retrieval. The previous experiments in the present study used a target rate of 2%; yet, rates in the literature range from 2% to 10% (Czernochowski, Horn, & Bayen, 2012). A presentation rate at the low end of this range was selected for the present studies to minimize the similarity between the prospective memory task and traditional vigilance tests, and in concern of ceiling effects. The previous experiments reported here did not yield any ceiling effects in focal prospective memory performance; thus, increasing the target presentation rate may not be a concern with respect to ceiling effects. The purpose of the studies was to find support for the hypothesis that prospective memory monitoring was supported by sustained attention. However, prospective memory performance for nonfocal targets was low. Thus, this study compares different rates of prospective memory target presentations to determine whether monitoring performance can be increased with higher presentation rates.

Frequency effects in prospective memory have been studied before, although the research was completed without considering the effects of the type of prospective memory load that was given. Previously, target frequency has been found to affect the likelihood of the use of monitoring (Loft & Yeo, 2007; Czernochowski, Horn, & Bayen, 2012). Target frequency has also been found to increase prospective memory performance across the task (Ellis, Kvavilashvili & Milne, 1999).

Loft and Yeo (2007) compared target rates of 1% and 3% and found that low target frequency reduced response costs and prospective memory performance. There was also the conclusion that low association targets were more reliant on monitoring than high association targets. Although Loft and Yeo (2007) had comparable presentation rates to those used in the present experiments and had focal and nonfocal loads, their results differed from the ones found here. Loft and Yeo used cues with high and low associations as focal and nonfocal loads respectively. Two elements could explain these differences. First, their experiment manipulated presentation rates, but still presented 8 targets. Thus, the two conditions were drastically different in length of time on task with high frequency being 272 trials and low frequency being 720 trials. Second, trials were presented on a schedule with the frequent condition being every 33 trials. Although schedule effects were not found in Experiments 1 to 3 of the current study, this could have been due to the low frequency rate used (1 in 50 stimuli).

Czernochowski, Horn, and Bayen (2012) used only nonfocal loads. The authors found that participants did monitor more for frequent compared to rare targets, as task interference increased for frequent targets. In their study, rare targets were on 3% of the trials whereas the frequent condition had a 20% target presentation rate. It is likely that this task changed more into a vigilance task with a presentation rate that high. This was supported from their finding that prospective memory performance was 85% correct for the nonfocal, high frequency condition. This is much higher than prospective memory accuracy performance found in the current set of experiments, which ranged from 33% to 41%.

Frequency rates of the target events are well known to affect vigilance performance. Vigilance research into the effects of target frequency dates back to Parasuraman and Davies (1977). They described a vigilance taxonomy between event rate and the level of mental workload for the task. Tasks that are characterized by high mental workload display greater vigilance decrements than low mental workload tasks, but only with high event rates (Warm, Parasuraman & Matthews, 2008). One of the factors found to increase the mental workload was event rate, where increased event rate increased the mental workload, thus driving an increase in the vigilance decrement.

Thus, the current study was designed to compare frequency rates between focal and nonfocal loads while keeping those rates more consistent with rates found in the prospective memory literature. It was expected that, unlike the previous studies without inhibition, monitoring effects would be found and that those effects would be different depending upon the type of prospective memory load in the task. In line with the Multiprocess theory, increased monitoring should increase performance on the nonfocal load, but have less of an effect in the focal condition. With the increase in mental workload, vigilance effects have a higher likelihood of being found. Thus, vigilance decrements were expected in the lexical decision task, with those effects being more likely with the nonfocal load than a focal load.

Experiment 4 Method

Participants. A total of 151 (110 females and 36 males, plus 5 participants that preferred not to answer) participants were recruited and participated in this study. Participants received one credit hour to satisfy a course requirement in their introductory Psychology class. Due to computer errors, 6 participants were dropped. Participants who stated in the exit questions that they did not know the prospective memory cue were not included in the analysis. Thus, 39 participants were excluded, leaving 106 participants (58 females and 17 males) included in the analyses. The demographic characteristics included age, gender and race. Age ranged from 18 to 42 years old, with an average age of 19.52 years.

Procedure. Unless otherwise noted, the apparatus and tasks for this experiment were the same as in the previous Experiment 3, except with the same maze completion filler task of Experiments 1 and 2 rather than the Number-Letter filler task from Experiment 3. The experiment lasted less than 1 hour in which participants performed the lexical decision task, a series of mazes and one of the conditions of the prospective memory task. Once again, the prospective memory task included the same prospective memory conditions as previous experiments with a no PM load (control) condition, the focal condition (target of *governs),* and the nonfocal condition (target of words beginning in the letter *G*) presented on a random schedule displayed over the course of 300 lexical decision trials. Participants were free to respond to targets before or after the lexical decision were made. In this study, the presentation schedule of critical targets was manipulated. Critical targets were presented on either 3% of the lexical decision trials for a total of 9 times or 5% of the trials for a total of 15 times. All other elements of the lexical decision task were the same as in the previous Experiment 3.

Experiment 4 Results

Analyses were conducted to determine whether age, gender, or race affected performance. Black/African American participants (mean = 907.07 ms, SE = 56.56 ms) were significantly faster on the lexical decision task than white/Caucasian participants (mean = 1361.57 ms, SE = 66.08 ms), $F(1, 44) = 27.30$, $p < 0.001$, $\eta^2 = 0.288$. Females (mean = 950.86 ms, SE = 33.63 ms) were significantly faster on the lexical decision task than males (mean = 1317.79 ms, SE = 80.22 ms), $F(1, 44) = 17.80$, $p < 0.001$, $\eta^2 = 0.288$. None of the other effects were significant, $p > 0.10$.

Experiment 4 was a 3 x 2 x 4 mixed design, with PM load (no PM load, focal, nonfocal) and frequency (3%, 5% target frequency) as between groups variables and task quarters (1 to 4) as the within-subject variable. The session was divided into 4 equal quarters, which included 75 trials each. An alpha level of $p < .05$ was used for all statistical tests.

PM Target Accuracy. A mixed ANOVA was conducted for the dependent variable of accuracy for the prospective memory trials. All means in the analysis were figured as percentages of correct PM trials compared to all PM target presentations. The focal load (mean = 78%) had significantly more accurate performance on PM target detection compared to the nonfocal condition (mean = 60%), $F(1, 62) = 4.17$, $p = 0.045$, $\eta^2 = 0.063$. There was a significant interaction between quarters and frequency

(Figure 12), $F(3, 186) = 3.12$, $p = 0.032$, $\eta^2 = 0.048$. To delve further into this interaction, the file was split on time on task with frequency conditions as the independent variable. However, target accuracy was not significantly different in the 3% frequency compared to the 5% frequency for any of the quarters. No other significant main effects or interactions were observed.

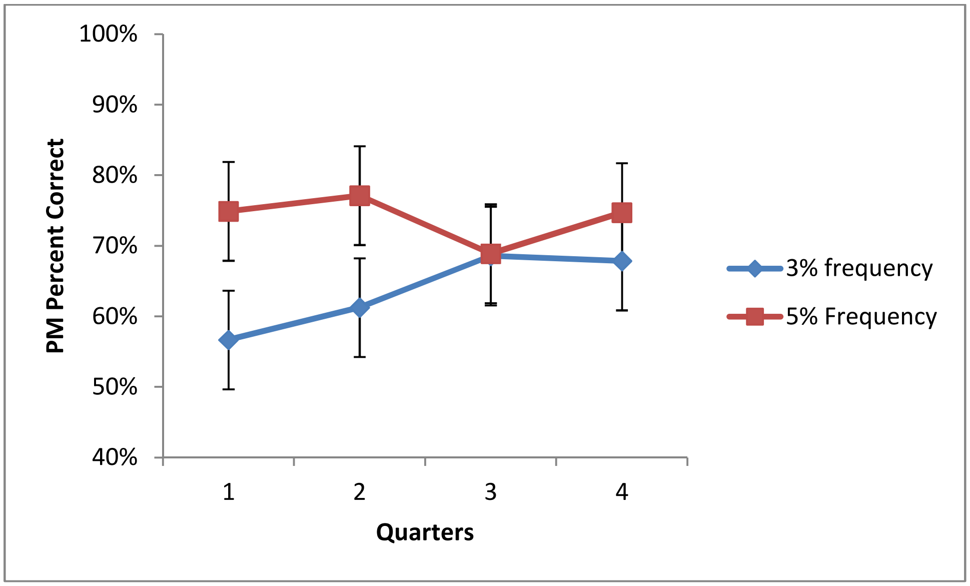

Figure 12 - PM Accuracy across Quarters per Frequency Condition: Mean prospective memory accuracy (percent correct) for 3% and 5% target frequency presentation rates across the task, which was divided into quarters. Target accuracy was not significantly different in the 3% frequency compared to the 5% frequency for any of the quarters. Bars represent standard errors.

Lexical Decision Accuracy. Lexical decision accuracy included trials with reaction times within 3 standard deviations and excluded trials that displayed PM targets. Accuracy varied significantly across quarters, $F(3, 309) = 36.31$, $p < 0.001$, $\eta^2 = 0.307$. In the pairwise comparisons, lexical decision accuracy was significantly higher in Q2 than in Q1, Q3 and Q4. Lexical decision accuracy in Q1 was M = 82%, SE = 0.011, Q2 was M = 84% (SE = 0.012), Q3 was M= 80% (SE = 0.013) and Q4 was M = 77% (SE = 0.012). This was qualified however by an interaction with frequency conditions, $F(6, 309) = 3.93$, $p = 0.001$, $\eta^2 = 0.087$ (see Figure 13). For the No-load (control) condition, lexical decision accuracy was significantly higher in the Q1 compared to Q4. No other quarters varied significantly from each other. With 5%

frequency, accuracy increased from Q1 to Q2, and then decreased significantly in Q3 and again in Q4. With 3% frequency, accuracy increased from Q1 to Q2, then decreased significantly in Q3 and did not significantly change in Q4.

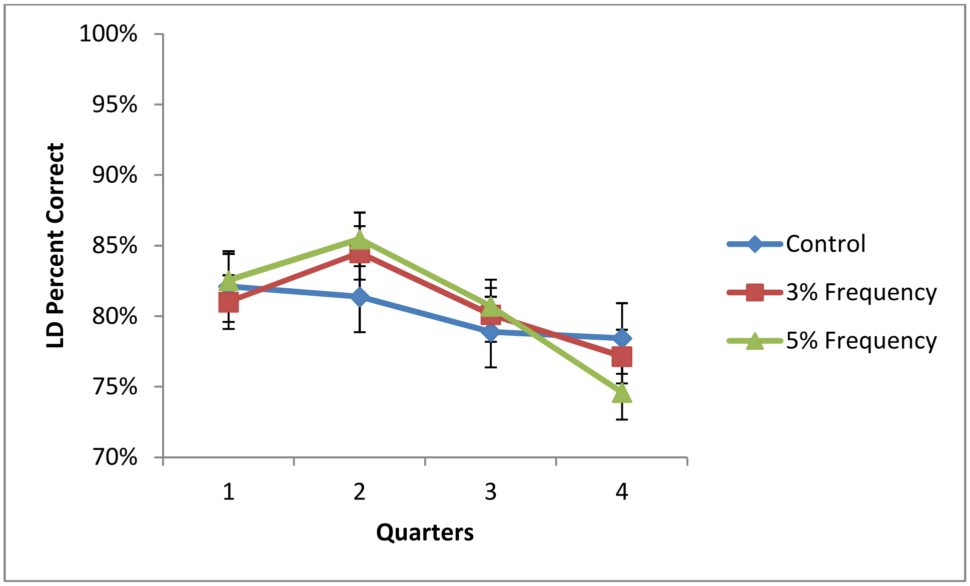

Figure 13 - LD Accuracy Rate across Quarters per Frequency Condition: Mean lexical decision accuracy (percent correct) for different target frequencies across the task, which was divided into quarters. With 5% frequency, accuracy increased from Q1 to Q2, and then decreased significantly in Q3 and again in Q4. With 3% frequency, accuracy increased from Q1 to Q2, then decreased significantly in Q3 and did not significantly change in Q4. Performance on the control condition was significantly higher in Q1 than rest of quarters. Bars represent standard errors.

Lexical decision accuracy also varied according to PM load interacting with the length of time on task, $F(6, 246) = 2.91$, $p = 0.011$, $\eta^2 = 0.066$ (see Figure 14). For the No-load, control condition, lexical decision accuracy was significantly higher in the Q1 compared to Q4. No other quarters varied significantly from each other. In the focal condition, accuracy increased from Q1 to Q2, and then decreased significantly in Q3 and again in Q4. In the nonfocal condition, accuracy increased from Q1 to Q2, then decreased significantly in Q3 and did not significantly change in Q4. No other significant main effects or interactions were observed.

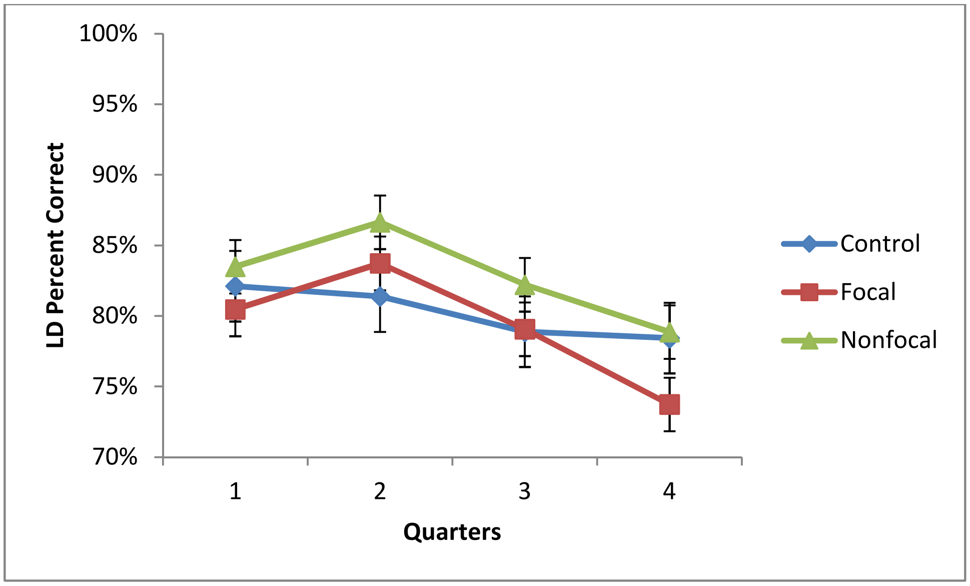

Figure 14 - LD Accuracy Rate across Quarters per PM Load: Mean lexical decision accuracy (percent correct) for different PM loads across the task, which was divided into quarters. In the focal condition, accuracy increased from Q1 to Q2, and then decreased significantly in Q3 and again in Q4. In the nonfocal condition, accuracy increased from Q1 to Q2, then decreased significantly in Q3 and did not significantly change in Q4. Performance on the control condition was significantly higher in Q1 than Q4. Bars represent standard errors.

Lexical Decision Reaction Times. For the two separate 3 x 4 ANOVAs, reaction times were significantly different for the PM Loads, $F(2, 103) = 12.26$, $p < 0.001$, $\eta^2 = 0.192$. Pairwise comparisons revealed that the No-load (control) condition with no prospective memory load (mean = 757.15 ms, SE = 51.32 ms) had significantly faster reaction times compared to the focal load (mean = 967.81 ms, SE = 35.56 ms) and nonfocal load (mean = 1092.28 ms, SE = 44.45 ms). Pairwise comparisons showed no significant difference between focal and nonfocal loads. Lexical decision reaction times were significantly different for the target frequencies, $F(2, 103) = 9.85$, $p = 0.001$, $\eta^2 = 0.161$. Pairwise comparisons revealed that the Control condition with no prospective memory load (mean = 757.15 ms, SE = 51.32 ms) had significantly faster reaction times compared to the 3% frequency (mean = 1038.01 ms, SE = 38.21 ms) and 5% frequency (mean = 990.09 ms, SE = 42.14 ms). Pairwise comparisons showed no significant difference between 3% and 5% frequencies.

Reaction times varied significantly across quarters, $F(3, 309) = 14.99$, $p < 0.001$, $\eta^2 = 0.127$ (see Figure 15). In the pairwise comparisons, lexical decision reaction time was significantly higher in Q1 than Q2 through Q4. There were no significant differences in reaction times between Q2, Q3 and Q4. No other significant interactions were observed (see Figure 16).

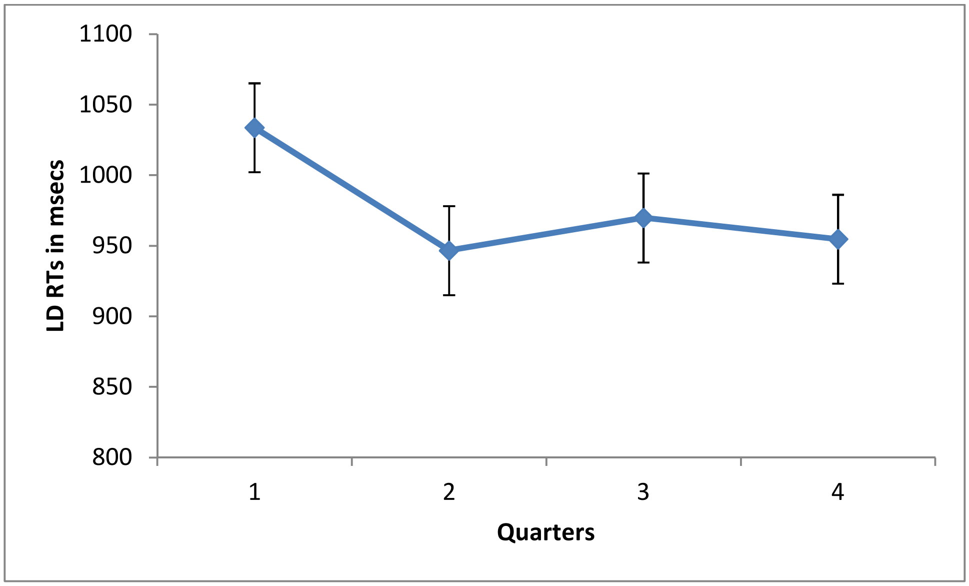

Figure 15 - Lexical Decision Reaction Times across Quarters: Mean lexical decision response time across the task, which was divided into quarters. Lexical decision reaction time was significantly slower in Q1 than Q2 through Q4. Bars represent standard errors.

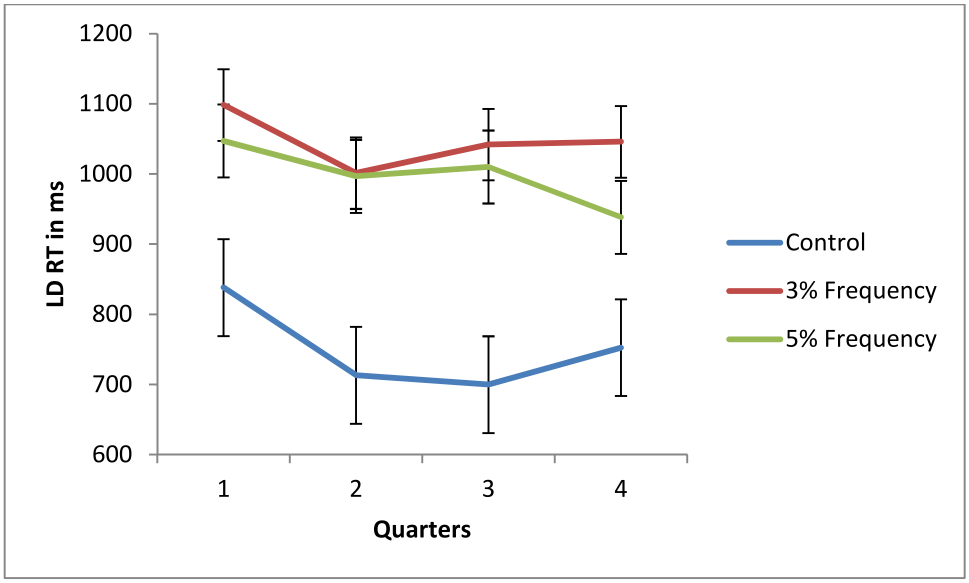

Figure 16 - Lexical Decision Reaction Times across Quarters for each Target Frequency: Mean lexical decision reaction times for different target frequency rates across the task, which was divided into quarters. Performance did not vary across the task for any condition. The control condition was significantly faster than conditions with a prospective memory. No significant difference between reaction times was found between frequency rates. Bars represent standard errors.

Pre-target Reaction Times. A mixed ANOVA was conducted for the dependent variable of pre-target reaction times. In this analysis, the repeated-measures variable was target performance such that pre-target reaction times for target hits or target misses. Trials that were accurate responses to the lexical decision and with response times within 3 standard deviations from the mean were included. No significant main effects or interactions were observed. Thus, there was no significant difference between reaction times before PM trials where targets were hit compared to when targets where missed.

Self-Report Measures. Levels of perceived difficulty and performance were taken after the task was completed. Difficulty ratings were Likert scales from 1 to 7, with 1 being that the task was very difficult to 7 being that the task was very easy. Performance ratings were also completed on the Likert scale from 1 to 7, with 1 being very poor performance to 7 being very good performance. Further analyses using a 2 x 3 ANOVAs with PM Load and Presentation conditions were completed on both difficulty ratings (mean = 4.40, SE = 0.15) and performance ratings(mean = 4.59, SE = 0.15). No significant main effects or interactions were found for either difficulty or performance ratings ($p > .05$).

Experiment 4 Discussion

Evidence for monitoring was found in this experiment—demonstrating conclusively (given that the Experiment 2 evidence on this point was mixed) that monitoring can be found even without the requirement of inhibition responding, as was used in Experiment 1. With a prospective memory load, task interference (i.e., slower lexical decision times, compared to the no-PM load control condition) was found for both levels of target frequency. However, there was no difference in the amount of task interference between the levels of frequency. Thus, monitoring was found with a target presentation rate of 3%, whereas it had not been observed consistently with the presentation 2% rate used in previous Experiments 2 and 3. Further increasing the target frequency to 5% did not produce additional interference in performance on the lexical decision concurrent task, with respect to either reaction times or accuracy.

Although evidence for monitoring was found in this experiment, support for sustained attention as the mechanism for this monitoring was not found. No vigilance decrement was found for reaction times in the lexical decision task. Reactions times were slowest in the first quarter, got faster in the second quarter and then held at that plateau. This has been seen in the previous experiments with free responding also. Lexical decision accuracy did show some decrements, with little change across quarters. Accuracy was slightly but significantly higher in the second quarter than in the others. Accuracy also decreased for the third and fourth quarters, but only for prospective memory loads. Lexical decision accuracy without prospective memory loads decreased slowly across the task, but was more stable than prospective memory load conditions. Attention appears to have waned slightly across trials of the task and more so with the addition of the prospective memory.

Not only was there no indication of a vigilance decrement, but also there was no evidence that rate altered performance across trials, as would be expected if the task required vigilance. There was no significant interaction between frequency rates and time on task, as would be expected in a true test of sustained attention. It is possible that the presentation rates used here were too low or too similar to produce such differences across trials—but this seems unlikely, because the rates did produce reliable overall differences in performance.

Performance on the prospective memory task was once again significantly higher with a focal load compared to the nonfocal load. This is typical and in line with previous findings; however, when comparing performance on prospective memory accuracy in this experiment to previous experiments, the findings are atypical. As was the expectation, increasing the target presentation rate did not seem to affect performance on the concurrent lexical decision task, but did significantly increase performance for nonfocal load accuracy. Nonfocal load accuracy in the current study was 60% correct, compared to nonfocal load accuracy in Experiments 2 and 3 at 41% and 33% respectively. Performance on the focal load accuracy was not similarly affected. Focal load accuracy levels were in line with previous experiments. When monitoring was encouraged by increasing the target presentation rate, performance for the nonfocal load was increased. Task interference was found during both nonfocal and focal loads, so participants were likely monitoring on and off in the task even with the focal load. However, monitoring did not improve performance for the focal load. One explanation for the lack of increased performance is that performance on the focal load could have already been at highest level and additional resources could not increase it above that asymptote. Additionally, monitoring could have been used much less consistently with the focal load and yet still the data would show overall task interference.

There was the concern that increasing the frequency of target presentations might cause performance to increase due to repetition of the target. However, there was no evidence found to support this. Indeed, accuracy in the focal condition, with the same exact target word (governs) presented multiple times, did not lead to increased prospective memory accuracy relative to earlier experiments. Target frequency rates did not significantly affect prospective memory hit rate. In fact, for frequency rates of 5% targets, performance was lower in the final quarter (where practice and priming effects would be the largest) than the first quarter. Also, when comparing prospective memory hit rate for the 3% frequency rate across quarters, there was no clear improvement to suggest that the priming or practice of early presentations produced better target detection later in the task.

In summary, in this experiment I increased the frequency of the target presentations above levels used in Experiments 1 to 3 to determine whether monitoring and prospective-memory performance would increase. Although there was no significant difference between presentation schedules of 3% or 5% target rates, monitoring was found for both rates in this free-responding task. The monitoring used in this task increased prospective memory accuracy in the nonfocal condition, as was expected. However, increased target frequency did not improve performance in the focal condition, and no vigilance decrement was found in any condition. Consequently, even with clear evidence for monitoring, there was no evidence to support that such monitoring was similar to maintaining vigilance (sustaining attention) across the task.

6: EXPERIMENT 5

Loft and colleagues utilized a dynamic display task that simulates air traffic controller tasks in order to look at the effects of different factors on prospective memory performance (Loft & Remington, 2010; Loft, Finnerty & Remington, 2011; Loft, Smith & Bhaskara, 2011). Like the present study, this line of research mixed the literature of prospective memory and vigilance, although with a vigilance-based task. The effects in the air traffic controller task for PM Load were repeated in another study looking at the effect of external aids (Loft, Smith & Bhaskara, 2011). External aids, such as spatial context, did improve prospective memory performance, but only when the aids directed attention appropriately. Evidence of spatial context cues increasing nonfocal prospective memory performance was also found (Loft, Finnerty, Remington, 2011).

The dynamic display task allowed the authors to manipulate the strength of the association of the prospective memory target to the routine actions. Loft and Remington (2010) manipulated the strength of the routine in which the prospective memory task was embedded, by manipulating how often a particular type of information was pertinent to the task, such as plane altitude or speed. Routines became firmly engrained and reinforced through experiences. The authors found that prospective memory hit rates decreased when routine strength was strong compared to weak. Task interference increased with a PM load compared to a no-load condition. This suggested that monitoring was found when a PM load was given and that monitoring increased more for nonfocal loads compared to focal loads. Task interference was also modulated by routine strength. Strong routines required more resources to suppress the habitual responses to prospective memory targets.

However, the dynamic display task was a more demanding task than the Einstein and McDaniel Paradigm. This is because the dynamic display task includes making different actions dependent upon the information given. For example, information such as altitude, speed and plane type were all given, along with direction and quadrant. Dependent upon that information, participants had to decide a course of action such as hand off to next controller, or if a conflict would occur with another aircraft. Although the task allowed multiple task manipulations in order to understand prospective memory in a more dynamic setting, it presented some difficulties as to understanding how their findings would apply to more simple tasks, such as remembering to stop a routine task to accomplish the prospective memory. It is necessary to take findings using the dynamic display task and determine whether those findings can apply in less demanding situations. Additionally, this allows more generalization in the prospective memory literature.

The theories in the prospective memory literature are not the only frameworks that could be applied when looking at routine strength. As was discussed above, the vigilance decrement that is typically observed in vigilance research is caused by an increase in the mental workload of the task (Warm, Parasuraman, & Matthews, 2008). Thus, the higher the workload during the vigil, the more likely it is to result in a vigilance decrement. This is caused by depletion of attention resources during the course of the task. In the present experiment, manipulation of routine strength could encourage participants to become more automated in the task. If this were to be true, fewer attention resources would be depleted. Thus, a vigilance decrement could be seen in the weak routine condition compared to the strong routine condition that has been used the previous experiments.

In the current experiment routine strength was manipulated to determine whether there would be any effect on prospective memory performance and sustained attention during the concurrent task. Routine strength was manipulated by the number of trials completed in the first block of lexical decisions (i.e., before the filler task). Weak routine included 25 trials whereas strong routine consisted of 200 trials. If routine strength affects prospective memory performance, performance should be poorer in the strong than the weak conditions. I further hypothesized that task interference would be higher for strong routines than weak routines. Attention allocation was predicted to be affected differently also, in that more automated tasks, such as in the strong routine, should be characterized by faster reaction times than the weak routines. Thus, I would expect to find evidence of monitoring for prospective memory loads and more monitoring required in the strong routine than the weak routine. I also hypothesized that prospective memory accuracy would decrease with nonfocal loads over focal loads. Evidence for sustained attention would be vigilance decrements in lexical decision reaction times or accuracy. Vigilance decrements seemed more likely to be found in the weak routine.

Experiment 5 Method

Participants. A total of 186 (118 females and 51 males, plus 17 participants that preferred not to answer) participants were recruited using Sona Systems at Georgia State University and participated in this study. Participants received one credit hour to satisfy a course requirement in their introductory Psychology class. Participants that stated in the exit questions that they did not know the prospective memory cue were not included in the analysis. Thus, 51 participants were excluded, leaving 135 participants (92 females and 30 males) included in the mixed ANOVA. The demographic characteristics included age, gender and race. Age ranged from 18 to 33 years old, with an average age of 18.85 years.

Procedure. Unless otherwise noted, the apparatus and tasks for this experiment were the same as in Experiment 4. Participants were assigned randomly to a PM load condition (no-load group, focal group, nonfocal group), with targets presented at a rate of 3% in a pseudo-random order within the lexical decision task, which included 300 trials. Participants were free to respond to targets upon target presentation or within 3 trials. As a new manipulation, the number of lexical decision trials before the prospective memory instructions were varied. Participants were randomly assigned to complete either 25 lexical decision practice trials or (as in the previous experiments) 200 lexical decision practice trials. This manipulation was used to vary the strength of the routine of the lexical decision task. The 25-trials condition was labeled “weak” whereas 200-trials condition was labeled “strong” with respect to the routine.

Experiment 5 Results

Analyses were conducted to determine whether age, gender, or race affected performance. Black/African American participants (mean = 971.30 ms, SE = 34.42 ms) were significantly faster on the lexical decision task than white/Caucasian participants (mean = 1185.90 ms, SE = 48.67 ms), $F(1, 83) = 12.96$, $p = 0.001$, $\eta^2 = 0.135$. Females (mean = 994.35 ms, SE = 29.29 ms) were significantly faster on the lexical decision task than males (mean = 1162.85 ms, SE = 51.92 ms), $F(1, 83) = 7.99$, $p = 0.006$, $\eta^2 = 0.088$. None of the other effects or interactions were significant, $p > 0.10$.

Experiment 5 was a 3 x 2 x 4 mixed design, with PM load (no PM load, focal, nonfocal) and routine strength (weak routine, strong routine) as between groups variables and task quarters (1 to 4) as the within-subject variable. The session was divided into 4 equal quarters, which included 75 trials each. An alpha level of $p < .05$ was used for all statistical tests.

PM Target Accuracy. A mixed ANOVA was conducted for the dependent variable of accuracy for the prospective memory trials. All means in the analysis were figured as percentages of correct PM trials compared to all PM target presentations. The focal load (mean = 73%, SE = 5.6%) had significantly more accurate performance on PM target detection compared to the nonfocal load (mean = 48%, SE = 6.2%), $F(1, 111) = 11.65$, $p = 0.001$, $\eta^2 = 0.095$. PM target accuracy varied significantly across the task, $F(3, 333) = 10.63$, $p < 0.001$, $\eta^2 = 0.087$. According to pairwise comparisons, performance was significantly lower in the first quarter (mean = 52%, SE = 4.2%) and then increased in the second quarter (mean = 62%, SE = 4.1%) where it stayed stable across the rest of the task (Quarter 3: mean = 64%, SE = 4.1% and Quarter 4: mean = 63%, SE = 4.1%). No main effect for schedule and no significant interactions were observed.

Pre-target Reaction Times. A 2 (load) x 2 (strength) x 2 (hits/misses) mixed ANOVA was conducted for the dependent variable of reaction times for the two lexical decision trials before a target was presented. In this analysis, the repeated-measures variable was pre-target reaction times for target hits or target misses. Trials that were accurate responses to the lexical decision and with response times within 3 standard deviations from the mean were included. Lexical decision reaction times with a focal load (mean = 582.38 ms, SE = 30.67 ms) were significantly faster than with a nonfocal load (mean = 801.11 ms, SE = 40.62 ms), $F(1, 111) = 18.47$, $p < 0.001$, $\eta^2 = 0.143$. However, this finding was qualified by multiple interactions. There was a significant interaction between PM load and target accuracy, $F(1, 111) = 5.93$, $p = 0.016$, $\eta^2 = 0.051$. The other significant interaction occurred between PM load and routine strength, $F(1, 111) = 4.25$, $p = 0.042$, $\eta^2 = 0.037$. To delve into the interactions, the data were split on routine strength and a mixed ANOVA was conducted including target accuracy and PM load. The weak routine, nonfocal load condition was significantly slower in pre-target reaction times compared to the weak routine, focal load condition, $F(1, 53) = 18.54$, $p < 0.001$, $\eta^2 = 0.259$ (see Figure 17). The strong routine pre-target reaction times did not vary between focal and nonfocal routines. For the strong routine, pre-target reaction times were significantly faster for misses than hits, $F(1, 58) = 5.10$, $p = 0.028$, $\eta^2 = 0.081$ with no significant difference between pre-target reaction times of hits and misses for the weak routine (see Figure 18).

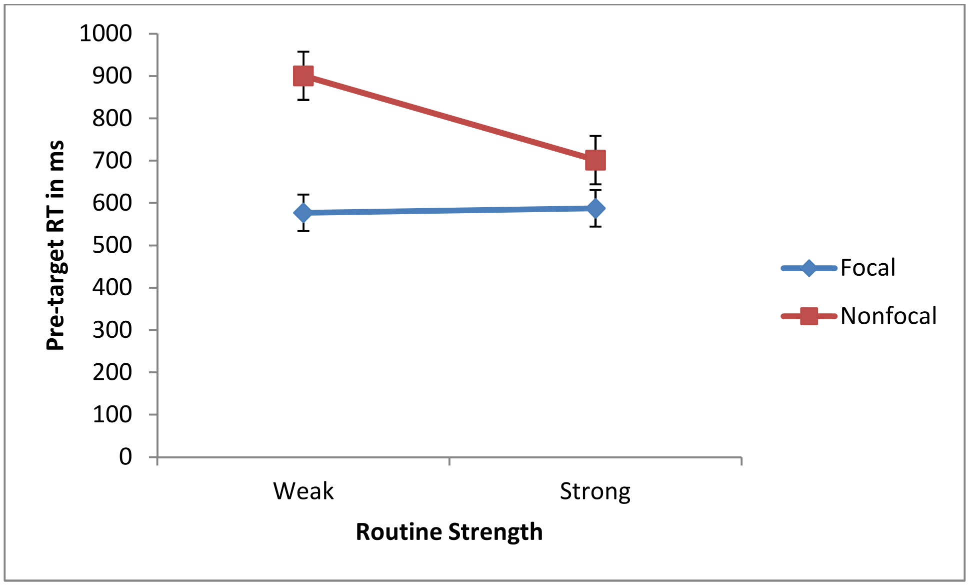

Figure 17 - Interaction between PM Load and Routine Strength for Pre-Target RTs: Mean pre-target reaction times in milliseconds for each PM load across routine strength. Performance did not vary for focal targets regardless of routine strength. Nonfocal targets had significantly slower reaction times with a weak routine than a strong routine. Bars represent standard errors.

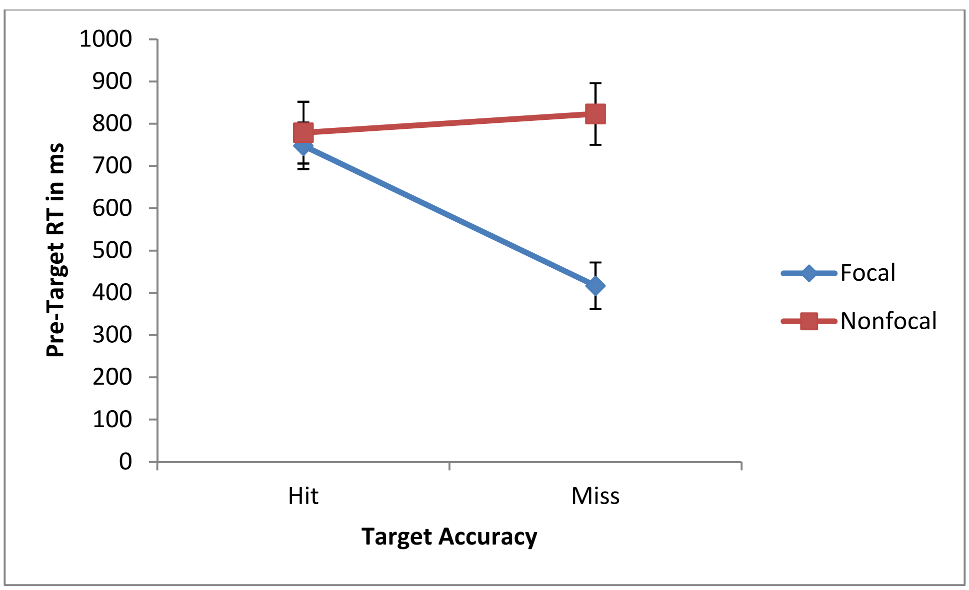

Figure 18 - Comparison of Hits and Misses across PM loads for Pre-Target Reaction Times: Mean pre-target reaction times in milliseconds for each PM load when targets were hit compared to missed. Performance did not vary for nonfocal targets regardless of whether the target was hit or missed. Focal targets had significantly slower pre-target reaction times when hit compared to missed. Bars represent standard errors.

Lexical Decision Accuracy. Lexical decision accuracy included trials within 3 standard deviations and excluded trials that displayed targets. Reported means were percentage of lexical decision trials that were corrected answered compared to all completed. Lexical decision accuracy varied significantly across quarters of the task, F (3, 333) = 10.63, $p < 0.05$, $\eta^2 = 0.201$. Pairwise comparisons were used to determine that Quarter 1 (mean = 83%, SE = 0.8%) was significantly lower than Quarter 2 (mean = 85%, SE = 0.8%) and 4 (mean = 78%, SE = 0.8%) but not Quarter 3 (mean = 82%, SE = 0.8%). All other Quarters were significantly different from each other. No other significant main effects or interactions were observed.

Lexical Decision Reaction Times. A mixed ANOVA and pairwise comparisons revealed that lexical decision reaction times differed significantly between each of the PM load groups. The no-load (control) condition with no prospective memory demand had significantly faster reaction times (M = 811.11 ms, SE = 48.59ms) compared to the focal load (M = 948.46ms, SE = 25.96 ms) which was significantly faster than nonfocal load (M = 1092.35 ms, SE = 34.22 ms), F (2, 132) = 11.86, $p < 0.001$, $\eta^2 = 0.152$. Pairwise comparisons revealed that each level of routine strength was significantly different from each other, $F(2, 132) = 7.70$, $p = 0.001$, $\eta^2 = 0.104$. The no-load (control) condition with no prospective memory demand (M = 811.11 ms, SE = 50.97 ms) had significantly faster reaction times compared to the strong routine (M = 962.53 ms, SE = 29.43ms) and weak routine (M = 1042.97 ms, SE = 30.74 ms); more important, the difference between these later two groups was also significant. Reaction times across the task, split into quarters, can be seen in Figure 17. Reaction times decreased significantly from the first quarter to Quarter 2, but then remained stable through Quarter 4, $F(3, 396) = 10.07$, $p < 0.001$, $\eta^2 = 0.071$.

However, these main effects were qualified by interactions. Lexical decision reaction times varied across the task dependent upon the type of PM load, $F(6, 396) = 4.33$, $p = 0.001$, $\eta^2 = 0.062$ (see Figure 19). Splitting the file upon PM load revealed that the lexical decision reaction times in the control condition varied significantly across task, $F(3, 57) = 15.34$, $p = 0.001$, $\eta^2 = 0.447$. Lexical decision reaction times were significantly slower in Q1 than any other quarter. Response speed did not vary after the first quarter. Neither focal nor nonfocal groups produced significant differences in lexical decision reaction time as a function of quarters, $p > 0.05$.

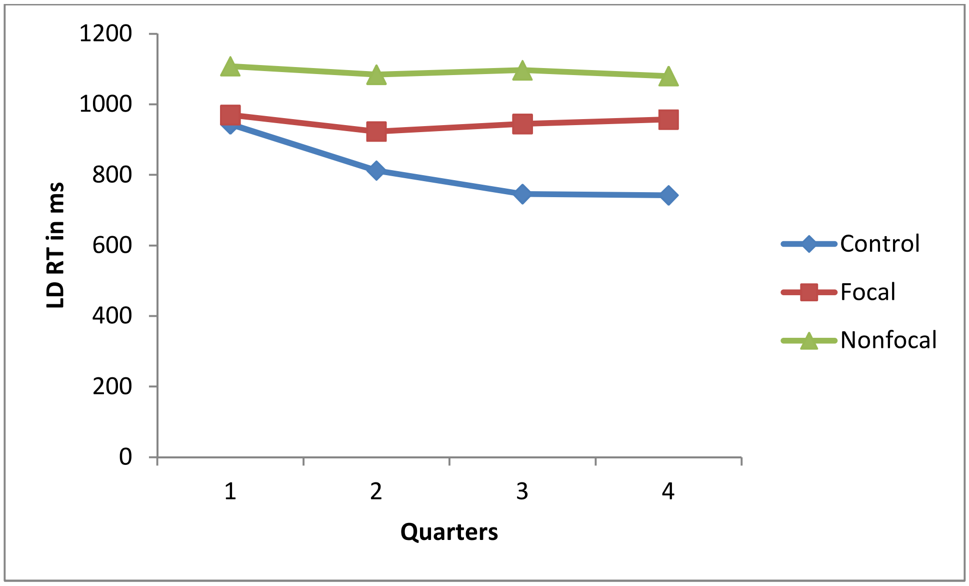

Figure 19 - Lexical Decision Reaction Times across Quarters per PM Load: Mean lexical decision reaction times in milliseconds for each PM load across quarters. Lexical decision reaction times in the control condition were significantly faster in Q1 than the following quarters. Lexical decision reaction times did not vary across the task with a prospective memory load of focal or nonfocal. Bars represent standard errors.

Additionally, lexical decision reaction times varied across the task dependent upon routine strength, $F(6, 396) = 4.21$, $p = 0.001$, $\eta^2 = 0.060$ (see Figure 20). Analyzing the routine strength separately revealed that the lexical decision reaction times in the control condition varied significantly across task, $F(3, 57) = 15.34$, $p = 0.001$, $\eta^2 = 0.447$. Lexical decision reaction times were significantly slower in Q1 than any other quarter. Speed did not vary after the first quarter. Neither weak nor strong conditions were significant, $p > 0.05$. No other significant main effects or interactions were observed.

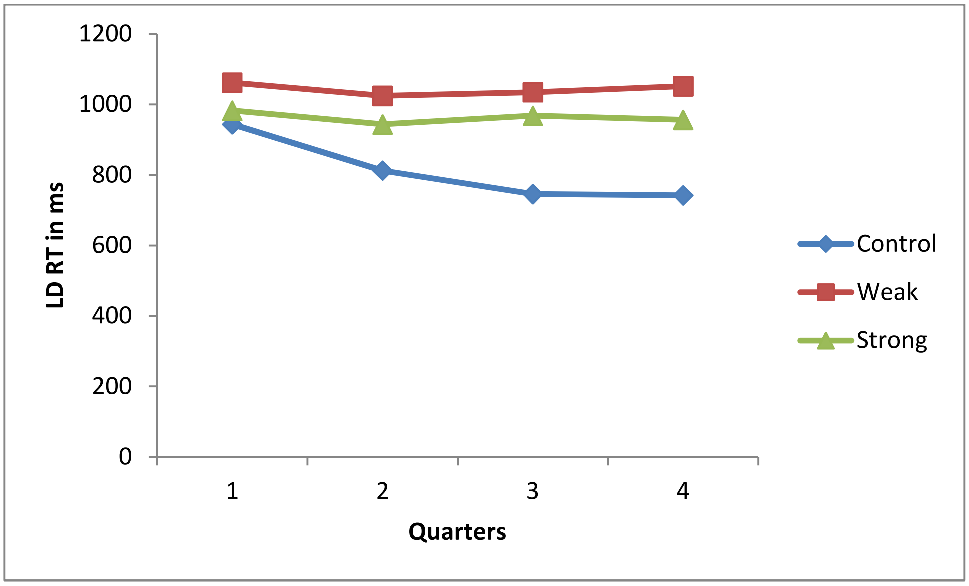

Figure 20 - Lexical Decision Reaction Times across Quarters per Strength Condition: Mean lexical decision reaction times in milliseconds for each strength condition across quarters. Lexical decision reaction times in the control condition were significantly faster in Q1 than the following quarters. Lexical decision reaction times did not vary across the task with a prospective memory load regardless of whether weak or strong routine. Bars represent standard errors.

Self-Report Measures. Levels of perceived difficulty and performance were taken after the task was completed. Difficulty ratings were Likert scales from 1 to 7, with 1 being that the task was very difficult to 7 being that the task was very easy. Performance ratings were also completed on the Likert scale from 1 to 7, with 1 being very poor performance to 7 being very good performance. Further analyses using ANOVAs with PM load and routine strength were completed on both difficulty and performance ratings. Difficulty ratings contained no significant effects or interactions. Pairwise comparisons showed that nonfocal load was significantly lower in performance ratings (mean = 4.29) compared to focal load (mean = 5.18), but not significantly different from no-load (mean = 4.00), $F(1, 80) = 7.32$, $p < 0.05$. Focal load had significantly higher performance ratings than no-load.

Experiment 5 Discussion

Consistent with previous experiments in this study, monitoring was found with a prospective memory load and free responding. Lexical decision task interference was found for both focal and nonfocal memory loads (relative to the control condition), with an increased amount of task interference for the nonfocal load above the focal load. Task interference was found in both the weak routine and the strong routine. Moreover, evidence to support monitoring was also found when comparing the pre-target reaction times across the PM loads. For the first time in this series of experiments, pre-target reaction times differed between hit and misses, but only for focal targets. Specifically, prospective memory target misses for the focal group were preceded by significantly faster lexical decision reaction times than were target hits for this same group. If these participants were not monitoring, resulting in relatively short lexical decision reaction times, then prospective memory targets were more likely to be missed. For the nonfocal group, lexical decision reaction times were equally long before hits and misses. The nonfocal condition could just be too difficult to accomplish regardless of the level of monitoring employed. This is supported by the finding that target accuracy with the nonfocal load was much lower than target accuracy with a focal load.

Pre-target reaction times were also used to look at performance differences between the weak and strong routines. Pre-target reaction times for the weak-routine group were generally slower (although not significantly different) than for the strong-routine group, ; but once again, an interaction with PM load qualified this effect. With a strong routine, reaction times were no different between the focal and nonfocal load. With a weak routine, reaction times were significantly slower with a nonfocal load compared to focal load. This was in line with the prediction from the vigilance literature. The weak routine did not encourage participants to prioritize the lexical decision task, thus monitoring resources for the nonfocal targets were utilized. Nonfocal loads are harder to accomplish the prospective memory, but the routine strength did not matter with the focal targets.

As expected, additional attention resources were required to find nonfocal targets compared to focal targets. This conclusion is suggested by a higher level of task interference found for the focal loads than the nonfocal loads during pre-target reaction times and by differing levels of task interference dependent upon routine strength. The pre-target reaction times for focal loads were faster than for nonfocal loads, and this variation of task interference suggests that different levels of attention resources were devoted to the prospective memory task depending on the PM load or the routine strength. The weak routine group was slower than the strong routine group, which in turn was slower than the control group.

Within these data, there is evidence to suggest that participants had variations in their performance across the task. However, these variations are not consistent with a vigilance decrement. Variability in accuracy and response time is expected in vigilance tasks, as attention waxes and wanes across a vigil; but on average the cycles tend to lead towards reduced performance as a function of time-on-task. In this experiment, there is no evidence of reaction times systematically increasing across the task, although reaction times did get faster after the first quarter for the no-load condition. In the second quarter, reaction times reached a plateau rather than showing further decrement, and remained at the same level for the rest of the task. Lexical decision accuracy showed a small vigilance decrement, as accuracy on the lexical decision increased from the first to the second quarter but then dropped for the third and fourth quarters. However this change could have been due to a speed/accuracy tradeoff occurring as the participant continued performing the task.

In Experiment 5, the Multiprocess theory was supported even though monitoring was found across the task for PM Loads. This is due to overall task interference caused by the PM Load, but the absence of consistent interference (i.e., found for focal but not nonfocal groups) in pre-target reaction times. This is in conflict with the PAM theory, which states that preparatory attention is required to accomplish prospective memory. There is little evidence that sustained attention is used during the prospective memory task, as the vigilance decrements are not consistent or robust.

7: GENERAL DISCUSSION

Most, and probably all, tasks designed to illuminate one aspect of cognition are actually tests of multiple cognitive constructs. Perception, attention, memory, language, executive functioning, and other cognitive processes work together, for example to allow individuals to remember to do something specific in the future, . Tests of prospective memory, including those used in the present study, have helped to elucidate the role of monitoring and spontaneous retrieval, but both of these mechanisms are themselves arguably complex constructs that tap multiple cognitive systems. In the present series of studies, I have explored the hypothesis that monitoring in prospective memory is very similar to—perhaps even synonymous with—sustained attention as it has been carefully studied using vigilance tasks. That is, I have attempted to consider whether prospective memory is essentially supported by spontaneous retrieval and vigilance. In order to determine whether monitoring in prospective memory is the same as sustained attention in vigilance, three premises must be established. First, evidence of prospective memory needs to be found. Secondly, monitoring has to be found during the prospective memory task. Thirdly, manipulations in the experiments should affect prospective memory performance similarly to the effects seen in vigilance studies.

In all experiments of the current study, evidence of prospective memory was found. Whether or not the target was presented in the focus of attention of the concurrent task did affect prospective memory accuracy. Thus, performance on the prospective memory task did vary, dependent upon the prospective memory load, regardless of whether spontaneous retrieval or monitoring was employed. For focal loads, such that the targets were in the focus of attention during the concurrent task, prospective memory performance was always higher than when a specific target was out of the focus of attention, a nonfocal load. Apart from of the task manipulations or load type, hit rate of the prospective memory targets never reached a ceiling effect. Spontaneous retrieval allowed participants to catch both focal and nonfocal targets, and when monitoring was utilized, this performance increased.

Prospective memory accuracy varied as a function of type of prospective memory load. However, not all participants did perform the prospective memory task. Some participants could not recall the prospective-memory targets at the end of the study, and accordingly failed to respond to prospective-memory targets during the study. The number of participants who failed to perform the prospective memory task was higher in the present study than had been reported previously in the literature. Dependent upon the experiment, 15% to 27% of the participants were not included in the analysis due to their inability to remember the prospective memory target after the tasks were completed. Although there were a few participants in the focal condition who did not remember the target word, a majority of the participants dropped came from the nonfocal condition. Changing the instructions and including a written (typed) confirmation of the target immediately after the instructions (as was introduced in Experiment 2) did not seem to improve prospective memory. It is unknown why the present task or the present population resulted in such a large percentage of the participants to fail to create or to maintain the prospective memory intention.

One possible explanation is the method of confirmation. In the current study, participants confirmed the target by typing the target into a text form presented by the program. However, Einstein and collaborators (Einstein et al., 1995) had participants tell the experimenter the prospective memory target. Vocally informing another individual of the prospective memory intention may have increased the priority of the intention and encouraged the participant to remember to perform the intention (although there is no theory that would predict this effect). Interestingly, comparisons of the prospective memory accuracy levels—for participants who were not dropped from the respective studies—do not differ between the current experiments and those published by others (e.g., Einstein & McDaniel, 2007). Future research will have to address this interesting dynamic to tease it apart.

Prospective memory accuracy was also affected by factors other than the focus of attention (or type of prospective memory load). Increased in target frequency increased prospective memory performance, and did so more for nonfocal targets that are more likely to require monitoring than for focal targets that can be found easily with spontaneous retrieval. Prospective memory intentions in which the targets are rare may present problems for continuous monitoring and may encourage reliance on spontaneous retrieval and other strategies to accomplish the prospective memory task. Thus, increasing target presentation rates reinforced monitoring in prospective memory tasks. These data suggested that if the frequency of memory relevant stimuli was low, participants use spontaneous retrieval rather than effortful monitoring processes. With higher target rates, some evidence for monitoring was obtained—but the threshold between target rates that result in monitoring versus no monitoring was amazingly small (3% versus 2% in the present study).

With the manipulation of the frequency of targets, repetition priming became a concern; across the experiments however, there was not a consistent effect of repetition priming. With inhibition responding in Experiment 1, there was a repetition effect in the focal condition that uses the same target every time; however, this was not duplicated with free responding (Experiment 2 and beyond). There was evidence that the prospective memory accuracy was lowest in the first quarter and then increased in the second quarter. However, accuracy seemed to plateau for the rest of the session, regardless of prospective memory load type. Thus, with low presentation rates such as those used in this study, repetition priming was not a concern.

Rare target presentation performance may be more in line with real world behavior. Many prospective memories that need to be performed in day-to-day life require long periods, even days, without any opportunity to perform the prospective memory task and may be only one opportunity. If participants have to remember to perform an action in the future, they may attend continuously for the stimuli that signal the timing for that action. Alternatively, they may fail to monitor continuously, but still respond appropriately if they perceive the target stimulus and spontaneously retrieve the to-be-performed action.

In addition to frequency, inhibition was found to play a role in prospective memory. The first experiment used inhibition responding where the participant had to inhibit their response to the concurrent task in order to respond to the prospective memory target. This led to testing in the second experiment using the same design of a prolonged dual-task with free responding. Free responding allowed participants to respond to the concurrent task first and then the prospective memory task. Free responding removed the need for inhibition during the task. Focal hit rate increased when participants did not have to inhibit their responses to the concurrent task (free responding) compared to when the prospective memory action had to be completed first (inhibit responding). However, the type of responding had no effect on prospective memory hit rate when the target was nonfocal. When inhibition is necessary to complete the prospective memory task, focal targets will be more likely to be missed. Thus, inhibition negatively affected spontaneous retrieval. Additionally, requiring inhibition encouraged participants to focus on the concurrent task (to the detriment of the prospective memory task) which caused a decrease in lexical decision reaction times across the course of the task. This increase of speed during the concurrent task was not found with free responding. It is unknown how inhibition would affect performance during a dual-task when monitoring was employed. Monitoring was not found in Experiment 2 or 3. Evidence for monitoring was produced by Experiments 4 and 5, but neither used inhibition-response requirements. Thus, this study does not have any data as to how adding inhibition during the prospective memory task will affect monitoring and performance. In the future, the interaction between monitoring and inhibition (and the role of attention in both) should be explored. As the lack of monitoring in Experiment 2 may have been caused by the inexplicable long reaction times for the control group, further research is necessary. The expectation would be that as monitoring causes response times to be slower, inhibition would have less of an effect.

Considerable space in this document has been dedicated already to the evidence, or lack thereof, for monitoring versus spontaneous retrieval in these participants' prospective memory performance. The PAM theory states that in order to accomplish a prospective memory task accurately, preparatory attention processes must be engaged when that target is presented (Smith, 2003). Preparatory attention is required for active monitoring for the prospective memory target in order for the prospective memory task to be completed. The preparatory attention processes take up attention resources and therefore should have a cost on the other tasks being performed during the prospective memory task. In previous studies done by Smith and colleagues (Smith 2003; Smith & Bayen, 2004; Smith, Hunt, McVay, and McConnell, 2007; Smith, 2010), task interference was the measure that reflected whether monitoring was being utilized. Task interference was defined as a significant cost to reaction times of the concurrent task with the addition of the prospective memory intention. According to the PAM theory, without task interference, prospective memory tasks should not have been able to be performed as no monitoring for targets is performed. By this criterion, monitoring was found in Experiments 4 and 5, with target presentation frequency rate increased to above 2% of the lexical decision trials. Monitoring was also found in Experiment 1 but not in Experiment 2, in which the procedures were identical except for the removal of the inhibition requirement for responding. This suggests that the task interference was due to the requirement to inhibit a lexical decision response on prospective-memory target trials (Experiment 1), rather than reflecting monitoring. However, this suggestion was qualified by the finding of interference (suggesting monitoring) when the results of Experiment 1 and 2 were analyzed together. Contradictory to the PAM theory, the prospective memory task was performed with both focal and nonfocal prospective memory loads without the presence of monitoring. In Experiment 3 of this study, there was no task interference due to the addition of the prospective memory task, regardless of whether the target was presented in the focus of attention or not. The PAM theory cannot explain why prospective memory tasks can be completed at all without preparatory attention costs shown in task interference, nor does it have any explanation for changes in target presentation rate causing monitoring.

In vigilance tasks, sustained attention has been found to wax and wane across the vigil (Davies & Parasuraman, 1982). One explanation could be that monitoring was waxing and waning across the task. This would suggest that task interference was consistently not found because monitoring, while used, was not consistent throughout the task. The present findings do not support this explanation however. Task interference is not the only measure that could be analyzed to determine whether monitoring was performed during the task. The PAM theory states that preparatory attention is necessary to find the prospective memory target. Consequently, the trials before target presentation would have to display slower reaction times for the lexical decision for targets hit compared to targets missed. Yet, pre-target reaction times for hits were not significantly different from misses in any of the first four experiments. Only in Experiment 5 was there evidence that hits had increased reaction times (or rather, that misses were preceded by faster reaction times) and this was only with focal targets. In Experiment 5, the increased reaction times were no different between hits and misses for nonfocal targets, which was where monitoring would be expected to improve performance. This pattern was true for both the focal and the nonfocal groups in Experiments 1 to 4. Thus, there is no evidence that monitoring occurring in the trials before target presentation was either necessary or sufficient for the target to be correctly identified. Generally, it appeared that participants tried to monitor for the prospective memory targets, even in the lexical decision trials that preceded failures to respond to targets. Regardless of whether participants were trying to monitor for the targets, monitoring was not found to be necessary to accomplish the prospective memory intention. This is more evidence against the PAM theory.

Spontaneous retrieval is another cognitive mechanism that is theorized to support prospective memory (Einstein & McDaniel, 1990). Spontaneous retrieval does not have a performance cost associated with it. Experiments 2 and 3 suggest the use of spontaneous retrieval as a mechanism that can be used to find the prospective memory target, regardless of the type of target (focal vs. nonfocal). In these experiments, no task interference was found across the task (although the evidence from

Experiment 2 was mixed on this point). When attention resources were drained in Experiment 3, it appears that spontaneous retrieval was relied upon to accomplish the prospective memory. Thus, spontaneous retrieval was used to performance the prospective memory task. With an increased target presentation rate, task interference was found in Experiment 4. With task interference, it is unlikely that participants relied solely on spontaneous retrieval, although it could be used periodically during the task. Reliance on spontaneous retrieval multiple times in conjunction with monitoring during the task would have decreased reaction times averaged across the task relative to a session with more active monitoring. In Experiment 5, there was a significant difference in the amount of task interference between all three levels (focal, nonfocal, and control) of prospective memory load. The nonfocal condition produced significantly more task interference than the focal condition. This difference in the amount of task interference could be that monitoring in the focal condition was much less consistent than monitoring in the nonfocal condition as monitoring did not help increase prospective memory performance for focal targets. In fact, the results from Experiment 5 suggest that adding monitoring with focal targets increased the likelihood of hitting the target.

Across the experiments, both spontaneous retrieval and monitoring were utilized. As both cognitive processes were used in different conditions with different task parameters, this study supports the Multiprocess theory of Einstein and McDaniel (1990). For example, the increased target presentation rate caused participants to switch from using spontaneous retrieval to monitoring as the cognitive process utilized to accomplish the prospective memory. With a target presentation rate of 2%, no consistent evidence for monitoring was found for focal or nonfocal conditions. Once the frequency of target presentations was increased above 2% target rate, monitoring was found in both the focal and nonfocal conditions. Thus, increased frequency of targets encouraged monitoring for prospective memory targets. This is in line with previous research where task interference was found to emerge only after the first target cue was presented (Scullin, McDaniel, Shelton & Lee, 2010). The authors concluded that unreinforced monitoring caused participants to reduce monitoring and rely on spontaneous retrieval. The increased presentation rate reinforced monitoring. Indeed, in Experiment 4, prospective memory performance was higher in the 5% frequency rate for the first half of the task compared to performance in the 3% frequency rate.

Although there are some findings that cannot be explained by the Multiprocess theory, overall the flexibility in the theory of allowing both spontaneous retrieval and monitoring to work together as the cognitive mechanisms to accomplish a prospective memory task explains most of the findings. However, contrary to the Multiprocess theory, nonfocal targets did not cause monitoring consistently. As frequency was discussed previously, the data suggest that rare target presentations encourage spontaneous retrieval and with more frequent target presentations, the cognitive process used switched from spontaneous retrieval to monitoring.

From relatively short prospective memory tasks to prolonged ones, vigilance decrements were not found to be robust. Sustained attention was not found as the extended version of the prospective memory task showed no significant vigilance decrement across the length of the task. What hints there were of declines in performance as a result of time-on-task (e.g., small effects on lexical decision accuracy) were not in any case specific to memory monitoring, and were more reasonably interpreted as trade-offs in service of complementary improvements in performance (e.g., increases in response speed). Lexical decision reaction times across the task did not show any sign of slowing, and when inhibition needed to be utilized (as in the first study), reaction times actually increased in speed across the task. Moreover, lexical decision response times were not consistently longer for the prospective memory load (focal and nonfocal) conditions relative to the control condition, as would be expected if prospective memory required the continuous allocation of sustained attention. Sustained attention could not be linked to the prospective memory performance even when monitoring was found during the task. For Experiments 1, 4 and 5 (and for Experiment 2 when combined with Experiment 1), monitoring was found with a prospective memory load, but there was no vigilance decrement, even with the different levels of target presentation rates.

In addition to looking for evidence of sustained attention through a vigilance decrement, other manipulations were performed with the expectation that they should have an effect on prospective memory if it was supported by sustained attention. Presentation schedule of targets was tested with both inhibition and free responding. Scheduling targets at regular intervals was expected to affect performance (the Signal Regularity Effect), as has been reported for vigilance tasks (Helton et al., 2005). This was not the case. There was no difference between random or regular presentation schedules, regardless of whether the task included inhibition. Additionally, when a difficult Letter-Number task was administered in an attempt to drain attention resources before participants completed the prospective memory task, there was still no evidence of increased vigilance decrement. However, depletion of resources from the Letter-Number task removed the resources to monitor and participants relied on spontaneous retrieval to perform the dual-task. If sustained attention was utilized during prospective memory, then a vigilance taxonomy was expected to be found also. This was also not found in the course of this study.

In summary, across the experiments there was no evidence that variables that typically affect vigilance performance produced effects on prospective memory performance. In this study, prospective memory was found with evidence that monitoring was used in certain conditions to accomplish the prospective memory, but factors affecting sustained attention did not consistently affect prospective memory. Thus, no evidence was found to support the hypothesis that sustained attention was supporting prospective memory, regardless of whether spontaneous retrieval or monitoring was employed to accomplish the prospective memory task. Recently, Langner and Eickhoff (2012) suggested that sustained attention is a multicomponent cognitive ability that is supported by sustained processes supported by arousal maintenance and transient processes subserving top down processing.

Prospective memory also could be caused supported by a division of the cognitive processes that included both top-down motivated attention and bottom-up processing. Further research needs to investigate in detail the different mechanisms of attention by dividing more simple attention mechanisms.

Unexpectedly, throughout the study, there were findings that suggest that manipulations to the task encouraged participants to alter their strategies during the task and that changed performance. Task emphasis in the instructions caused different performance on the prospective memory task and the lexical decision task (Einstein et al., 2005; Kliegel, Martin, McDaniel & Einstein, 2004; Loft & Yeo, 2007; Marsh, Hicks & Cook, 2005). Effort was manipulated by instructing the focus of attention. Additionally, attention can be shifted by experiences with the task. For example, Scullin, McDaniel, Shelton and Lee (2010) found that task interference was found to emerge only after the first target cue was presented. Although not the point of the current study, the series of experiments supported the hypothesis that attention is shifted through experience. As discussed previously, inhibition responding likely encouraged participants to prioritize the lexical decision task above the prospective memory task, regardless of the instructions. Additionally, more frequent target presentations induced monitoring in Experiment 4 (discussed above) with free responding. Although it was unclear whether monitoring was present in Experiment 2 with presentation rates of 2%, monitoring was clearly found when those rates were increased to 3% presentation rate. In Experiment 3, task emphasis was changed, not by task instructions, but by experience of the participant before the dual-task. The Number-Letter task used as a filler task inadvertently encouraged a change in strategy as to how the dual-task was performed. The one-rule condition of the Number-Letter task encouraged participants to focus on concurrent task, which increased accuracy of the concurrent task and slowed down reaction times. The two-rule condition sped up reaction times of the concurrent task and lowered accuracy. The experience of the condition changed the focus in the one-rule condition from the concurrent task to the prospective memory task. However, in the two-rule condition, prospective memory performance was higher in the Two-Rule condition than the one-rule condition. Thus, the filler task that was incorporated in a study could have broad reaching effects on the strategies and intentions used to complete the dual-tasks. Future research will have to examine what elements of the filler task affected the subsequent dual-task (lexical-decision and prospective memory) performance.

These unexpected findings suggest that not only do manipulations to the task change intentions, but experiences throughout the task can change intentions also. This was not the focus of the study, but may influence further research into effects of how individuals will alter their responses during a task to better complete that task. Of particular interest would be to manipulate target schedules to determine whether target schedules could induce monitoring quickly and how long the monitoring will be continued before switching back to spontaneous retrieval to preserve resources.

Reconsidering the series of experiments conducted in the current study, future research needs to address some concerns and unanswered questions. Experiments 1 and 2 should be replicated with higher target-presentation rates to determine whether the Signal Regularity Effect would occur with more frequent targets. Additionally, it would be interesting to track the time-course of acquisition of the Signal Regularity effect, as that would have its own repercussions. Future research could replicate the current study and could test the hypothesis that sustained attention is monitoring. This study did not find vigilance decrements with the dual-task method of presenting prospective memory, but it could be that other paradigms would show the vigilance decrement. Of particular interest would be conducting a prolonged prospective memory test using the dynamic air traffic controller task, which did show vigilance effects (Loft, Finnerty & Remington, 2011; Loft & Remington, 2010; Loft, Smith & Bhaskara, 2011). That is, it would be interesting to embed a prospective memory study into a task designed as a vigilance test, to see whether that changes the relation between sustained attention, monitoring, and prospective memory performance. It may be, for example, that the concurrent task of lexical decision and the requirement to respond to every stimulus on every trial (which is atypical of vigilance paradigms) could have counteracted any tendency toward vigilance decrements. That said, the present study was designed to test whether sustained attention and monitoring in prospective memory were the same cognitive mechanism. As has been discussed, I have not found any support that those mechanisms are one and the same. These data and emerging studies (e.g., Langner & Eickhoff, 2012), suggest that multiple cognitive mechanisms are supporting the performance in vigilance and prospective memory. These two tasks both could be using similar cognitive mechanisms in varying levels to accomplish the task. Thus, future research needs to determine which basic cognitive mechanisms are being used and how those mechanisms interact to support remembering to perform an action in the future. Future research would also benefit from testing multiple different types of tasks that provide multiple measures of attention, memory, monitoring, and spontaneous retrieval, so that multivariate analyses could be used to identify the contributions of various basic constructs on prospective memory performance.

Although the study failed to reveal a relation between the sustained attention used in vigilance and the monitoring used in prospective memory, it did produce strong and clear support that prospective memory relies on both spontaneous retrieval and monitoring as purported by the Multiprocess theory (Einstein & McDaniel, 1990). The results revealed that both cognitive processes are used in prospective memory intentions and that the findings cannot be explained by the PAM theory (Smith, 2003). The study extends current research of prospective memory in areas such as target presentation rates and strength of routines. Additionally, the study suggests new avenues of prospective memory research into limitations of responding, complications of inhibition in the tasks and the potential effects of the task to influence the mechanism used to accomplish the prospective memory.

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APPENDIX

Survey 1: Post Prospective Memory task Survey.

1. Would you please enter in the space below the item for which you were searching:

2. Please rate how difficult it was for you to watch for the words during your task

   Very Difficult Very Easy
   1 2 3 4 5 6 7 8 9 10

3. Please rate how well you did on finding all the words during your task

   Very Poorly Very Well
   1 2 3 4 5 6 7 8 9 10

4. Please choose which strategy you used to find the target words:

   a. Relying on the word to just pop out and notice it

   b. Watching for the word consistently throughout task

   c. Mixture of actively looking for word and just noticing the word

   d. Other

5. Did you notice any patterns in how the target was presented? Please describe.

   a. Yes

   b. No

   c. Don't Know