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The role of attentional focus in event-based prospective memory

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THE ROLE OF ATTENTIONAL FOCUS IN EVENT-BASED PROSPECTIVE MEMORY

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
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in

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by

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ABSTRACT

Two experiments were conducted to investigate how attentional resources are utilized in event-based prospective memory (PM). A PM component (make a designated response when you see a bird word) was embedded in a living/non-living judgment task (Experiment 1) and a recall task that required participants to alphabetically re-order sets of items (Experiment 2). One hypothesis predicts that the focus of attention (as defined by Cowan's model of working memory) will be narrowed, or zoomed-in, when PM target items appear during an ongoing task. This could lead to task benefits or costs depending on the nature of the ongoing task. The zoom hypothesis was supported in Experiment 1, but high performance rates in Experiment 2 reduced the ability to observe any potential effects. The second hypothesis predicts that attentional control resources, as indexed by measures of working memory capacity, will be associated with PM performance, and this hypothesis was not supported in either experiment. The outcome of this research addresses several assumptions present within prominent theories of PM, and takes the first step in investigating how focal attention processes, in particular, influence PM performance and other ongoing cognitive activities.

INTRODUCTION

Over the past several decades a growing body of research has focused on the study of prospective memory (PM; for review, see McDaniel & Einstein, 2007). PM can be defined as the ability to perform a delayed intention (i.e., perform a given action sometime in the future). There are two major classes of PM tasks, time-based and event-based. In time-based tasks people are told to perform a certain action after a given amount of time has elapsed, and their ability to make this response within the designated time window determines their PM performance level. A real-world example of a time-based PM task is remembering to take the cookies out of the oven in 20 minutes. In a typical laboratory event-based PM task participants are instructed to make a designated response when certain target items appear during some ongoing task. PM performance reflects the number of times the intended action is made in response to the appearance of target items. A real-world example of an event-based PM task is remembering to give your colleague a message when you see him/her at the department meeting this afternoon. It is becoming increasingly clear that attentional processes play a role in certain PM situations; however, the specific nature of their influence is not fully understood. The present research sought to investigate this issue by merging the theoretical viewpoints present within the PM and working memory literatures.

The notion that attentional processes contribute greatly to human memory function is an inherent theme present within many current theories of working memory (WM; Baddeley, 1999; Cowan, 2001; Engle, Tuholski, Laughlin, & Conway, 1999). Cowan's model of WM is particularly relevant to the present research, as it discusses the important role of attentional focus in memory function, and how it can be adjusted to meet current demands. For this reason, Cowan's model will be discussed in more detail.

Cowan (1995; 2001; 2005) has depicted the human memory system through an embedded process model that stresses the importance of a rich interaction between attention and memory mechanisms. According to this model, information present within the memory system fluctuates between various activated states, and in its non-activated state these elements represent long-term memory. This stored information can become activated for a variety of reasons, including its association to incoming sensory input from the environment, explicit retrieval attempts, or as a by-product of these retrieval attempts (e.g., your old dog's name becoming activated while you try to recall the name of the dog "Blue" from the popular cartoon). Thus, the activated portion of the memory system can consist of long-term memory traces, as well as incoming sensory input. This information is maintained in an activated state in order to meet current demands within the organism and in the environment. The nature of these demands will determine an item's level of activation. For instance, when trying to recall the name of the dog "Blue", other dog names stored in memory could be triggered, but would likely not be stimulated to the level of "Blue." Cowan noted that the small portion of highly active information comprises the scope, or focus of attention. He further proposed that the only capacity-limited portion of the WM system is the scope of attention. In a recent book, he reviews evidence that supports a capacity limit of about 3-5 items or chunks (Cowan, 2005). In other words, attentional resources provided by the central executive are only distributed to a restricted set of items at any given time. The central executive is believed to play an important role in maintaining information in this highly active state. The scope, or focus, of attention is considered to be a flexible mechanism that can adjust to meet changing goal states. In its global setting, a maximal amount of information can be appraised simultaneously (about 3-5 chunks), or the "zoom" function can be used to isolate a single item or chunk, thereby minimizing the potential for distraction.

A further stipulation of Cowan's model suggests there are certain situations where it is advantageous to attend to more than one item, whereas the task demands present in other situations result in the narrowing of attentional focus in an effort to isolate a single important item. A common shopping experience provides a good real-world example of this premise. If you are at a department store and have a limited amount of time to find a new black suit, you will first scan the entire suit section, taking in as much information as possible. Once you have spotted a black suit, it would be wise to focus or "zoom in" on that item in an effort to keep yourself from being distracted by all of the surrounding colorful suits that you don't have time to consider. The purpose of the proposed research is to determine if the presence of a prospective memory demand within an ongoing task will provide a situation in which attentional resources are constrained to an important target item. The following review will outline several important studies that investigated the adjustment of attentional focus in visual attention paradigms, as well as theories and research that point to the potential importance of focal attention processes in prospective memory.

Adjustment of Attentional Focus

The zoom-lens model proposed by Eriksen and St. James (1986) offers a description of focal attention mechanisms, specifically relating to visual attention. The basic premise of this model is that the distribution of attentional resources is a continuous process that fluctuates between two polar extremes. In one end of the continuum, attentional resources are widely distributed across the visual field, allowing more information to be present within the attentional lens. On the other end of the continuum, attentional resources are more densely packed into a smaller region of the visual scene. The authors argued that in the former setting, attentional resources are distributed evenly across the visual field, leading to the need for more time to

process all of the information. In the latter setting, attentional resources are tightly packed in a narrow lens, enabling faster and more detailed processing of a limited set of information. A further stipulation of this model is that a widened attentional focus is the default mode, as narrowing the lens is a resource-consuming process.

In two experiments, Eriksen and St. James (1986) tested several of the assumptions of their model. In Experiment 1 participants were engaged in a discrimination task requiring them to respond to the presence of one of two target letters within the cued area of a visual array (containing 8 letters). Several experimental conditions were used, but the findings associated with the incompatible noise condition (the other target letter was located in a noncued position) were most interesting. First, costs (slower response latencies) were observed in target identification when an incompatible distracter item was positioned either one or two items away from the target, regardless of the time lapse between cue and target onset. Second, target identification was slowed with a very brief time lapse in between the cue and target (50ms) when a distracter item was placed three positions away from the target; however, when the time lapse in between cue and target onset was extended to 100ms, this distracter did not adversely affect target identification. The authors interpreted these findings to suggest that the short cueing time in the 50 ms condition did not allow enough time for attentional focus to narrow, leading to continued influence from the distant distracter items. In the 100 ms condition, however, attentional focus had time to narrow, thus excluding the influence of distant distracter items. Further results revealed that, in general, target identification times increased as the number of cued positions increased. This is consistent with the assumption of the zoom-lens model that widening attentional focus across the visual scene results in fewer processing resources available for any given object.

In Experiment 2 a few modifications were made to the design, such as manipulating the amount of information within the attentional lens by increasing the number of spatial locations cued in certain conditions. One important result was that the spatial location of the incompatible distracter letter did not matter when all eight items were cued. The results also revealed that a distracter letter that was two positions away from the target and inside of the focus area was more disruptive than a distracter letter that was two positions away from the target but outside the focus area. The authors interpreted these findings as demonstrating that attentional resources were distributed evenly across the focal area. Taken together, the results from these two experiments support the claims of the zoom lens model and have several interesting implications: 1) people will adjust attentional focus to meet task demand, allocating more resources when necessary, 2) these resources will be distributed evenly across the visual field, and 3) allocating more attentional resources when the lens is widened does not necessarily lead to more efficient processing (Eriksen & St. James, 1986).

The flexible nature of attentional focus has also been observed within the Stroop paradigm (Chen, 2003). In this research, participants were instructed to respond to the color of a non-matching color word (incongruent) or a string of letters (neutral). Prior to the presentation of the word/letter string, participants were cued to the location of the upcoming item with two vertical bars positioned to the right or left of a fixation cross. The cue appeared for 120 ms, followed directly by the target item. On $\frac{3}{4}$ of the trials the cue was valid, and on the remaining $\frac{1}{4}$ of the trials it was invalid. The prediction was that greater Stroop interference (RT difference between neutral and incongruent trials) would occur on valid trials. This counterintuitive prediction stems from the belief that the narrowing of attention focus elicited by a cue leads to a greater concentration of attentional resources on the upcoming stimulus that will appear in the

cued location. This could be problematic in the incongruent condition where the heightened processing of the word's meaning will cause greater distraction from naming the color of the word. On the other hand, when an invalid cue is used attentional resources must be spread from the cued location to the actual location where the target will appear, leading to a lower concentration of resources on the briefly displayed target item (120 ms) and less opportunity for interference from the word's incongruent color and meaning. This prediction was confirmed with greater Stroop interference being observed on valid relative to invalid trials, despite the fact that overall people responded more quickly and accurately to valid trials.

Chen (2003) took several approaches to rule out alternative explanations for these findings. A dual-task approach was utilized within the current Stroop paradigm to facilitate a widened attentional focus across conditions (Experiment 2), leading to no differential Stroop interference effects in the valid versus invalid cue conditions. This finding was consistent with the attentional focus hypothesis, in that holding the attentional setting constant abolished the effect of cue type. Manipulating the amount of perceptual load via the complexity of the cue used to initiate color identification (Experiment 3) did not lead to differential Stroop interference effects, which is inconsistent with the perceptual load hypothesis that assumes the processing of more perceptually-rich stimuli is associated with the presence of fewer attentional resources. Finally, manipulating the range of attentional focus through cue size (Experiment 4) led to Stroop interference effects that were similar to those observed in Experiment 1. Narrowing attentional focus by means of a smaller cue led to larger interference effects relative to a widened attentional focus. Chen concluded that these findings point to the importance of certain stimulus characteristics in determining the relationship between attentional focus and distraction effects. Constraining focal attention is associated with greater task costs when the target and distracting

information are encompassed within the same item, such as in the Stroop paradigm. In contrast, the narrowing of attentional focus leads to performance benefits when the target and distracter information is present in different spatial locations of the visual display (Eriksen & St. James, 1986). Thus, the nature of the stimuli being used and the specific demands of the ongoing task, determine whether or not the narrowing of attentional focus will lead to performance costs versus benefits.

Much of the research examining changes in attentional focus has stemmed from theories of visual attention, and the experimental designs used in these studies reflect this orientation. There are, however, other situations in which the narrowing of attentional focus should be initiated; the presence of a prospective memory demand within an ongoing cognitive task could pose such a situation.

Attentional Focus in Prospective Memory

Existing theories have attempted to explain the kinds of cognitive processes that are associated with the execution of a delayed intention. The multiprocess framework outlined by McDaniel and Einstein (2000) is an influential theory that highlights the importance of several key processes in the successful completion of a intended action. They proposed that the presence of certain cognitive activities is determined by a variety of features, such as the retrieval situation or internal traits of the individual. There are situations in which it is necessary to use attentional resources to monitor the environment for cues that signal the appropriate time to carry out a pre-determined plan. In other situations, however, the retrieval of an intention can occur automatically without having to monitor the environment. The former case is referred to as monitoring, and is believed to result from strategic processes that consume cognitive resources. The latter case is referred to as spontaneous retrieval, and it is assumed to occur in the absence of

consistent strategic activity or the need for attentional resources. McDaniel and Einstein further argued that continually monitoring the environment would not be adaptive to real-world situations where people are involved in multiple ongoing activities.

Smith (2003), on the other hand, emphasized the vital role of strategic monitoring processes with her preparatory attentional monitoring (PAM) theory. This theory reflects the notion that successful performance on PM tasks is based on an interaction between capacity-limited preparatory processes that require attention and retrospective memory of the target items and intended response to those items. In other words, when an intention is formed people are always monitoring their environment for cues that will prompt the retrieval of the intended action, and ultimately lead to the execution of the planned response. A further stipulation of this theory is that execution of delayed intentions always involves resource-consuming preparatory processes, suggesting that this never occurs spontaneously. Thus, PAM theory strongly advocates for the pivotal role played by attentional processes in all PM situations. Smith does acknowledge that people are not necessarily consciously aware of these cognitive activities (i.e., the PM-relevant information is not always in the focus of one's attention), but costs to ongoing task performance do, nevertheless, occur. Furthermore, conscious resources will always be consumed during the PM-relevant time interval, even if a person is unaware that resources are being devoted to the preparation process (Smith, Hunt, McVay, & McConnell, 2007).

The emergence of these theories has sparked an interesting line of research examining the role of attention in event-based PM (Einstein, McDaniel, & Thomas, 2005; Hicks, Cook, & Marsh, 2005; Marsh, Cook, Meeks, Clark-Foos, & Hicks, 2007); McGann, Ellis, & Milne, 2002; Meier, Zimmermann, & Perrig, 2006; Penningroth, 2005; Smith, 2003; Smith & Bayen, 2005; Smith et al., 2007; West, Krompinger, & Bowry, 2005). The outcome of this research has

demonstrated that attentional processes often play a role in the execution of delayed intentions; however, most of these studies have focused on how attentional resources are distributed among ongoing task demands, response to the PM targets, and other dual-task requirements. There are two issues related to the function of attention in PM that are particularly relevant to the current research question: 1) does information related to an intended action recruit attentional resources when it appears during an ongoing task, and 2) will the recruitment of these resources elicit the zoom function of attentional focus, and consequently, impact other ongoing activities? While little empirical work has dealt with the latter issue, the former issue has been addressed by a number of studies.

Several studies have demonstrated that information related to an intended action recruits additional attentional resources relative to the other information present in the ongoing task (Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998; Marsh et al., 2007). Goschke and Kuhl (1993) used the term “intention superiority effect’ to describe their belief that once an intention is formed, information related to this intention is maintained in memory above a baseline level and receives priority from the attention system. In research on this topic, Marsh et al. (1998) found that participants responded more quickly to intention-related words presented in a lexical decision task relative to words that were not related to the delayed intention. In another study, Marsh et al. (2007) embedded a PM component (e.g., press the F1 key when you see items that can be categorized as breakfast foods) within a pleasantness-rating task that was presented visually, and told participants to ignore the items being presented through the speakers. Once they completed this task a surprise recognition test was given that consisted of intention-related items (e.g. breakfast food items that were presented through the speakers, but not in the pleasantness-rating task) and intention-unrelated items presented through the speakers. The

results revealed significantly higher recognition of intention-related relative to intention-unrelated information. Thus, attentional resources were drawn to items from the PM category, even though these items were presented in an auditory channel that participants were instructed to ignore. In this regard, it is reasonable to assume that forming a delayed intention provides a situation in which attentional focus is narrowed in response to the presence of target-relevant information.

An alternative explanation for why PM targets and their associated responses may receive preferential attention from the cognitive system is offered by the discrepancy-plus-search theory (McDaniel, Guynn, Einstein, & Breneiser, 2004). This theory was proposed to account for situations in which spontaneous retrieval, or the reflexive association between a PM target event and intended action, does not occur. In other words, the discrepancy-plus-search framework accounts for situations where cue focused processing (i.e., PM target events) must take place for an intended action to be properly executed. This theory suggests that when a PM cue or target item appears in these situations the cognitive system realizes that it is discrepant or unique relative to the current activities in some way. This initiates a search of the memory system to isolate why this event is important, and what action needs to take place (i.e., the PM response). This is somewhat different than an intention superiority explanation that assumes information related to a target event or intended action receives priority from the attentional system, and therefore, is maintained at a heightened level of activation throughout an ongoing task. The discrepancy-plus-search account, on the other hand, suggests that once the target event is noticed, the processing explanation relies on memory rather than attention mechanisms. This latter account is also in line with the present theoretical stance that predicts attentional resources will be narrowed in response to noticing a PM target event. This should occur if this information

is highly activated in the attentional system, or if the cognitive system suddenly determines that it is discrepant from ongoing activities.

There is minimal empirical work geared towards specifically investigating the role of attentional focus in event-based PM. In fact, most studies within this paradigm always present intention-related information within the focus of attention. In other words, the PM targets are presented alone, embedded within the ongoing task in which focal attention is being applied (e.g., PM targets are the same words being judged in a pleasantness-rating task). In one set of studies, however, Hicks et al. (2005) examined the impact of manipulating characteristics in the focus versus periphery of attention on PM performance. Participants were engaged in a lexical decision task (LDT) and the PM component required a response to the appearance of a red border surrounding the letter strings in the LDT (Experiment 1) or to letter strings presented in red (Experiment 2). The focal or periphery cues were made more salient by either increasing the font size or border size, respectively. Increasing the border size significantly improved performance when the intention was to respond to borders presented in red; however, increasing the font size did not improve PM performance when the goal was to respond to words presented in red. These findings suggest that when the PM target appears within the focus of attention, making this item more salient does not significantly affect PM performance. In contrast, when the target appears in the periphery, increasing its salience helps to focus attention on the relevant information, increasing the likelihood of executing the intention. The authors concluded that these findings point to the importance of attentional processes in event-based PM. Furthermore, these data speak to perceptual limitations in attention, whereas most current theories of event-based PM focus on resource limitations of attention. In terms of the present ideas being discussed, these studies provide one example of how attentional focus can be manipulated within

a PM paradigm. Additionally, the results suggest that drawing attentional focus to certain stimulus features can be beneficial for improving event-based PM.

The primary goal of the present research was to investigate how attentional processes influence people's ability to execute an intended action, within an event-based PM paradigm. One intriguing possibility is that the dynamic nature of attentional focus is influential in determining how people react when they encounter a PM target event. In this regard, the outcome of this research has the potential to inform several areas of cognitive psychology. First, the examination of particular aspects of attentional focus other than its physical size could promote a better understanding of key cognitive processes associated with this mechanism. Second, the findings from the present research will also inform the study of PM by investigating how the focal attention mechanism adjusts to the presence of intention-related information, as well as how ongoing cognitive activities that coincide with PM demands are impacted by these changes.

Another way in which attention has been implicated in PM is through strategic monitoring processes (Smith, 2003; Smith and Bayen, 2005; Smith et al., 2007; West, et al., 2005), that are used to prepare for an upcoming target event. The description of how these processes influence PM is comparable to the explanations that have been offered to account for findings of attentional control mechanisms playing a pivotal role in working memory function (Conway, Cowan & Bunting, 2001; Kane & Engle, 2000; Kane & Engle, 2003; Kane, Bleckley, Conway, & Engle, 2001). Furthermore, past research suggests that the prospective and working memory constructs are related to one another (Smith & Bayen, 2005). Thus, the present research attempted to replicate and extend these findings to determine if individual differences in WM could account for people's performance in an event-based PM paradigm.

EXPERIMENT 1

The purpose of this experiment was to investigate how attentional focus adjusted in response to the appearance of important information related to an intended action. A living/non-living judgment task was used as the ongoing task in order to provide reaction time (RT) data for each trial. The state of attentional focus was manipulated within the task by using single versus multiple items to determine whether the presence of a PM target would better facilitate living judgments when attentional resources were distributed among multiple items.

The current premise is that forming an intention to respond to certain items during an upcoming task will lead to attentional resources being drawn to these items; therefore, when the PM targets appear during the experimental task, attentional focus should be localized, or zoomed in on the PM portion of the task. If attentional focus is narrowed very quickly (such as that observed by Eriksen & St. James), then the concentration of resources on the PM targets (*bird words*) should help facilitate the living judgment on these trials. This in turn should help to lessen the burden of having to make judgments based on multiple items rather than a single item.

Another factor being investigated in the present experiment that speaks to the role of attention in PM is whether individual differences in working memory capacity (WMC) can predict overall performance on the PM component of the ongoing task. PAM theory assumes that PM performance is associated with capacity-consuming attention processes, similar to those used to perform WM tasks (Smith, 2003; Smith & Bayen, 2005). The multiprocess framework, on the other hand, predicts that PM responses can often be successfully executed without the need for the capacity-consuming processes that are typically associated with WM performance (McDaniel & Einstein, 2000). Several measures of WMC will be administered to test the predictions stemming from these prominent theories of PM.

Method

Participants. The participants in this study were 136 undergraduates from Louisiana State University who received extra credit or partial fulfillment of course credit in psychology courses. All of the participants retained for this final sample were native English speakers, had normal to corrected vision, and responded accurately to at least 80% of the items in the processing component of all three complex memory span tasks described below. The demographic information for one of the 136 participants (44 males and 91 females) was lost, but the mean age for those remaining was 20.6.

Materials. The primary experimental task was a living/non-living judgment task in which participants had to make judgments about items being presented on each trial. The words used for this task were generated from the MRC Psycholinguistic Database (Coltheart, 1981) using the following criteria: concreteness (400-700), familiarity in the English language (400-700), number of syllables (1-2), and part of speech (noun). Approximately 300 words were selected from the generated list, with half of the items consisting of living objects and the other half consisting of non-living objects. The task was programmed using EPrime software (Schneider, Eschman, & Zuccolotto, 2002).

A within-subjects design was used for this experiment; participants completed trials that determined their baseline PM performance when their attention was already focused on a single item, as well as the experimental trials that forced attentional resources to be distributed across pairs of items. In the baseline (single) segment of the task each item was presented individually in the center of a white screen in black uppercase, 18-point, Arial font. A fixation asterisk flashed in the middle of the screen for 250 milliseconds to indicate the onset of each test item. Five PM targets (*canary, dove, eagle, crow, pigeon*) were presented during the first portion of

the task. In addition, five other living items were randomly chosen to serve as control words (*bear, catfish, hamster, pony, turtle*) to assist in constructing a measure of ongoing task costs on the PM target trials. These control words were always presented on the trials immediately preceding the PM target trials. There were 100 trials in this section of the judgment task.

On the experimental (pair) trials, pairs of stimuli were presented in the center of the screen with one item positioned approximately 1 inch above the other. The font characteristics of these items were identical to those used in the baseline segment of the task. The physical separation of the items on each trial was used to induce a global state of attentional focus in the participants (Chen, 2003; Experiment 2), as a decision had to be made between the items to determine which item represented a living object. One item in the pair always represented a living object, while the other item always represented a non-living object. The position (top or bottom) of the living item was randomly distributed across the trials to prohibit the participants from being able to predict the location of the living item. There were five PM targets (*hawk, robin, sparrow, goose, duck*) presented on separate trials in this segment of the judgment task. The PM targets always appeared in the top position of the pair. Additionally, five living items were chosen to serve as controls (*wolf, frog, lady, baby, grass*) and they were presented in the top position on the trials immediately preceding each PM target. The same set of PM targets and control-matched words were always presented in a particular component of the task to ensure that any condition (baseline vs. experimental) differences did not reflect the particular words being used. In other words, *canary, dove, eagle, crow, pigeon* (and their respective control-matched items) always served as the PM target items in the first task segment completed, while *hawk, robin, sparrow, goose, duck* always served as the PM target items in the second task segment that was completed. There were 100 trials in this section of the judgment task.

Three of the WM tasks used in the present study were complex span tasks that contained separate storage and processing components. The purpose of the separate processing component is to block strategic activities, such as rehearsal, while gaining an index of WM capacity (WMC). The materials used for the first complex span task, the automated operation span (Ospan), were constructed by Unsworth, Heitz, Shrock, & Engle (2006) using EPrime software. In this task participants are presented with a math problem followed by a single letter. The storage requirement is to retain all of the letters in a given trial, as the participants will be asked to recall the letters from each trial in the correct order. The processing component of the task consists of responding to the correctness of the solutions presented with each simple math problem. Half of the time the solution is correct and the rest of the time it is incorrect. The number of letters/math problems presented in a given trial ranges from 3-7, with three trials presented at each list length. At the end of each trial, participants are shown a visual display with a series of letters, and they are told to use the mouse to choose the letters that were presented in the preceding trial in the correct order. Throughout the task they are encouraged to maintain a high level of accuracy on the math portion of the task, and to make these responses in a timely fashion. The performance index calculated for all three of the complex span tasks reflects the total number of items they recalled in the correct serial order from the storage component.

In the second complex span task, the automated reading span (Rspan), participants were asked to make judgments about the sensibility of presented sentences. If the sentence made sense (e.g., the fish is swimming in the water) they would respond “yes” after reading it, and if the sentence did not make sense (e.g., the fish is swimming in the apple) they would respond “no” after reading it. After a determination was made about the sentence a letter would appear on the screen for 1 second. At the end of a series of sentences, a set of letters were presented to the

participants (identical to those used in the Ospan), and they had to indicate which letters had been presented in that trial, in the correct serial order. The task consisted of three trials at each list length (3-7).

In the final complex span task, the automated symmetry span (Sspan), participants made symmetry judgments, as well as retained the spatial sequence of a series of colored squares. For the symmetry judgments, an 8 x 8 matrix appeared with some of the squares filled in black, and participants had to determine whether the pattern represented in the matrix was symmetrical (relative to the vertical axis). After each symmetry judgment was made a 4 x 4 matrix appeared with one square filled in red. At the end of a set of trials participants had to fill in an empty 4 x 4 matrix (by clicking with their mouse) with the location of the red squares from the preceding trials, in the correct order. This task consisted of three sets of trials at each list length (2-5).

Recently, alternative approaches to measuring WM function have been proposed. Cowan et al. (2005) noted that one problem with traditional storage and processing measures is that reliance on certain task-specific skills, such as mathematical aptitude, cloud their interpretability; therefore, performance on these tasks likely reflect an index of storage capacity, as well as proficiency in the processing component. Thus, scores derived from traditional storage and processing measures do not provide a pure measure of WMC. Scope of attention tasks, such as the Visual Array Comparison (VC) task, are also designed to block strategic processes, such as rehearsal and chunking, but in the absence of a separate processing component that requires specific skills. The VC task will be administered to participants to provide an alternative measure of WMC. The task was identical to the one used by Cowan et al. (2005). Cowan et al. used this measure to assess the capacity of the scope, or focus, of attention, which he has claimed to be the only capacity-limited portion of the WM system (Cowan, 2005). In this task participants view

arrays of colored squares with 4, 6, 8, or 10 randomly dispersed squares. An array is presented on the screen briefly (250ms), followed by a gray screen that appears for 1s, which is followed by a second array that is identical to the first array, except for one square that is sometimes a different color. In the second array one square is encircled with a black ring, and the participant is instructed to press a certain key (/) if the encircled square is the same color as the square presented in the same position in the previous array, or press another key (z) if it is a different color. Once they have answered they proceed to the next trial. Participants respond to 64 trials at each array size, and trials at a given array size are randomly distributed across the 256 trials of the task. The capacity index derived from the VC task is based on a formula used by Cowan et al. (2005) that assumes people will respond correctly to the encircled item on the second array if the cued item from the first array is still active in WM, regardless if there was actually a color change. The formula takes into account the number of hits and false alarms, and the numerical output of this formula is believed to increase with set size until the individual's capacity is met. Once the level of asymptote is achieved, this measure is believed to represent the capacity of the focus of attention (see Appendix A of Cowan et al., 2005 for more details).

Procedure. Participants completed this experiment individually on a Dell desktop computer during two sessions spaced 48 hours apart. When they arrived for the first session they filled out informed consent forms and provided demographic information. During the two one-hour experiment session participants completed a variety of memory tasks, but only those that are pertinent to the present research question will be discussed in this paper. The Ospan and Sspan tasks were completed during the first session. In the second session they completed the judgment task, along with the Rspan and VC tasks.

The instructions for the judgment task consisted of several components, and participants were encouraged to pay careful attention to each component. In the instructions for the single segment of the task the participants were told that single items would be presented on the screen and they should determine whether each item represented a living or non-living object. Examples were given for types of items within these categories. They were told to position their left index finger over the “F” key, their right index finger over the “J” key, and an “L” and “N” sticker were placed over these keys to indicate “living” or “non-living” judgments, respectively. Participants were told to make their judgments as quickly and accurately as possible by pressing the appropriate key. Pressing the “space” bar allowed them to proceed to the next trial. Five practice trials were completed for this component of the task before moving on to the next set of instructions.

Instructions were also given for the pair segment of the task. Participants were told that in this section of the task pairs of stimuli would be presented and they were to determine which item in the pair represented a living item. They were instructed to press the “R” key if the living item appears on top and the “U” key if the living item appears on bottom. These keys were marked with “T” and “B” stickers, respectively. Five practice trials were completed on this component of the task before moving on to the next set of instructions.

Once participants appeared to understand how to perform both segments of the judgment task, they were given instructions for completing the PM portion of the task. The instructions for the PM portion were as follows:

We are also interested in testing your memory for doing something in the future. If at any point during this experiment while you are making your living/nonliving judgments or top/bottom judgments and you happen to encounter a word that represents a type of bird (i.e., OWL), please press the '/' key at the bottom right of the keyboard after you have made your living/nonliving or top/bottom judgment but BEFORE you press SPACE. To reiterate, every time you see a word

that represents a type of bird during both sections of the upcoming task, you will first make your living judgment, then press the '/' key, then press the SPACE key to move onto the next trial.

YOU WILL NEED TO DO THIS FOR BOTH SECTIONS OF THE TASK THAT HAVE BEEN DESCRIBED!

The experimenter then asked the participant to tell them what they were supposed to be doing in this task. Before they were able to proceed, participants had to list all four of the following; 1) in the single item component they had to determine whether the item represented a living or non-living object and respond appropriately, 2) in the paired item component they had to determine which item represented a living object and respond appropriately, 3) every time they saw a bird word in either component of the task they had to make the designated keypress, and 4) they were supposed to make the living/non-living judgment, as quickly as possible, prior to making their response to the bird words. Half of the participants completed the single condition first and the other half completed the pair condition first to control for any potential order effects. A screen appeared for 10 seconds in between the two components, and it instructed them to get ready for the next segment. The order of task instructions corresponded to the order in which the task segments were administered.

Results

Several approaches were taken to analyze the data. First, data from the judgment task was evaluated to determine how people performed in the single versus pair condition. Second, PM performance was examined according to how often people responded to the presence of the PM targets within the single and pair conditions, as well as the response latencies to the ongoing task on the trials in which the PM target appeared. Third, regression analyses were conducted to determine if individual differences in WMC could predict how well people remember to execute

a delayed intention. All of the significant effects discussed throughout the paper were based on an alpha of .05.

The data will be collapsed across the order variable (whether people performed the single or pair condition first) to allow for within-subject comparisons. There were, however, several instances where order effects were observed, and these will be discussed along with the relevant data.

Judgment Task. Overall, participants were quite accurate in making living/non-living judgments in both of the within-subject conditions. In the single item condition participants falsely identified a living item as non-living on 6.7% of the trials containing a living item, and inaccurate responses to the non-living items only occurred on 1.9% of these trials. Similar levels of accuracy were observed in the pair condition. The top item of the pair was misidentified as the living item on 2.9% of the trials, and the bottom item was misidentified as living on 2% of the trials.

Next, reaction time (RT) trends were examined for each trial type of the single and pair segments of the task. A median RT was calculated for each individual to represent their response latencies on all of the trials in which they responded to accurately in each of the following instances: a living item appeared in the single segment, non-living item appeared in the single segment, top item in pair was living object, bottom item in pair was living object. The average RT on trials containing living items in the single segment ($M = 887\text{ms}$) was comparable to that observed on non-living trials ($M = 895\text{ms}$). In the pair segment, however, people did respond significantly more quickly if the living item appeared in the top position ($M = 1279\text{ms}$) relative to the bottom position ($M = 1357\text{ms}$), $t(135) = 6.64$. This is not surprising given the probable tendency for people to first see if the top item was living before examining the word in the

bottom position. Granted, the finding of considerably longer response latencies occurring when the living item was in the top position of the pair condition relative to when the living judgments were made in the single condition, suggests that a choice was being made between the two items in the pair condition.

The RT data was also examined across the single and pair conditions, while collapsing across the trial type (living versus non-living). A median RT was calculated for each person based on all of the trials they responded to correctly in each segment of the task (removing the trials in which the PM targets appeared). A paired-samples t test was conducted to compare the means of these median RT values, and one participant was excluded from the analysis due to missing data. The results revealed that participants responded significantly more quickly on single ($M = 888\text{ms}$) relative to pair ($M = 1315\text{ms}$) trials, $t(134) = 20.29$. As a reminder, the purpose of the pair condition was to force people to distribute attentional resources among multiple items when making judgments on each trial. Even if people first zoomed in on one item to determine if it was a living object before moving onto the next item, if necessary, this would still lead to longer response latencies since it was not possible to predict in which position the living item would appear on a given trial. The single item condition, on the other hand, allowed people to focus their attentional resources on one item, presumably facilitating a quicker decision on each trial. The finding of significantly faster RT's being observed on the single relative to the pair trials supports this premise.

It should be noted that order effects were observed in the pair condition concerning the average response time across trials. Participants responded more quickly when the pair condition was completed first ($M = 1242\text{ms}$) relative to when it was completed second ($M = 1359\text{ms}$), $t(133) = 2.08$. This is not a surprising outcome given one might expect slower responses to occur

after the response criteria had changed during the ongoing task (making living/non-living judgment for one item versus deciding which of two items was living); however, there were no order effects observed in the single condition. It is possible that a small cost was only associated with changing from the single to the pair component because the pair condition demanded more cognitive resources, making it a more difficult transition, but there is no way to be sure that this is the case. The primary purpose of evaluating overall RT patterns was to establish that responses in the single condition were faster than in the pair condition; therefore, follow-up analyses were conducted to ensure that the observed pattern was not driven by the order in which a given task component was completed. The same outcome was observed, as participants who completed the single segment first, as well as those who completed it second, all responded significantly more quickly on this component relative to the pair trials.

Prospective Memory. Participants were told to make a designated keypress (after responding to the judgment task) every time they saw a PM target (*bird* word) in the single and pair conditions. Few participants ever made erroneous responses to non-target items (3 in the single condition and 2 in the pair condition), but credit was only given if the correct response was made on the designated target trials. There were five PM targets presented in each condition, and the proportion of times people responded correctly to the PM target was equivalent in the single ($M = .74, SD = .03$) and pair conditions ($M = .73, SD = .03$). The proportion of correct responses to each of the PM targets in both task components is presented in Table 1.

Table 1 Experiment 1 Prospective Memory Performance and Related Costs. Values in first two lines represent the mean proportion of correct responses made to each PM target in the single and pair conditions, as well as the mean proportion correct across these targets. The bottom two lines display response costs to the ongoing task, as indexed by average difference in RT's, in milliseconds, between judgments made on PM relative to control trials.

| Condition | PM1 | PM2 | PM3 | PM4 | PM5 | Mean |
|-------------|-----|-----|-----|-----|-----|------|
| Single | .79 | .82 | .86 | .54 | .66 | .74 |
| Pair | .83 | .79 | .78 | .57 | .68 | .73 |
| Single Cost | 504 | 410 | 416 | 233 | 277 | 368 |
| Pair Cost | 574 | 398 | 342 | 346 | 61 | 344 |

Comparisons were made between the PM targets appearing in each ordinal position of the single and pair conditions (i.e., 1st target in single segment versus 1st target in pair segment, 2nd target in single segment versus 2nd target in pair segment, etc.), and no significant differences were observed. These findings were in line with the present theoretical stance, which does not anticipate people will be less likely to execute a delayed intention when their attentional resources are distributed between two rather than one item. In fact, if the presence of a PM target leads people to zoom-in on that item, then PM performance should be equivalent in the single and pair components.

It should also be noted that PM performance was worse for the targets presented in the fourth and fifth ordinal position of both the single and pair components. This is consistent with previous research that suggests PM performance will decrease across the ongoing task (Einstein et al., 2005). Another possible explanation for this trend concerns the level of association between the category word *bird* and these exemplars. The 4th and 5th PM targets were always *crow* and *pigeon* during the first component of the task, and *goose* and *duck* during the second component of the task, respectively. None of these words are listed as first associates of the word *bird* in the South Florida Free Association Database (Nelson, McEvoy, & Schreiber, 1998). The target words from the present study were selected from the word pool that was created according

to the previously mentioned criteria. The fact that ratings based on normed data did not produce these items as associates of the category *bird* could have diminished the probability that participants recognized these items as PM target words. There are, however, two other items used as PM targets in the present study (*sparrow* and *hawk*) that are not listed as associates to the word *bird*, and were identified as target items at a higher level than those items located in the 4th and 5th ordinal positions. Thus, the lower PM performance observed in these final two conditions likely reflects a combination of these two factors.

Order effects that appear to stem from these questionable PM targets were also observed. The proportion of times people responded correctly to the target items in the single condition was significantly less when it appeared as the second relative to the first component of the judgment task, $t(134) = 4.37$. Table 2 summarizes PM performance for each target item by condition, depending on the order in which the single and pair conditions were presented during the judgment task.

Table 2 Experiment 1 Prospective Memory Performance by Task Segment and Order Variable. Values represent the mean proportion of correct responses made to each PM target in the single and pair segments of the judgment task, depending on the order in which the task segments were completed by the participants.

| Task-Order | PM1 | PM2 | PM3 | PM4 | PM5 |
|------------------------|-----|-----|-----|-----|-----|
| Single-1 st | .77 | .87 | .88 | .88 | .92 |
| Single-2 nd | .80 | .80 | .85 | .33 | .50 |
| Pair-1 st | .80 | .79 | .74 | .62 | .80 |
| Pair-2 nd | .88 | .81 | .85 | .50 | .50 |

Further examination of these data revealed that the order effect in the single condition resulted from the fact that PM performance was much lower for the 4th and 5th targets presented in the second component relative to the 4th and 5th targets that were presented during the first component of the judgment task. Conversely, the order effect was not observed in the pair condition even though performance tended to be lower on the 4th and 5th target items when the pair segment was completed second relative to when it was the first component of the judgment task. The reason why the order effect did not reach statistical significance in the pair segment is most likely due to the similar level of PM responses being made to the 4th target in the first and second sections of the judgment task. Follow-up analyses were conducted to evaluate whether the same pattern of results would occur if the PM proportion correct score only included the first three target items in each component of the task. No order effects were observed when this index was used; furthermore, PM performance was still comparable in the single ($M = .82, SD = .31$) relative to the pair condition ($M = .80, SD = .31$), when collapsed across the order variable. In any case, the problems associated with the final two target items presented during the second component of the judgment task in particular (*goose* and *duck*), suggests they might not be good target exemplars of the category *bird* in an event-based PM paradigm.

Reaction Time Data. Response latencies were examined on the trials of the judgment task that contained *bird* words (target trials) as well as for the trials that directly preceded the target trials (control trials). Past research has demonstrated slowing costs on the ongoing task for trials in which the PM target was presented (Loft & Yeo, 2007; Marsh, Hicks, & Watson, 2002; West et al., 2005). Additionally, difference scores based on the RT's for the PM target trials and a control trial have been utilized to compare the costs that are experienced in various conditions (Loft & Yeo, 2007). Difference scores (RT on target trials minus RT on respective control

trials) were constructed on the present data to enable a comparative look at ongoing task costs in the baseline (single) versus experimental (pair) conditions. It is anticipated that costs will be observed in both conditions; however, if the presence of the PM target leads participants to focus their attentional resources on that item then no additional costs should be observed in the pair segment of the task, even though responses in this condition are considerably slower in general.

These data were evaluated in several ways to ensure the observed effects were a result of the intended experimental manipulation rather than an artifact of the data. In the first set of analyses, the RT data for all of the target and control trials were considered, regardless if the participant responded accurately on the judgment task or to the PM target. The second set of analyses only used data from trials in which the correct judgment was made and the PM target was accurately identified. Finally, indices were calculated based on each individual's median RT for all of the target trials, as well as the control trials in the single component. The same indices were also calculated to reflect performance in the pair component. This latter approach was taken to control for any extreme RT values. The same results were observed regardless of how the data were analyzed; therefore, the explanation of the data will focus on the latter approach, which allowed for a more concise evaluation of the data.

A value was computed for each individual to represent their median RT across the 5 trials of each trial type being considered (e.g., single control, single target, pair control, and pair target), resulting in 4 values being computed for each individual. A 2 x 2 repeated-measures ANOVA was then conducted using these values, with task (single versus pair) serving as the first factor and condition (control versus PM) serving as the second factor. As expected, there was a main effect of both task, $F(1, 135) = 133.77$, $MSE = 13615514.65$, $\eta_p^2 = .50$, and condition, $F(1, 135) = 68.03$, $MSE = 9546095.53$, $\eta_p^2 = .34$. The two main effects reflect that fact that

responses were made significantly more quickly in the single segment of the task, and people responded more slowly on the judgment task, in both the single and pair components, when the items represented PM targets. This former effect is consistent with the notion that attentional resources were constrained to one item in the single segment, but were distributed among both items in the pair segment. The latter effect supports previous findings that suggest RT costs will be observed for ongoing task trials that contain PM target items.

The interaction term in this analysis is most pertinent to the predictions of the zoom hypothesis. The prediction is that a significant interaction between task and condition will not occur, given no additional costs should be observed on the target trials in the pair condition if participants are zooming in on the target item. This prediction was supported, as there was no significant interaction between task and condition. As mentioned previously, one approach to examining costs related to the presence of PM targets is to calculate a difference score based on RT's on the PM relative to control-matched trials. Table 1 displays the mean difference score associated with each control/target pair in the single and pair conditions. A follow-up analysis was conducted using a difference score based on the median values discussed previously, which indicated that there was no significant difference in average RT costs associated with the presence of PM targets between the single ($M= 303\text{ms}$) and pair ($M= 329\text{ms}$) conditions, $t < 1$.

Taken together, these findings are consistent with the predictions made by the zoom hypothesis. Specifically, greater PM target costs were not observed on the relevant pair trials of the judgment task even though performance was considerably slower in all other respects for the pair relative to the single component of the task. Participants were likely able to respond more quickly in the single component because all of their attentional resources were focused on one item, whereas in the pair component these resources had to be distributed between two items

before making the appropriate decision. The fact that greater costs were not observed on the trials in which PM targets appeared, however, suggests that attentional resources were drawn to the *bird* word, which helped to better facilitate their living response on that trial. If these resources were not narrowed to the target item then you would expect an additive effect of the general slowing in the pair condition (an average of 427 ms) along with the costs stemming from the presence of a PM target (329 ms). Of course, the recruitment of attention resources to the PM target word in the pair should not completely alleviate the response costs that are virtually always associated with the presence of PM targets (see Marsh et al., 2002 for alternative findings on missed targets), but if the nature of the PM target is consistent with ongoing task demands (i.e., bird being a living object) then it should help lessen the burden of an otherwise more demanding task.

Individual Differences. Several analyses were conducted to determine if individual differences in working memory capacity (WMC) could account for people's ability to successfully execute the designated response to the PM targets. Multiple indices were constructed to reflect an individual's WMC. First, a total score index was calculated based on performance in each of three complex span tasks (operation, reading, and symmetry span), which reflects the total number of items they recalled correctly in the correct serial position. A factor composite score was then created based on the average z-scores from these three indices. It is assumed that this is a more powerful approach to assessing individual differences associated with WMC, as the shared variance among these tasks represents a purer measure of this construct (Colflesh & Conway, 2007; Unsworth, 2007). Second, an alternative index of WMC was also constructed based on performance in the visual array comparison (VC) task. It has been suggested that performance on this task reflects the number of items people can hold in the focus

of attention (Cowan et al., 2005). Third, the top and bottom quartiles of the complex span composite index were used to divide participants into high ($n = 34$) and low ($n = 38$) span groups, respectively.

Linear regression was used in the first set of analyses to investigate whether individual differences in WMC could predict PM performance in either the single or pair conditions. Two participants were not included in these analyses due to missing data in one of the WM tasks. In the first analysis both the composite span index and the VC index were used to predict proportion of correctly identified PM targets in the single condition. The results revealed that the measures of WMC did not account for a significant amount of predictive variance in PM performance, $F(2, 133) = 2.46, p > .05, R^2 = .04$. The same outcome was observed when the two composite indices of WMC were used to predict PM performance in the pair segment of the judgment task, $F(2, 133) = 1.69, p > .05, R^2 = .03$.

Two independent-samples t tests were also conducted to determine if high and low spans performed differently on the PM component of the task. Again, the results indicated that high spans were no more likely than low spans to successfully execute the designated response to PM targets in either the single, $t(70) = .80, p > .05$, or pair condition, $t(70) = 1.02, p > .05$. These results clearly indicate that in the present paradigm individual differences in WMC are not able to account for event-based PM performance. This was true despite the use of several different indices of WMC, and an examination of the highest and lowest functioning groups within this construct. These results are inconsistent with previous research that suggests PM accuracy levels are correlated with measures of WM (Smith & Bayen, 2005). Conversely, these findings support the views of the multiprocess framework that suggest people can often perform event-based PM

tasks without recruiting capacity-consuming attention processes, such as those being used to perform tests of WM (Einstein et al., 2005; McDaniel & Einstein, 2000).

EXPERIMENT 2

The results of Experiment 1 were consistent with the premise that executing a delayed intention will initiate the zoom function of attentional focus proposed by Cowan (2001; 2005). This hypothesis was further tested in Experiment 2 using a different ongoing task that would allow for the opportunity to observe costs related to the narrowing of attentional focus. In the present experiment, participants were presented with a visual display consisting of four words, and they were asked to recall these items in alphabetic order. The number of items chosen to appear in each display was based on the assumption that most people can maintain approximately four items or chunks in the focus of attention at a given time (for review see Cowan, 2005). Half of the participants were given the additional assignment of making a designated keypress every time they saw a *bird* word during the ongoing task. If the presence of PM targets causes people to focus their attentional resources, or zoom-in, on that information then recall performance should suffer, leading to memory decrements on PM target trials in the experimental relative to the control group. Previous research has demonstrated that constraining attentional resources can lead to performance costs when the concentration of these resources on a particular item hinders the ongoing task processing in some way (Chen, 2003). In this case, devoting these resources to the PM target could reduce the ability to process and encode the other items in the display.

The findings from Experiment 1 did not support the assumptions of PAM theory that suggest individual differences in WMC should be associated to people's ability to make a designated response to target items during an ongoing task. This could have been due to the paradigm that was used in the previous experiment; thus, the individual differences factor was further examined in Experiment 2 using a different ongoing task. In addition, the use of an

experimental and control group in the present experiment enabled an alternative approach to testing the predictions of PAM theory. Past research has attributed slower response within an ongoing task (that has an embedded PM component) to the costs associated with capacity-consuming monitoring (Einstein et al., 2005; Smith, 2003; Smith & Bayen, 2005; Smith et al., 2007; West et al., 2005). Thus, in the present study, comparisons were made between memory performance on the non-target trials of the experimental and control conditions to investigate whether strategic monitoring processes are taking place. If ongoing task performance, in this case word recall, is worse on the non-target trials of the experimental relative to the control condition then it can be assumed people are using capacity-consuming attention processes to monitor for PM targets. On the other hand, if no ongoing task costs are observed for the experimental group it would provide support for the multiprocess framework that suggests strategic monitoring is not always necessary. In many instances, people perform their ongoing activities without considering an action they are supposed to initiate at a later point, and the presence of a cue in the environment (such as a PM target) leads to spontaneous retrieval of the intended action. The predictions of the zoom hypothesis are consistent with this notion, given the act of spontaneously retrieving an intended action in response to the presence of a PM target could still negatively affect other information being processed along with the target.

Method

Participants. Undergraduate students enrolled in psychology courses at Louisiana State University participated in this experiment for partial fulfillment of a course requirement or for extra credit. A total of 94 participants were kept in the final sample for the PM analyses (mean age = 20.21) after excluding people who were non-native English speakers or had hearing impairments. Only 90 participants reported information about their gender (female = 79, male =

11). Twelve additional participants were dropped for the WM analyses due to processing errors on the complex span tasks that were administered.

The three complex span tests used in Experiment 1 (automated operation, reading, and symmetry span) were administered to undergraduate psychology students from Louisiana State University as part of a large-scale screening process. The tests were administered in the same order for all participants: operation span, symmetry span, reading span. During the testing sessions participants were seated at individual computer stations, and there were up to six participants in each testing session. Only people who completed the WM screening were eligible to participate in the PM portion of the present experiment, which took place within 1-6 weeks after they had completed the screening process.

Recall Test. Both living and non-living items used in the judgment task from Experiment 1 were used to construct the recall test for the present experiment. In this task participants were shown a set of four words on each trial, and the words were presented simultaneously for 3 seconds. The words appeared in lowercase letters with black 18-point Arial font on a white background, and they were presented vertically with approximately 1 inch separating each word. The first letter of each word was never the same on a given trial, and they were never presented in perfect alphabetic order. Other than these two constraints, the words were chosen randomly for each of the 36 trials, but each trial was held constant across participants. After the words were presented a blank gray screen appeared for 1.5 seconds followed by the recall screen. A reminder of the instructions for the task was presented at the top of each recall screen, as follows:

Recall the items in alphabetical order (without capitalization). Use the letter "x" as a filler if you don't remember a word. Press SPACE after each word recalled...

Participants were given as much time as needed to recall the words in alphabetical order.

They were asked to use a place filler if they could not remember a word, but did know at

which point in the alphabetic sequence the word should be placed. There were only two instances in which participants did not use the place filler. Once the participants had typed in their answers and pressed ENTER to move onto the next trial, a blank white screen appeared for 2.5 seconds before the next trial began. This blank screen was the point in which the designated response to the PM targets was made in the experimental group.

The only difference between the experimental and control group was that the experimental group was instructed to make a specific keypress every time a *bird* word appeared on one of the recall trials. A delay-execute procedure was used for the PM portion of the task, which required participants to wait and make the designated keypress after they had recalled the words from that trial. The purpose of using this procedure in the present study was to ensure that any differences that might arise between the experimental and control group were due to the presence of a PM target for those participants who were told to look for these items, not because they had to make an extra response while actually encoding these items. The requirement of a motoric response at this point could have led to poorer encoding of the items. Research has shown that college students are capable of delaying their response to PM targets, with little to no detriment to PM performance (Einstein & McDaniel, 2000). The PM target words (*sparrow, eagle, dove, robin, hawk*) were presented on trials 7, 16, 21, 28, and 35, respectively. They were always presented as the second item down in the list.

Procedure. When the participants arrived at the lab the experimenter verified that they had participated in the WM screening prior to administering informed consent. The demographic information was collected during the screening process. They were then

randomly assigned to either the control (n = 49) or experimental (n = 45) condition. Each participant completed the recall test individually while seated at a computer station. The experimenter read the instructions for the recall test out loud while the participant read the instructions silently from the computer screen. Next, they completed five practice trials. After completing the practice trials the control participants were asked to tell the experimenter what they were supposed to be doing in this task. If it was clear that they understood, they were instructed to complete the test trials.

Once the participants from the experimental group had completed the practice trials they were shown and read aloud the following instructions for the PM portion of the task:

In addition to recalling the words, you will need to make a special response when you encounter any word that represents a type of BIRD (i.e., PIGEON). When you encounter a BIRD word, perform the task just as you normally would by recalling the words in alphabetical order. After you recall the fourth and final word of the list that contains the BIRD word, you will need to press the "/" key on the keyboard AFTER you press the ENTER key but before the next list of words appears. Thus, the brief delay in between each trial that appears after you press the ENTER key is the point in which you should make the response to the bird word.

At this point the experimenter asked the participant to recite to them what they were supposed to be doing in both the recall and PM portions of the task. They were not allowed to move onto the test trials until they had successfully recited this information. The recall test took 15-20 minutes to complete.

Results

Performance on the recall test was based on the number of items they recalled in the correct alphabetic order on each trial, giving participants a proportion correct score for each of the 36 test trials. All of the data were checked for misspellings, and credit was given if it was

obvious the participant was attempting to enter the correct word. An additional index was calculated to reflect the proportion of total items recalled across the entire recall test. Serial position functions were created to determine if serial position effects interacted with group (experimental vs. control) on the PM target trials. This interaction was not observed; therefore, the remaining analyses were based on the total number of items they recalled correctly in each trial, collapsed across the serial positions. A proportion correct score was also created to represent how many PM targets were recognized by participants in the experimental group.

Examination of the proportion of total items recalled correctly on non-PM target trials in the recall task did not reveal any significant differences between the experimental ($M = .83$, $SD = .17$) and control ($M = .82$, $SD = .21$) conditions, $t < 1$. This outcome suggests that there were no ongoing task costs due to strategic monitoring for PM targets in the experimental group. Furthermore, it is clear that recall performance was relatively high for both groups. PM performance was comparable to that observed in Experiment 1 ($M = .76$, $SD = .31$), consistent with previous research that indicates college students are quite capable of delaying their response to target items until a later point (Einstein & McDaniel, 2000). The average proportion of times people made the appropriate response to each of the five PM targets ranged from .64 to .87. The number of participants who made an erroneous PM response was abnormally high. Fourteen participants made the designated PM keypress at inappropriate times during the task. There was a systematic error that accounted for the majority of these responses; eleven of these participants made a PM response on a trial that contained the words *daisy*, *fawn*, *mistress*, and *rock*. It is likely that the only item from this set that might be ambiguous to a sample of college students is the word *fawn*. This suggests that the word *fawn* may have been commonly mistaken as a *bird* word. None of the erroneous responses were treated as correct target identifications.

The analyses that are most pertinent to the zoom hypothesis concern recall performance on the trials in which the PM target appeared. To reiterate, this hypothesis predicts that recall performance should be lower on these trials for the experimental group if the presence of the PM target facilitates the narrowing of attentional focus to that item. Table 3 summarizes the proportion of correctly recalled items for each of the target trials by condition.

Table 3 Experiment 2 Prospective Memory and Recall Performance on Target Trials. Values in first two lines represent the mean proportion of correct responses made to each PM target in the experimental condition (T7=Trials 7, T16=Trials 16, T21=Trials 21, T28=Trials 28, T35=Trials 35), as well as the total proportion correct across these targets. The bottom two lines display the mean proportion of items recalled correctly on PM target trials in control and experimental groups.

| | T7 | T16 | T21 | T28 | T35 | Total |
|------------------------|-----|-----|-----|-----|-----|-------|
| PM Accuracy | .87 | .78 | .78 | .64 | .73 | .76 |
| Recall (PM group) | .87 | .86 | .78 | .77 | .89 | .84 |
| Recall (Control group) | .82 | .82 | .83 | .77 | .83 | .81 |

These indices include data for all of the experimental participants, regardless if the designated response was made to the PM target. A 2 (experimental vs. control) x 5 (trials that contained bird words) mixed-model ANOVA was conducted to determine if recall performance was lower for the PM relative to the control group on the relevant trials. The results revealed that there were no significant differences in recall accuracy between the two groups. There was a main effect associated with the within-subjects factor, $F(4, 364) = 3.80$, $MSE = .13$, $\eta_p^2 = .04$. A follow-up Bonferoni test revealed the source of this main effect; overall, recall performance was significantly worse on the trial in which the fourth *bird* word appeared ($M = .77$) relative to the trial in which the final *bird* word appeared ($M = .86$). Recall performance, collapsed across the experimental and control groups, was similar on all of the other target trials.

A second set of analyses were performed that only considered recall data from the target trials that were associated with correct identification of the PM targets. Due to the fact that only the experimental participants would be excluded from analyses for this reason, within-subjects

comparisons were made; therefore, the values that will be reported for these analyses will not be consistent with those presented in Table 3. Thus, an individual's recall performance from each target trial was compared to their performance on the trial that directly preceded a given target trial (i.e., trial 7 versus trial 6, trial 16 versus trial 15, etc.). The results of the first three comparisons were consistent with the previous analyses, and did not reveal any significant differences between recall performance on the target versus preceding trials. The fourth comparison, however, demonstrated that the number of items that were recalled on the fourth PM target trial ($M = .83$) was significantly less than the number of items recalled on the preceding trial ($M = .93$), $t(32) = 2.62$. The final comparison resulted in a marginal effect, suggesting that recall levels on the fifth PM target trial ($M = .93$) were less than those observed on the preceding trial ($M = .97$), $t(34) = 1.97$, $p = .06$. Mean performance in these final two conditions, as well as across the task, suggests that near ceiling effects were present.

The individual differences data were examined in a similar fashion as Experiment 1. A composite index was created based on the average performance across the three complex span tasks (operation, reading, and symmetry span). This score was treated as the predictor, and overall PM performance was the dependent measure in a regression analysis using participants from the experimental group ($n = 39$). In line with the findings from Experiment 1, WM performance was not a good predictor of how often participants remembered to respond to the PM targets, $t < 1$. In fact, the zero-order correlation between WM and PM performance was near 0. Another approach to investigating this potential relationship is to look at a measure of cost on the ongoing task to see how it relates to WM; however, this is not possible in the present experiment, as no ongoing task costs were observed. This is based on the finding that the mean

proportion of items recalled correctly on non-target trials was equivalent in the experimental ($M = .83$, $SD = .17$) relative to the control ($M = .82$, $SD = .21$) condition.

The present results do not fully support the zoom hypothesis, nor the predictions from PAM theory that assume a relationship should exist between WM and PM and strategic monitoring processes should lead to ongoing task costs when a PM demand is present. There are several issues that could have contributed to these outcomes, particularly those related to the zoom hypothesis. First, recall accuracy was quite high across the task, which could have greatly diminished any chance of observing potential costs due to the narrowing of attentional focus. Specifically, the demand of the ongoing task (retaining and reordering four items) might have been low enough to be met without suffering any costs from attentional resources being temporarily narrowed to the target item. Second, using the delay-execute procedure could have encouraged participants to minimize attentional resources being devoted to the PM targets at encoding since they would not have to make the designated response until after the items were recalled. These possibilities will be evaluated more thoroughly in the General Discussion.

DISCUSSION

The purpose of the present research was to investigate how attentional resources were utilized in an event-based PM paradigm. One hypothesis that was explored predicted that the presence of PM targets in an ongoing task would initiate the “zoom” mechanism held by the focus, or scope, of attention. A second hypothesis that was explored was based on the premise that the attentional processes associated with people’s ability to successfully execute delayed intentions are similar to the capacity-consuming attentional processes utilized in tests of WM. The findings from the present research that speak to each of these possibilities will be discussed in turn.

Zoom Hypothesis

Cowan (2001; 2005) proposed that the scope of attention could flexibly adjust to hold the maximum amount of information allowed by its capacity, or could be “zoomed in” to isolate a single item that is highly activated in the WM system. Past research using visual attention paradigms has demonstrated that, in fact, attentional resources can be localized to a single item or area, and this concentration of resources can lead to performance benefits (Eriksen & St. James, 1986; Heitz & Engle, 2007) or ongoing task costs (Chen, 2003), depending on the nature of ongoing task demands. The intention superiority effect has been taken as evidence for the notion that delayed intentions experience heightened activation in the cognitive system (Goschke & Kuhl, 1993; Marsh et al., 2007). Alternatively, the presence of a target or cue that is associated with a formed intention could signify a discrepant event, and prompt an evaluation that will help facilitate the designated response (McDaniel et al., 2004). In either case, this suggests that the presence of a PM target event should initiate the “zoom” function of attentional focus, and several findings from the present research support this assumption.

The purpose of Experiment 1 was to compare how people would respond to ongoing task trials that contained PM target items if their attentional resources were constrained to a single item versus when they were spread across two items. In general, the living/non-living judgments were made more slowly when participants were confronted with two items; however, additional costs were not observed on the PM target trials in this condition relative to a condition where the nature of the ongoing task allowed them to maintain a zoomed-in state. If the presence of the PM target did not recruit attentional resources directly to the target item of the pair, then one would expect the response latencies on these trials to reflect the general slowing that occurred in this condition plus the normal costs associated with the presence of PM targets. The calculation of the difference scores enabled an examination of RT's on the PM target trials while controlling for the costs that reflect general task slowing in the pair condition, and the results revealed no significant differences between the single and pair conditions. These findings are consistent with the predictions of the zoom hypothesis, which assumes that the presence of PM target items will result in the narrowing of attentional focus to those items. In this particular situation (where the target items are *bird* words), this process actually benefits ongoing task performance by helping to facilitate the living judgment.

There is at least one alternative explanation for the findings of Experiment 1 that should be mentioned. It could be argued that a consistent amount of ongoing task costs will be observed when a PM target appears on a test trial, regardless of differences in task demands. Consequently, response costs should be similar in the single and pair conditions of the present experiment, even though the decision processes utilized in the pair condition (deciding which of two objects is living) appears to be more demanding. Contrary to this prediction, a recent series of experiments demonstrated that greater costs were associated with performance on PM target

trials in a more demanding task. Marsh, Hicks, & Watson (2002) measured response times in a lexical decision task for trials that contained PM target words (animals or articles of clothing) versus control-matched trials, and found average RT costs to be 357 ms (Experiment 1) and 300 ms (Experiment 2). In Experiment 3, however, they used a less demanding ongoing task (naming the word presented on the screen) and only found an average cost of 127 ms. These costs only reflect performance on trials in which the PM target was accurately identified, as does the median cost index that was used in the present experiment. The median cost score reflects the RT difference on PM and control trials when the ongoing task decision was correct, and the PM target was correctly identified. A comparison of these indices revealed that no significant differences were observed between the costs experienced in single (303 ms) versus the pair condition (329 ms). Of course no statistical tests were conducted in the Marsh et al. study to determine whether cross-experimental cost values were significantly different from one another, but the pattern of these data clearly suggest that greater response costs were experienced on PM trials of the more demanding task. Thus, the zoom hypothesis offers a more plausible explanation for the present findings.

The theoretical framework outlined in the Marsh et al. (2002) study is relevant to the interpretation of the present findings. They argued that performance on event-based PM tasks likely reflects several distinct processes, and they identified three: noticing the target item, retrieving the intended action, and coordinating the execution of the intended action with ongoing task goals. In the present research these components would translate to: recognizing the *bird* word as being important in some way, remembering to press the ‘/’ key in response to these items, and coordinating this keypress with the demands of the judgment (Experiment 1) or recall (Experiment 2) task. The zoom hypothesis is most clearly associated with the first component, in

that it assumes attentional resources will be narrowed in response to a PM target item; however the dependent measure in this research (ongoing task costs) likely reflects a combination of these PM processes. Future research is needed to better understand how attentional processes might influence each of these components differently.

In Experiment 2, the primary goal was to investigate whether attentional resources were constrained in response to a PM target, by evaluating potential costs to other items presented along with the target items. This notion translates easily into real-world examples of how people execute delayed intentions. For instance, if you intend to give your colleague a message at the departmental meeting, but see him in the hall while you are talking to a student, your attentional resources could be drawn to the colleague and the message you intended to deliver. This would likely lead to costs on your current activity, which is discussing an upcoming test with a student. A laboratory recall paradigm was used in Experiment 2 to test this premise, where the ongoing activity required that you pay attention to other information presented along with the PM targets. The zoom hypothesis predicts that recall will be worse on trials that contain *bird* words, because participants who are told that these words are important will constrain their attention to these items when they appear. This outcome only occurred on 2 of the 5 PM target trials. Furthermore, recall performance was quite high throughout the task, suggesting that even the predicted outcome for these 2 trials should be interpreted with caution. Additionally, the fact that participants could reliably recall 3-4 items supports Cowan's (2005) claim that the capacity of the focus of attention is about 4 items. These findings should not be taken as evidence against the zoom hypothesis; instead, the high performance levels observed in Experiment 2 do not allow for a clear examination of the predictions stemming from this hypothesis.

Several factors could account for the outcome of Experiment 2. First, it is possible that participants were able to momentarily zoom-in on the PM target and still have time to zoom back out and encode the rest of the items present on that trial. Previous research suggests that, in some situations, participants can narrow their attentional focus within as quickly as 100 ms (Eriksen & St. James, 1986). This research does not speak directly to the speed in which people can fluctuate in between the local and global states of attentional focus; however, it is reasonable to assume that this adjustment process could have taken place in the 3 seconds of encoding time present in Experiment 2. Another possibility concerns the delay-execute procedure that was used for the PM response. The reason for using this procedure was to avoid the potential confound of including an additional response (designated keypress) during the encoding phase of each trial. Consequently, participants could have decided not to attend to the PM component of the task until the recall phase where there would be a second opportunity to encounter the target item, and still make the appropriate response in a timely fashion.

The attention allocation policy proposed by Marsh, Hicks, and colleagues supports the premise that people will attempt to develop an efficient strategy for meeting their cognitive goals. It assumes that people are capable of evaluating how attentional resources should be distributed across an upcoming task, and these resources will only be allocated to a task if necessary. For example, research has demonstrated that PM-related costs to ongoing activity will only be observed in a designated section of the task if participants are told in advance that PM responses should only be made during this portion of the task (Cook, Marsh, Clark-Foos, & Meeks, 2007; Marsh et al, 2007; Smith, 2003). This outcome occurs despite the fact that PM targets will appear in other sections of the task. In other words, participants were able to fully devote their cognitive resources to the ongoing task until it was necessary to allocate some of

those resources to other activities. In Experiment 2, it is possible that participants decided to withhold any resources from the PM portion of the task until it was time to make the designated response.

A few modifications could be made to the design of Experiment 2 to control for these issues. First, an alternative to using the delay-execute procedure is to have participants make a keypress immediately after every trial (in response to certain features of the items) to ensure that any potential effect observed on the PM target trials could not be explained by the additional keypress on those trials. Second, the number of items presented on each trial could be varied to determine if the narrowing of attentional focus leads to differential costs depending on the memory load. Finally, less encoding time could be allowed considering attentional resources might be adjusted rather quickly. Applying these modifications would help to facilitate a better examination of the zoom hypothesis.

Working Memory Hypothesis

Another way in which attentional resources have been implicated in event-based PM is via strategic monitoring processes. Research has revealed that ongoing task costs will be observed on non-PM trials, at least in some situations (Cook et al., 2007; Einstein et al., 2005; Smith, 2003; Smith et al., 2007; West, Krompinger, & Bowry, 2005). PAM theory stipulates that these costs are due to capacity-consuming strategic processes that are used to monitor for the presence of PM target items, and successfully execute the delayed intention (Smith, 2003; Smith & Bayen, 2005; Smith et al., 2007). These processes are believed to be similar to the attentional control processes associated with WM function. The multiprocess framework also assumes that strategic activity will be employed in certain situations, but in many instances, intended actions can be carried out fairly automatically (McDaniel & Einstein, 2000). Research has, in fact,

indicated that an intended action can be carried out without any detriment to other ongoing activities, and the presence or absence of strategic monitoring processes depends on the nature of the PM and ongoing task (Einstein et al., 2005; Meier et al., 2006). For example, Einstein et al. (2005) had participants complete a word categorization task in which they had to determine if one of the words in a pair was a category member of the other word in the pair. For the PM portion, participants were told to make a designated response every time they saw cues that were considered focal to the demands of the ongoing task (e.g., *tortoise*, *dormitory*) or if they were non-focal to the demands of the ongoing task (e.g., the syllable *tor*). Ongoing task costs were only observed when the target words were not focal to the task, which supported their claim that strategic monitoring processes only take place when the factors associated with the ongoing/PM task do not lend themselves to spontaneous retrieval of the intended action.

The findings from the present set of studies provide support for the multiprocess framework. Performance on several different measures of WMC did not predict people's ability to respond appropriately to PM target items. In fact, an examination of participants who fell in the top and bottom quartiles for their performance on the complex span tasks (Experiment 1) did not reveal any significant differences in the PM portion of the task. These findings are inconsistent with previous research that suggests a relationship will be observed between complex span measures of WMC and event-based PM performance (Smith & Bayen, 2005), and the assumption that similar attention processes are associated with working memory function and the ability to perform a designated action at a later point. In addition, no ongoing task costs were observed in the recall task of Experiment 2, which allowed for comparisons to be made between recall levels on the non-target trials for the experimental relative to the control conditions. All of these findings are in line with the predictions stemming from the multiprocess framework, but

fail to support the assumptions of PAM theory. The category of target items used in the present research (*birds*) likely helped to facilitate the ongoing task requirements (making a living/non-living judgment or retaining a list of words for later recall), suggesting that target identification was focal to the ongoing task. Regardless, PAM theory suggests that preparatory attentional processes should always be present in PM tasks, and should lead to some form of costs to other ongoing activity.

In a recent set of studies Smith et al, (2007) found ongoing task costs in event-based tasks that used salient focal PM targets, and several other conditions that the multiprocess framework predicts would lead to acts of spontaneous retrieval. One key difference between these studies and the present research is the way in which ongoing task costs were measured. Smith et al. looked at RT differences in a control versus PM group on responses during an experimental block of the ongoing task. In all experiments, participants in the PM group responded significantly more slowly on ongoing trials relative to the control group. In the present research, this particular type of ongoing task costs could only be assessed in Experiment 2, and they were evaluated in terms of performance differences in the experimental versus control groups on the proportion of items recalled on non-target trials. The lack of a difference could be interpreted as evidence against the claim that preparatory attentional processes will consume resources when an intention is being formed. Alternatively, these findings could simply reflect the high level of performance generally observed in the recall task.

In support of this latter explanation, Cook et al (2007) recently found significant costs associated with memory performance when a PM component was embedded in a free recall test. Participants were instructed to study a list of 40 words that they would be asked to recall at a later point (Experiment 1). There were three PM groups (categorical, one-word, or six-word

intention), a context-linked group (told to respond to PM target items that would appear after the recall task) and a control group (not given an intended action to execute). Before moving on to the study phase, the experimental groups were told they should press a designated key if they saw certain words (or a category of words) during the study phase. In reality, none of the PM targets ever appeared during the study phase, but performance was, nevertheless, impacted by the anticipation of this event. Recall levels were significantly worse in the three PM groups compared with the control and context-linked conditions, and the lowest recall rates were observed when a categorical intention (*furniture*) was given. Thus, ongoing task costs occurred in the form of memory deficits when participants believed PM target words would appear during list-learning. Having participants free recall 40 words in the Cook et al. study versus having them alphabetically re-order four words in the present study could, therefore, account for the different outcomes. Future research is needed to fully address this possibility, which has implications for how attention processes might interact with variations in ongoing task demand to influence event-based PM.

Potential Implications

These findings have several implications for the flexible nature of attentional focus in general, and how this dynamic system operates in the presence of PM demands. The visual attention literature has offered insight into how these adjustments are made in the face of distracting information present within various spatial locations of a visual set (Eriksen & St. James, 1986) and in the Stroop paradigm (Chen, 2003). The present research offers insight into the nature of these processes in a novel situation. It is interesting to note that in addition to target locations that have been spatially cued, attentional focus may adjust in response to a unique set of information that arises during ongoing cognitive activity, such as that related to a formed

intention. This finding provides important knowledge about specific aspects of the role of attention in event-based PM. Maintaining a delayed intention could elicit changes in attentional focus, which ultimately impacts people's ability to respond appropriately, as well as their ability to perform other ongoing cognitive activities. One of the important contributions of the present research is that it evaluates how the cognitive response to a PM target event will *simultaneously* impact other ongoing activities. Most of the experimental paradigms used thus far in PM research have utilized single item designs where PM targets are presented alone. In these designs costs are typically assessed in terms of performance on other ongoing task trials. There were certain limitations to the present research design that reduce the strength of these findings; however, the present trends in the data suggest that stronger effects would likely be observed if a few modifications were applied to the methodology.

The fact that individual differences in WMC could not account for significant variability in PM performance offers insight into the role of attentional processes in the execution of delayed intentions. Specifically, the attentional control mechanisms that have consistently been shown to play a vital role in working memory function do not appear to be a good indicator of how likely people are to respond appropriately to the presence of a PM target event, at least within the judgment and recall paradigms used in the present research. As previously mentioned, the common index of PM accuracy that was used likely reflects multiple cognitive operations that contribute to PM performance. It is possible that the attention mechanisms responsible for WM function are differentially related to these separate components, and future research is needed to properly disentangle these component processes.

If individual differences in WMC cannot account for performance, but attentional focus is narrowed in response to PM targets, then what are the implications for the role of attentional

control processes? Cowan (2001; 2005) claimed that the zoom mechanism in the scope of attention uses central executive resources to flexibly adjust in between its' narrowed and global states. One might assume that the attentional control processes implicated in the zoom function are the same processes that are used to complete tests of WM; however, little research has directly examined this assumption.

One recent study did investigate if individual differences in WMC could account for the rate in which people adjust their attentional focus. Heitz & Engle (2007) had participants complete a flanker task, as well as measures of WMC. In the flanker task participants had to respond to the identity of the middle letter (S or H) in a string of letters. The letter string either consisted of the same letter (compatible) or a mixture of the two letters (incompatible). The authors argued that in the incompatible condition participants would be compelled to narrow their attentional focus in order to block interference from the surrounding letters. Furthermore, this adjustment takes time, and individual differences in WMC should predict the time-course of this process. The latter part of this prediction is based on the premise that the attentional control processes that have been linked to WMC play an important role in the adjustment of attentional focus. Conditional accuracy functions (CAF's) were calculated to reflect the rate at which participants accuracy levels reached asymptote on compatible and incompatible trials. Individual differences in WMC were only predicted for the CAF's based on incompatible trials, considering it was not necessary to constrain attentional focus on compatible trials. The results confirmed the author's predictions: People with high WMC narrowed their attentional focus more quickly than people with low WMC; however, once attention had been properly constrained no individual differences in task performance were observed. Heitz and Engle proposed a rate of attentional

constraint model, suggesting that people's ability to control their attention impacts how efficiently they constrain the focus of attention.

The present research was conducted to address the initial question of whether or not attentional focus is narrowed in response to the appearance of PM target items, and was not geared towards understanding the temporal nature of this process. The findings from this research only provide partial support for the zoom hypothesis, but once further empirical support is established, future studies should address how individual differences in the adjustment of attentional focus influence ongoing task performance. For example, it would be useful to investigate whether people who adjust the focus of attention more quickly and efficiently are also better able to notice an upcoming target event while sustaining minimal costs to other ongoing activity. In any case, it is clear that there are similarities between the theoretical underpinnings of working and prospective memory models, and making connections between these two research areas has proven to be a useful endeavor for gaining knowledge about prospective memory.

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