Cognitive Control and Prospective Memory Performance: A mediation approach

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Cognitive Control and Prospective Memory Performance: A mediation approach

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SUMMARY

The majority of memory research, and research on its cognitive underpinnings has thus far focused on retrospective memory, or memory for things learned or rehearsed in the past. More recently, however, prospective memory, or the memory for future intentions, has become a major area of research. It is theorized that prospective and retrospective memory may both rely on similar constituent parts such as working memory and selective attention; the relationship between these constructs and prospective memory is, however, significantly less clear than for retrospective memory. In this study we sought to further clarify the role that cognitive process play in prospective memory performance using an SEM approach that included monitoring as a mediating variable in addition to focal, non-focal, and time-based prospective memory task condition. Results suggest a monitoring component is important in both focal and non-focal conditions, and that the type of monitoring observed in this study is related primarily to proactive interference, and reflects participants' ability to disengage from no longer relevant stimuli.

CHAPTER 1

INTRODUCTION

The majority of memory research, and research on its cognitive underpinnings has thus far focused on retrospective memory (Craik, 1986; Morris, Bransford, & Franks, 1977; Tulving & Thomson, 1973), or memory for things learned or rehearsed in the past. More recently, however, prospective memory, or the memory for future intentions, has become a major area of research. It is theorized that prospective and retrospective memory may both rely on similar constituent parts such as working memory and selective attention (Brewer et al., 2005; Guennead et al. 2011). The relationship between these constructs and prospective memory is, however, significantly less clear than for retrospective memory. In this study we sought to further clarify the role that cognitive process play in prospective memory performance.

Unlike retrospective memory tasks, which involve the recall of previously presented information, prospective memory refers to memory for to-be performed actions (e.g. remembering to take medicine, giving a message to a friend, pick up bread from the store on your way home, mail a letter, etc.). Further, prospective memory is characterized by the intention to carry out an action in the future, without an immediate reminder of the action to be performed (there is no experimenter reminding you that there is something you need to do on our way home). In retrospective memory tasks, such as recognition or free recall, the experimenter, at some point, initiates a retrieval mode in the participants. In a free recall task for example, a list of items are presented followed by explicit instructions to recall as many items from the list as possible. This request in turn initiates a retrieval search on the part of the participant. In prospective memory tasks, however, retrieval must occur in the absence of an explicit request to retrieve (Craik, 1986). For example, when remembering to give a message to a friend, seeing that person serves as the cue to remember the message, and there is no external reminder to deliver the message prior to the interaction. Thus, prospective memory differs from retrospective memory in the amount of self-initiation required for its execution, as your friend will not be wearing a sign reminding you to talk to them.

Prior to the development of a laboratory paradigm, prospective memory was studied by asking participants to perform an action in the future, such as mailing a questionnaire or calling an experimenter at an assigned time in the future, in a naturalistic setting (West, 1988). However, this method did not allow for systematic assessments of how participants remembered to carry out the intention. Participants could, for example, write a note or reminder to themselves to carry out the action, or they could be leaving the letter in plain sight in hopes of seeing it and remembering to send it in. In order to systematically examine the processes involved in successful prospective memory execution, a more basic approach was developed, allowing for the study of this phenomenon in the laboratory. Currently, the most frequently used laboratory paradigm for studying prospective memory is that of Einstein and McDaniel (1990) which involves engaging participants in one or more ongoing tasks, while at the same time asking them to perform an action in the future in response to a target item that appears in the context of the ongoing task (the prospective memory intention). For example, participants might be given an image rating task in which they must provide pleasantness ratings for a variety of images. While performing this task, participants might also be asked to press the *q* key whenever they see a picture of a cat. Thus, *cat* becomes the target for carrying out the prospective memory intention of pressing the *q* key. Participants are frequently told that the ongoing task is the most important component of the experiment, and that there is only a secondary interest in their ability to remember to perform the intended action in the future in order to keep prospective memory performance below ceiling. Einstein and McDaniel (1990), for example, advertised their experiment as a study on increasing short-term memory capacity; however, the primary dependent measure was the execution of the prospective memory task (i.e. pressing the *q* key in response to the target item).

Two competing theories have emerged to explain how individuals execute prospective memory intentions, the Preparatory Attention Model (PAM, Smith, 2000), and the Multi-Process theory (MP; McDaniel & Einstein, 2000). According to the Preparatory Attention Model, in order for an individual to respond to a target cue while performing another task, they must consciously, or unconsciously (Smith, 2000), maintain this intention to execute a prospective memory response in order to carry out the execution. If sustained attention is not used to maintain the intention, then it is impossible to execute to prospective memory intention, according to this theory. In the laboratory, maintaining this intention ultimately leads to a slowing of performance in the ongoing task when a prospective memory intention is added compared to their performance on the ongoing task alone. This slowing of the ongoing task, or monitoring, can also be conceptualized as *proactive control* (Braver et al., 2009). In proactive control, individuals actively maintain an intention or goal in order to facilitate future execution. In prospective memory, this resource allocation is most frequently reflected by slowing in ongoing task performance.

In Smith (2003), participants performed a lexical decision task that was performed alone, in conjunction with an embedded retrospective memory task, or in conjunction with an embedded prospective memory task. Smith found that participants performing an embedded prospective memory task had longer response times on non-prospective memory target trials of a lexical decision task than participants performing the lexical decision task alone, participants' reaction times slowed overall when a prospective memory task was added, and that longer lexical decision response times were associated with better prospective memory performance (a pattern not present when performing an embedded retrospective memory task). Smith concluded that the addition of a prospective memory intention results in an additional allocation of memory resources, and further, that this slowing was necessary for successful prospective memory task execution.

The second theory, the Multi-Process theory of prospective memory (McDaniel & Einstein, 2000), proposes that under certain conditions (when there is strong environmental or task support for the processing of the cue), spontaneous retrieval processes can be used in place of, or in addition to monitoring. The Multi-Process theory argues that it is more adaptive to use automatic processes for prospective memory retrieval when possible (Einstein & McDaniel, 1990). Thus, while monitoring can be, and is frequently used, it is not always necessary for prospective memory execution. One such process by which individuals can 'spontaneously retrieve' an intention without attentional resource allocation, is a reflexive associative process in which the occurrence of a target triggers the previously established relationship between a target and its corresponding prospective memory intention. This process can also be conceptualized as a *reactive control* process in that it is not a pre-existing intention prior to the onset of the stimulus, but occurs after or in response to, the presentation of the target word. Both the Preparatory Attention Model and the Multi-Process theories agree that the allocation of attentional resources to monitoring can be assessed by accuracy costs or slowing in the ongoing task into which the prospective memory task is embedded; thus, the *absence* of a cost would suggest an attention-free mechanism (Einstein & McDaniel, 2000). This result has indeed been obtained (Einstein & McDaniel 2000; Einstein, McDaniel, Thomas, Mayfield, Shank, Morrisette & Breneiser 2005; Scullin, McDaniel, & Einstein, 2008; Harrison & Einstein, 2010), however, only under certain task conditions.

Whether or not participants rely on monitoring or spontaneous retrieval processes is influenced by the nature of the relationship between the ongoing task and the prospective memory intention. One example, that I will examine here, is cue focality. More specifically, when the nature of the ongoing task facilitates or directs attention towards processing of the prospective memory cue, that cue is considered to be focal. Focal cues afford and/or enhance the use of spontaneous retrieval processes, due to this facilitation of cue processing. In contrast, when the nature of the ongoing task does not lead to or facilitate the processing of the prospective memory cue, this cue is considered to be non-focal in nature and successful execution is typically related to increased levels of monitoring rather than the use of spontaneous retrieval processes. Einstein et al (2005) demonstrated this phenomenon by asking participants to make a special response to either a specific word (e.g., ‘tortoise’) or a syllable (e.g., ‘TOR’) in the context of a category verification task. Einstein et al (2005) argued that the semantic nature of the ongoing (category verification task) makes a semantic cue (tortoise) more salient or focal than a syllable cue (TOR) as the ongoing task did not encourage conscious awareness of syllables. Their results showed that not only did participants respond significantly more often to the prospective memory intention in the focal condition than the non-focal condition (93% vs 61%), but that they did so with significantly less slowing of the ongoing task.

While the PAM and MP theories differ in their explanation of prospective memory performance under focal task conditions, both theories highlight the importance of attention for successful prospective memory execution. For example, according to the Multi-Process Theory, if attention is not paid to the ongoing task, the initiation of spontaneous retrieval would be impossible, and in a non-focal condition the cue to initiate retrieval of the intention could be passed over (Scullin, 2010). Furthermore, both the PAM and the MP Theories state that 'attention allocation' is necessary for execution of the prospective memory task. However, the term attentional control, or attentional allocation is often used interchangeably to describe not only the directed focus of attention, but also cognitive processes such as working memory capacity and executive control (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2011). For the purposes of this thesis, and towards establishing a more systematic vocabulary with which to describe processes involved in prospective memory tasks, the term attention will be divided into the constructs of selective attention (attending directly to a stimulus, or what is in the focus of attention) and resource allocation (individual differences in the ability to allocate attention are captured in this study by working memory capacity and updating). In non-focal conditions, for example, the incongruent nature of the ongoing task and target processing result in a more resource demanding maintenance of the prospective memory intention overall. It is this operationalization of attention allocation that is perhaps better described as resource allocation. This process is akin to proactive control, and is evidenced by slower RTs in the ongoing task, and lower successful PM responses in its absence under non-focal task conditions (McDaniel & Einstein, 2000).Thus, in addition to simply allocating attention, as in the focus of one's attention, is one aspect of performance, successful execution of prospective memory tasks in non-focal task settings requires an allocation of attentional resources dedicated to maintaining and or revisiting the prospective memory intention. Subsequently, there are individuals who are better at this kind of maintenance under non-focal task conditions: those with high working memory capacity (Bisiacchi, Tarantino, Ciccola, 2008; Brewer, Knight, Marsh, & Unsworth, 2010; Logie, Maylor, Salla, & Smith, 2004).

Working memory capacity is described as "the general capability to maintain information such as task goals in a highly active state," (Engle, Kane, & Tuholski, 1999). Moreover, this active maintenance is particularly important in the face of interference (Engle at al. 1999; Kane et al., 2001). In prospective memory performance, this active maintenance allows for a prospective memory intention to be kept in mind in the face of interference from the ongoing task. Studies have shown that high working memory capacity individuals are less prone to a buildup of interference in retrospective memory tasks (Braver et al., 2009), making it easier to maintain the prospective memory intention. Further, one would anticipate the buildup of interference to be higher in the non-focal condition due to task incongruency as shown by Brewer et al. (2010).

Brewer et al. had participants with high and low working memory capacity (WMC) perform a lexical decision task with a prospective memory component that was either focal or non-focal. Both high and low WMC participants performed equally well when the PM task was focal. The high WMC participants did, however, detect significantly more PM targets in the non-focal condition. Brewer et al. also found no differences in mean latencies of responses on the lexical decision task between the two groups, indicating that both groups allocated equal amounts of attention to the task at hand. Brewer and colleagues go on to say that the increased performance by those with a higher WMC, therefore, reflect differences ability to maintain the prospective memory intention with more efficiently in the non-focal condition, and that when this additional attentional allocation is not required, as seen in the focal condition, both high and low working memory capacity individuals perform the prospective memory task equally well. In other words, high working memory individuals are able to monitor for targets more efficiently. Once again, however, we see a somewhat confusing use of attention allocation and attention control in describing what is going on in this task.

Further, the degree to which this ability to monitor, or maintain attention allocation, is solely the result of working memory capacity or other cognitive mechanisms (selective attention, updating, task switching, etc.) remains unclear. Moreover, the role of monitoring as a potential mediating variable between executive control processes and prospective memory performance has not been investigated. In Brewer et al., for instance, monitoring immediately preceding target items was not reported, therefore it is unclear as to whether the difference in performance reflects an advantage in the ability to easily maintain an allocation policy, an increased use of selective attention preceding the prospective memory cue, or an ability to rapidly update and revisit the initial intention throughout the course of the ongoing task. Furthermore, although there was no difference reported in reaction times between the two groups, there is no mention of accuracy differences in the ongoing task aside from the statement that all participants performed the task well. Differences in accuracy with stable reaction times across conditions would further elucidate the role, or degree of interference of the ongoing task, across task conditions.

Other recent studies showing differential activation across prospective memory task types suggest that there is reason to believe that there may be a significant impact of basic cognitive abilities, including measures of executive control such as inhibition and task switching on performance beyond a general working memory capacity advantage (Marsh & Hicks, 2008; Martin, Kliegel, & McDaniel, 2003; West & Craik, 2001). Craik and Bialystok (2005) for example, suggest that executive control processes independent of working memory capacity may be involved in the successful execution of prospective memory tasks, due to an advantage in prospective memory performance of bilinguals over monolinguals. This difference in performance points to processes other than working memory capacity, due to the lack of evidence of a working memory capacity advantage for bilinguals, in spite of evidence for a bilingual advantage of executive control type tasks (Craik & Bialystok, 2005).

Finally, the examples above regarding focal and non-focal prospective memory conditions have been of ‘event-based’ tasks where the participant sees a cue, and then makes a response to that target (*cat, tortoise, TOR, etc.)*. As discussed earlier, in these studies, conditions with a ‘non-focal’ cue require more self-initiation (and arguably more proactive control) in order to respond to the prospective memory target. There is, however, one more type of prospective memory task that requires even more self-initiation than non-focal event-based tasks: The time-based task. In a time-based task, there is no specific target cue to which participants respond, either related or unrelated to the ongoing task. Rather, participants make a response after a certain period of time has elapsed, while also performing an ongoing task. In theory, this type of task requires more self-initiation to maintain and complete then even an event-based prospective memory task (Maylor, 1998), as there is no cue that appears to help prompt the participant, or potentially initiate spontaneous retrieval. Thus, relying entirely on self-initiated proactive control to maintain or re-initiate the intention. It follows that, just like non-focal event-based cues require more self-initiation than focal event-based cues, time-based responses require even more self-initiation than even non-focal event-based conditions. Although these studies support the idea that different mechanisms are used in different task settings, the cognitive mechanisms facilitating performance across focal, non-focal, and time-based task settings is not fully addressed by the PAM or the MP theory of prospective memory performance.

The idea that cognitive processes are differentially involved in tasks depending on the amount of self-initiation that is required to execute a prospective memory intention is also supported by studies showing differences in activation in sub-regions of the prefrontal cortex during event and time-based prospective memory tasks (Okunda et al. 2007; Volle et al., 2011). Volle et al. investigated the role of the Prefrontal cortex (PFC) in prospective memory performance, in event-based vs. time-based tasks. The participants for this study had lesions in the PCF and were shown a series of event and time-based task consisting of photo or semantic categorization tasks. Volle et al. found a dissociation between areas of the PFC used exclusively in time-based, but not-event based tasks and vice versa, suggesting that event and time-based tasks are governed by different brain regions. However, in both of these studies, the event-based task is arguably focal, thus showing an extreme difference in level of self-initiation. It is less clear how event-and time-based tasks would be processed when there is less discrepancy in level of self-initiation (such as between a non-focal and a time-based task).

This processing difference is also reflected in behavioral studies showing different correlations between executive functioning and prospective memory task type (REF); however, discerning how cognitive measures correlate with event versus time-based tasks has led to conflicting findings. Kliegel et al. (2003) for example, found that performance on event-based tasks was related to inhibition, and that time-based tasks showed a relationship to task switching, while Gonneaud et al. (2011) found a relationship between inhibition and event and time-based tasks, but not event-based tasks.

In conclusion, not only do studies investigating the relationship between cognitive functions and perspective memory performance differ in task design and task complexity, the majority of these studies do not account for monitoring strategies used by participants, particularly during event-based tasks. Thus, although executive functions have been shown to correlate with prospective memory performance, it is not clear whether the specific executive functioning processes are directly related to performance (as the PAM framework would lead on to expect) or whether they are related to individual differences in monitoring strategy (as the MP framework would suggest). Subsequently, it is unclear whether executive function correlates of successful prospective memory performance are directly responsible for improved performance of if they are more intricately related to individual differences in monitoring strategy.

Building on the differential findings regarding involvement of executive functioning in PM performance, the present study sought to reconcile the differences found in the field by including measures of monitoring during task execution, as well as a set of basic ability measures, using both event and time-based tasks while manipulating focality. This allowed for a more complete evaluation of the connection between prospective memory performance and the cognitive control measures. I anticipated that working memory capacity will have a statistically significant impact on performance on the non-focal prospective memory task, but not the focal prospective memory task; and that a significant relationship would emerge between working memory capacity and level of monitoring, such that high working memory capacity individuals relay less on monitoring than those with low working memory capacity. Finally, I anticipated finding a significant relationship between selective attention and performance on both the focal and non-focal prospective memory tasks, and a direct relationship between working memory capacity and time-based performance. An SEM approach was used in order to explore these causal relationships.

The present study included both event and time-based prospective memory tasks, with the event-based portion including a control, focal, non-focal event-based condition. As done in McDaniel and Einstein (2000), monitoring was moderately discouraged, due to the tendency for individuals to slow excessively when this is not the case. Monitoring was operationalized as the overall costs for each block. Additionally, slowing during trials immediately preceding the cue word was analyzed, assessing whether or monitoring was present immediately before a PM target occurred as a check against any substantial slowing that may have impacted performance (Scullin et al, 2008). Monitoring in the time-based task was calculated using the number of time participants checked a computerized clock while performing the task; however monitoring as slowing to the ongoing task was also assessed for comparison between the event and time-based factors.

Prospective Memory Predictions

In line with the Multi-Process theory, no differences in ongoing task costs between the control and focal conditions were anticipated, because participants would use spontaneous retrieval processes in both of these conditions. I did, however, anticipate a slowing of ongoing task performance in the non-focal and time-based conditions, due to the increased task demand, and incongruent cue processing. Overall, I anticipated that in the non-focal condition, prospective memory performance would correlate significantly with working memory capacity, selective attention, and updating. In the time-based condition, only selective attention would correlate significantly with prospective memory performance. I also expected higher working memory capacity individuals to be faster in monitoring, resulting in an inverse relationship between this construct and monitoring. The same was anticipated for the time-based condition. Finally, I anticipated seeing an inverse correlation between selective attention and monitoring in all event and time-based conditions – the need for monitoring would be less pressing in individuals with better selective attention abilities.

I further anticipated to see these relationships replicated in the final model, with working memory capacity impacting prospective memory performance in the non-focal condition, but not the focal prospective memory task. Additionally, no significant relationship was anticipated between working memory capacity and the focal condition. A significant relationship between updating and selective attention and prospective memory performance on both the focal and non-focal prospective memory tasks was also anticipated.

Mediation Predictions

In addition to the manifestation of the correlational relationships in the model (i.e. wmc significant to non-focal, but not focal, etc), this SEM approach also allowed me to evaluate the role of monitoring as a mediating variable in the conditions that require additional self-initiation (the non-focal and event-based). The initial prediction was models that included a monitoring factor would provide a better fit than models without. Next, monitoring would show an inverse relationship to working memory, with selective attention, and updating also contributing to enhanced or lower monitoring in the non-focal and time-based condition. In the focal condition, selective attention and monitoring were hypothesized to be the primary paths to prospective memory performance, with monitoring increasing prospective memory performance in both focal and non-focal conditions. These patterns could help identify the mechanisms driving monitoring, and better explain the role monitoring plays in prospective memory performance. For example, if monitoring shows an inverse relationship to WMC, as suggested in previous studies, individuals who have a high working memory may simply be holding both intentions in mind, or retrieve this information from memory very quickly without interference to the ongoing task (Engle & Kane, 2004; Kane, Conway, Hambrick, & Engle, 2007). Alternately, should the paths from both working memory capacity and selective attention to monitoring be significant, the degree to which the two represent a similar construct can be determined by the strength of the relationship between these factors.

CHAPTER 2

METHOD

Participants and Design

Participants were 200 younger adults recruited from the Georgia Tech student, and local community populations. Participants were awarded course credit and/or monetary compensation for their participation in the study (at the rate of $10 per hour of completion, or $30 total), or 1 course credit per hour of study participation (3 hours total). A total of 172 Individuals were included in the final analysis. Twelve participants were excluded due to performing more than 2.5 standard deviations away from the mean of the ongoing task in either prospective memory condition, 7 were excluded for not following instructions to the extent it was detrimental to their data (performing tasks out of order, taking breaks at will during tasks, using cellphones while performing tasks), 8 were excluded due to technical issues regarding E-Prime failures, and 1 was excluded due to cheating on the complex span tasks.

Materials

Prospective Memory Task Materials

A lexical decision task, similar to that used by Einstein et al (2005), served as the ongoing task for both the time and event based conditions. Word lists used for each section (focal, non-focal, and control) containing 75 words and 75 non-words that will occur three times for a total of 450 trials per condition.

During each block of the experiment (PM and control), the 450 trials were divided into 3 blocks containing 150 trials each, with the target cue occurring on trials 75, 150, and 225. These trials were chosen because they occur towards the end of the first second and third blocks respectively, and would thus discourage continuous monitoring (Loft, Kearney, and Remington, 2008). By not encouraging monitoring from the beginning of the task, we hoped to observe a more reflective measure of individual monitoring strategy.

During the time-based PM task, participants performed the same lexical decision task, but instead of responding to a given target, they were asked to press the 'Q' key every 3 minutes. Pressing the 'C' key allowed participants to access a clock to monitor the time throughout the task (Craik & Bialystock 2006).

Working Memory Capacity Tasks

<u>Symmetry Span (Kane et al., 2004;Unsworth et al., 2009)</u>

Participants must make a vertical symmetry judgment about a 3x3 grid containing white and black squares. Participants then see a single highlighted square in red on the grid, and must remember the location of these squares, and the order in which they were presented. After two to seven symmetry-square elements, participants are required to recall the squares in the order in which they were presented. The proportion of squares recalled in the correct order is taken as the individual's score.

<u>Reading Span (Daneman & Carpenter, 1980; Unsworth et al., 2005)</u>

Participants must read a sentence and determine whether or not it makes sense. After they make their judgment they are presented with a word that is to be remembered. After three to ten sentence judgments/words, participants are required to recall the words in the order in which they were presented. The proportion of words recalled in the correct order is taken as the individual's score.

Verbal Running Span (Broadway & Engle, 2010)

Participants are presented with a brief series of letters. After the letters have been presented, participants must recall a certain number of the last letters. For example, a participant might be asked to recall the last 3 letters and then are presented with the letter set "QTJKD." The participant must enter the response "JKD." Participants do not know how many letters will be presented for each trial. The proportion of letters recalled in the correct order is taken as the individual's score.

Selective Attention Tasks

Antisaccade

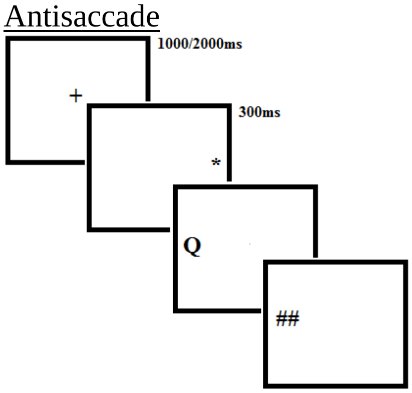


Figure 1. Antisaccade screen presentation.

Participants stare at a fixation cross. After a few seconds a star flashes on one side of the screen. Human reflexes will make them want to look at the star. However, the participant must look to the OPPOSITE side of the screen where either a Q or an O will be briefly presented. If the participant looks at the star, the letter will be gone before he or she can look to the other side of the screen.

Flanker Task

→→→→→
- -→- -
→→←→→

Figure 2. Flanker arrow presentation.

Participants see a series of arrows (a target center arrow with two other arrows on each side either facing the same or opposite direction) and must report which direction the middle of five arrows is pointing.

Visual arrays tasks (Luck & Vogel, 1997)

Figure 3. Before and after screen presentations of the visual arrays task. *Note*: The target block will be marked with a white dot; it is only this block that participants must make an assessment of change in orientation.

Participants see a pattern on colored squares or rectangles at various orientations. They will be directed to either remember the Red or the Blue rectangles. Information then disappears for 1000ms. The array is then flashed briefly (250ms), followed by a static presentation where one of the rectangles highlighted by a white dot. Participants must judge whether or not the designated block color pattern has changed, relative to its first presentation.

Updating Tasks

Columnized Numerical N-back 1 Numerical (Jonides et al., 1997; Kane et al., 2007)

For this task, participants are presented with a stream of numbers (self-paced presentation with a new number appearing after each response is made). They have to indicate whenever a number is the same number as the one presented previously. The critical dependent variable is the measure of sensitivity, *d'*.

Columnized Numerical N-back 3 (Jonides et al., 1997; Kane et al., 2007)

For this task, participants are presented with a stream of numbers (self-paced presentation with a new number appearing after each response is made). They have to indicate whenever a number is the same number as the one presented three numbers prior. The critical dependent variable is the measure of sensitivity, *d'*.

Garavan Task (Unsworth, 2005)

For this task, participants see a series of triangles, circles, and squares. Participants advance the stimuli that will change order, and keep track of the number of circles and squares presented, and respond to a probe asking for the number of each in the preceding blocks. The task consisted of 5 practice trials and 45 real trials. A trial consists of 11–15 shapes (585 total) and a screen asking for the number of presentations for each shape at the end of each trial.

Procedure

Upon entering the laboratory, the experimenter explained to participants that they would perform a variety of tasks, and that they should pay close attention to the instructions for each section of the experiment. The experimenter then distributed informed consent and demographic forms. Participants begin the session by completing the assessments of working memory capacity, selective attention, and updating tasks, followed by the event-based prospective memory task, and finally the time-based prospective memory task. Participants were allowed to take short breaks in between tasks if they so desired. Upon completing the time-based task participants were debriefed regarding the full extent of the assessments being made, and compensated.

During the prospective memory portion, participants began by practicing the lexical decision task, which served as the ongoing activity for the duration of the experiment. During this task, participants decided whether strings of letters are valid English words or not. Following the lexical decision instructions, and 20 practice trials, participants were presented with letter strings, half of which were words and half of which were non-words. Participants responded using the keyboard by pressing the '*x*' key for words and the '*m'* key for non-words. All words and non-words were presented one at a time, and in upper case font. Words and non-words were taken from the English Lexicon Project (Balota et. Al., 2007); they were three syllables or less, and had a mean lexical decision time from 685-725 ms. Words and non-words remained on the screen until participants responded. This initial series of trials served as the baseline or control RT for all participants.

After completing the baseline trials, participants received the focal prospective memory block. At this time, participants were informed that the experimenter has a secondary interest in their ability to remember to perform an action in the future. They were then given the prospective memory target 'PINTER', and instructed to press the '*q'* key if they saw the target during the course of the lexical decision task. Participants were asked to repeat the instructions to the experimenter, and were once again instructed that their primary objective was to perform the lexical decision task as quickly and accurately as possible. Participants then completed a distractor task consisting of a personal demographic questionnaire before beginning the prospective memory section. No reminders of the prospective memory intention were given before beginning the lexical decision task.

After participants completed the 225 trials in the focal prospective memory block, they completed a vocabulary test, which served as the next distracter task, before beginning the Non-Focal Cue block. Before beginning the Non-Focal Cue block, participants will be told that there would be no more occurrences of the previous target word, but that they must now press the '*q'* key whenever the see a word that begins with the letter 'C' during the lexical decision task. After completing this second series of 225 trials, participants will fill out a post-experimental questionnaire. The order of the prospective memory blocks, control, focal, non-focal, as well as the vocabulary quiz and demographic questionnaires, was the same for all participants to minimize measurement noise due to order effects, as is usual in individual-differences research.

Finally, participants completed the time-based prospective memory task, which consisted of the same ongoing task, but instead of responding to a cue, participants were asked to press the *q* key every 3 minutes. Participants were also able to press the "*c"* key to display a clock to check the elapsed time.

CHAPTER 3

RESULTS

For all tasks, outliers were defined as an individual mean score that exceeded 2.5 standard deviations from their own mean, and or the group mean score, time, or accuracy measure for that task. Participants' mean reaction time on the lexical decision task were trimmed against their own mean for the block, as well as the group mean for each block (control, focal, and non-focal). If the participant's data was outside of this group cutoff during the prospective memory section, or more than one measure of a latent variable, then their data was excluded from the final analysis. Of the 200 participants tested, 17 met these criteria, and were excluded from the final analysis. An additional 9 subjects were excluded due to equipment malfunction, and 1 was excluded for cheating. Cronbach's alpha is reported below for the reading span, symmetry span, and running letter span tasks, and was calculated using the procedure of Kane et al. (2004) in which the first, second, and third presentations of each list length were summed and then entered into the analysis. For the visual arrays tasks, k at each set size was entered into the analysis. Descriptive statistics are displayed in Table 1 and correlations among tasks are displayed in Table 2.

Table 1. Descriptive Statistics. Abbreviations to be used henceforth are as follows: RunSpan= running span score, ReadSpan= reading span score, SymmSpan= symmetry span score, Flanker=flanker accuracy score, Garavan= Garavan accuracy score, VAk5= visual arrays k score for set size 5, VAk7= visual arrays k score for set size 7, PM.focal (or F.pm.ACC)= prospective memory performance in the focal condition, PM.nonfocal.ACC (or NF.pm.ACC)= prospective memory performance in the non-focal condition, ASaccade= Anti-saccade accuracy score, Focal.Mon.RT.Diff (F.LDT.RT)= difference score between the LDT reaction time in the focal and control conditions, NFocal.Mon.RT.Diff (NF.LDT.RT)= difference score between the LDT reaction time in the non-focal and control conditions (this measure was originally intended to be used as the measurement of monitoring), Focal.Mon.ACC.Diff (F.LDT.ACC)= difference score between the LDT accuracy in the focal and control conditions (focal-control),

NFocal.Mon.ACC.Diff (NF.LDT.ACC)= difference score between the LDT accuracy in the non-focal and control conditions (non-focal-control).

	N	Mean	Std. Deviation
	Statistic	Statistic	Statistic
Run.Score	172	47.47	11.82
Read.Score	168	59.51	10.89
SymmSpan.Score	172	31.15	8.009
Flanker.ACC	170	-.0488	.106
Garavan.ACC	172	.8672	.15
VisualArray.k5	171	268.24	42.95
VisualArray.k7	171	177.82	31.45
PMfocal.ACC	172	.8043	.31
PMnonfocal.ACC	172	.7074	.40
NBackDiffAcc	171	.3185	.16
Saccade.ACC	170	.7872	.15
FocalMon.Diff.RT	172	-25.21	71.11
NFocMon.Diff.RT	172	-22.18	86.57
Clcheck	172	10.5116	7.57
FocalACC.Diff	172	-.0124	.045
NonFocalACC.Diff	172	-.0230	.048

Prospective Memory and Ongoing Task Performance

Prospective memory performance was calculated as the percentage of responses to the targets in the focal and non-focal conditions (each of which contained 3 targets). As anticipated, the focal condition yielded higher prospective memory accuracy score (M= 80.43%) than the non-focal condition (M = 70.74%). The difference in performance between these two conditions was significant F (1, 172) = 8.47, $p < .05$.

Ongoing task performance during the control, focal, and non-focal conditions was assessed using accuracy and reaction time during the lexical decision task. Participants' mean reaction times and accuracy were calculated for each condition under the following constraints: Only accurate responses for trials preceding the prospective memory target in each block were included (McDaniel & Einstein, 2000).

Monitoring was initially calculated by subtracting each of the resulting mean control block reaction times from participants' focal and non-focal block reaction times. An omnibus ANOVA revealed a significant increase in speed from the control condition to the focal condition F (2, 172) = 11.69, $p < .05$. Pairwise comparisons revealed a significant *decrease* in reaction time from the control (M= 623.10) to the focal condition (M= 597.88) and from the control to the non-focal condition (M= 600.91), but no significant difference from the focal to the non-focal condition. See Table 1 for descriptive statistics for the lexical decision task.

Analyses of group accuracy on the lexical decision task did show a significant difference between ongoing task accuracy in the control, focal and non-focal conditions F (2, 172) = 10.78, $p < .05$. Pairwise comparisons revealed a significant difference between all three conditions with participants performing most accurately in the control condition (M=96.39%) than in the focal condition (M= 95.15%), and least accurately in the non-focal condition (M= 94.09).

Finally, an analysis of performance across the three blocks within each condition (control, focal, and non-focal) did not suggest the presence of practice effects within any of the conditions (F (2, 172) = .14; P > .05).

Correlates of Prospective Memory Performance

As anticipated, working memory capacity (running span, reading span, symmetry span) was correlated with prospective memory performance in the non-focal, but not the focal prospective memory condition (Table 2). Selective attention tasks (visual arrays, anti-saccade) were also correlated with performance in the non-focal condition, and with performance in the focal condition. The updating measures did not reliably correlate with either condition or one another. Please refer to Table 2 for the full correlation matrix.

Table 2. Inter-Item correlation matrix. *Note:* Bold items represent significance to the.05 level. See Table 1 for item descriptions.

Inter-Item Correlation Matrix															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. RunScore	-														
2. ReadScore	**.48**	-													
3. SymmSpan	**.30**	**.38**	-												
4. Flanker	-.03	-.03	-.14	-											
5. AntiSaccade	.28	**.28**	**.36**	-.04	-										
6. VA5	.39	.32	.34	.06	**.49**	-									
7. VA7	.39	.35	.37	.04	**.46**	.91	-								
8. Garavan	.52	.33	.29	-.03	**.45**	.44	.40	-							
9. NBack	.00	-.05	-.03	-.12	-.10	-.15	-.13	.00	-						
10. PMfocal	.12	.08	**.18**	.02	**.20**	**.34**	**.32**	**.33**	.06	-					
11. PMnon-focal	*.16*	**.24**	**.26**	.06	**.33**	**.31**	**.26**	**.39**	**-.16**	**.26**	-				
12. FocalMon.RT	-.10	-.05	.11	.01	**.00**	.05	.04	-.09	.00	.02	-.10	-			
13. NFocMon.RT	.05	.10	**.21**	.00	.12	**.20**	**.18**	.10	.00	.12	.08	**.67**	-		
14. FocMon.ACC.	-.05	-.06	.17	-.02	.01	.08	.08	-.06	**-.15**	.13	.08	**.41**	**.27**	-	
15. NFocMon.ACC	.13	.02	.13	.01	.14	**.17**	*.15*	.15	**-.19**	**.29**	.19	**.20**	**.25**	.68	-

In the time-based condition (Table 3a), the only factor that correlated with prospective memory performance was clock-checking behavior. In this condition, participants did differ from the control condition in reaction time and accuracy. The only correlation between either of these difference scores was between time-based monitoring (RT difference score) and the selective attention variables (visual arrays 5, visual arrays

7, and the antisaccade tasks). See Table 3a & 3b below for the full correlation matrix for the time-based condition.

Tables 3a & 3b. *Note*. Tables showing the correlations between the measures of performance and monitoring in the time based task, and these measures and the cognitive control tasks. Above and below: Time.ACC= overall ongoing task accuracy in the time-based condition; Time.RT= overall ongoing task reaction time in the time-based condition; TMonitoring (ACC) and TMonitoring (RT) are the difference scores between ongoing task accuracy and reaction time respectively from the control condition to the time-based condition; ClockCheck= the number of times participants pulled up the digital clock; TimePM.ACC= accuracy of the prospective memory task in the time-based condition. Here the bold represents significance at the .05 level, and * represents marginally significant correlations.

	ClockCheck	TMonitoring (ACC)	TMonitoring (RT)
ClockCheck	-		
TMonitoring (ACC)	.086	-	
TMonitoring (RT)	.138	-.086	-
TimePM.ACC	.**349**	-.003	.051

	Run	Read	Sspan	ASaccad	VAk5	VAk7	Flanker	NBack	Garavan
Time.ACC	-.04	.06	.**21**	.06	.13	.04	-.06	-.09	-.03
Time.RT	-.04	-.09	-.01	-.16	-.**18**	-.**24**	-.04	-.01	-.01
TMonitoring (ACC)	-.12	-.03	.14	-.03	-.02	-.01	-.11	-.03	-.08
TMonitoring (RT)	.08	.08	.19*	.16*	.**26**	.**23**	-.02	.01	.04
ClockCheck	.08	.12	.05	.**20**	.16*	.10	.07	-.09	.07
TimePM.ACC	.02	.10	.11	.16	.09	.01	-.08	-.**22**	.08

Finally, correlations between the time-based and event-based prospective memory performance and monitoring factors can be seen in Table 4. Monitoring (accuracy difference score) in the focal (event-based) condition correlated with both clock checking and monitoring (reaction time difference score) in the time-based condition.

Table 4. *Note.* Table showing the correlations between the time-based prospective memory performance and ongoing task performance, and the event-based ongoing task

and prospective memory task performance measures. Here, the * represents marginal significance, and bold represents significance to the .05 level.

Ongoing task correlations						
	PMfoc.ACC	PMnfoc.ACC	FocMon	NFocMon	FocalDiff	NonFocalDiff
TB.LDT.ACC	.066	**.210**	.093	.132	**.194**	**.231**
ClocklCheck	.091	.168*	.112	.146	**.189**	.003
TB.Mon.ACC	.007	.049	.058	.023	**.445**	**.238**
TB.Mon.RT	.059	**.220**	**.715**	**.796**	.059	-.018
TBpm.ACC	.022	.047	.151	.138	.091	-.081

Latent factors of working memory capacity, selective attention, and updating were initially build based on previous studies, however, the factors used in the final models were based on the outcome of the principal components analysis in Table 5.

Table 5. *Note*. Table includes the principal components analysis used for the building of latent factors seen in the following models.

	Component		
	1	2	3
Run	.071	**.822**	.009
Read	.060	**.816**	-.065
F.ACC	-.076	.043	-.846
GACC	.378	.497	-.069
Sspan	.348	**.535**	.147
VAk5	**.818**	.274	.202
VAk7	**.772**	.290	.276
NBackDiffAcc	-.213	-.015	.153
Saccade	**.743**	.075	-.219

Ultimately, the Garavan, and N-back tasks were unreliably related, sometimes correlating with the working memory capacity (span) tasks, and other times with the selective attention measures, and subsequently, the updating factor was not included in the final models. The factor analysis did not show as clear of a factor division as I had hoped based on the literature, particularly for the selective attention and updating factors, resulting in the elimination of the flanker task for the selective attention factor, and the removal of the updating factor completely. Thus, the selective attention was intended to be comprised of both visual arrays tasks, antisaccade, and flanker, but flanker task had a very low correlation to the antisaccade and the visual arrays task, and was subsequently exuded from the final selective attention factor due to its low factor loading. This left a working memory factor comprised of Symmetry Span, Running Span, and Reading Span, a selective attention factor comprised of the two visual arrays tasks, and the antisaccade task, and a monitoring factor that included lexical decision task accuracy difference scores, as well as number of clock checks in the time-based prospective memory condition. Finally, the prospective memory factor consisted of the accuracy scores in responding to the prospective memory cue by pressing '*q*' when the target word appeared (or within one trial of its appearance).

Due to the unexpected lack of a reaction time difference in the event based prospective memory tasks, an exploratory factor analysis of the time-based monitoring measures was conducted to see if change in accuracy was an appropriate measure to include in the ultimate monitoring factor, and if it held with either the reaction time difference or clock checking behavior. The factor analysis in Table 4 below revealed two clear factors with accuracy difference being by itself, and the difference score for reaction time between the time-based condition and the control condition and clock checking behavior (implications of this division will be discussed in terms of several exploratory models, including this combined clock checking/reaction time difference factor).

Ultimately, change in accuracy in the time-based condition, was explored in addition to the clock checking monitoring measure (the only measure to correlate with performance in the time-based prospective memory condition.

Table 6. *Note.* Principal components analysis for the time-based monitoring factor, including reaction time difference score (TB.Mon.RT), accuracy difference score (TB.Mon.ACC), and number of clock checks.

	Component	
	1	2
TB.Mon.RT	**.76**	-.37
TB.Mon.ACC	-.00	**.89**
ClockCheck	**.75**	.37

An initial event-based model evaluated model fit with and without mediation in a scenario where assessments of monitoring and PM performance from the focal, non-focal, and time-based conditions were combined. This model fit was assessed to evaluate the idea proposed by Smith (2000) and others that there is always some level of monitoring involved even when executing a focal prospective memory intention. If this were the case, we would expect a similar pattern of results across conditions (see Figure 4).

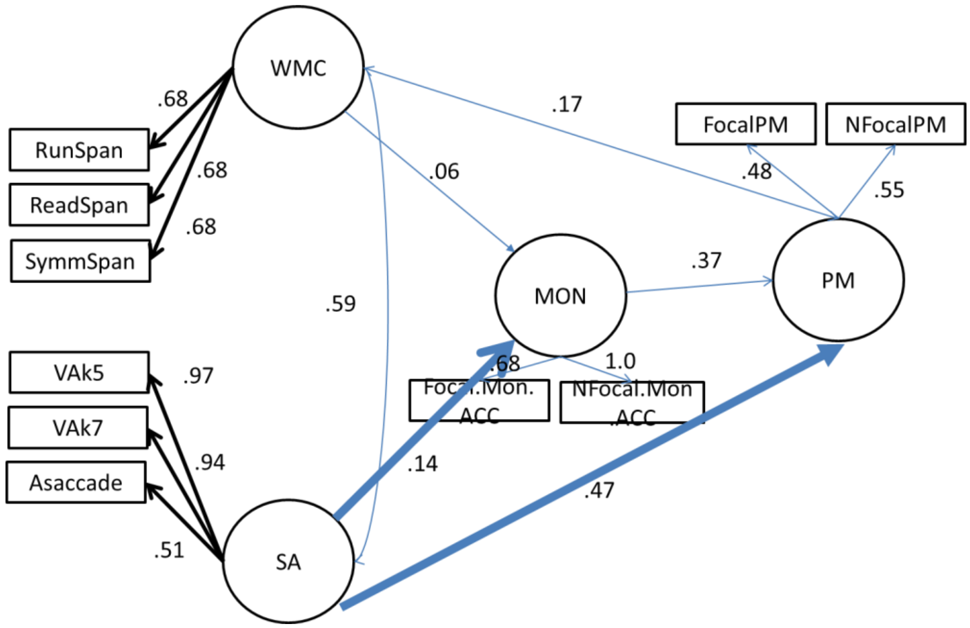


Figure 4. Event-based mediation model using a prospective memory factor combining prospective memory performance in the focal and the non-focal conditions. *Note:* Model fit: $\chi^2 = 73.53$, df = 34, $p < .05$; RMSEA = .09; CFI = .95; NNFI = .90; AIC = 5.53; SRMR = .06

In order to explore the relationship between our latent factors and prospective memory performance on a more informative format, separate event and time-based models were run. This division also allowed us to explore the possibility of a model that could explain event-based prospective memory as a whole (i.e. a general model could possibly explain performance on both types of prospective memory performance, suggesting that strategy is an individual differences factor, rather than an extension of cognitive control or WMC). This event-based model (shown below) produced a much better fit than a comprehensive model spanning event, and time-based performance. Furthermore, the event based model that included the mediation factor resulted in a better fit than did the model with those paths fixed to zero (see Table 5). The model below shows the significant paths in the event-based model that included monitoring as a mediating variable.

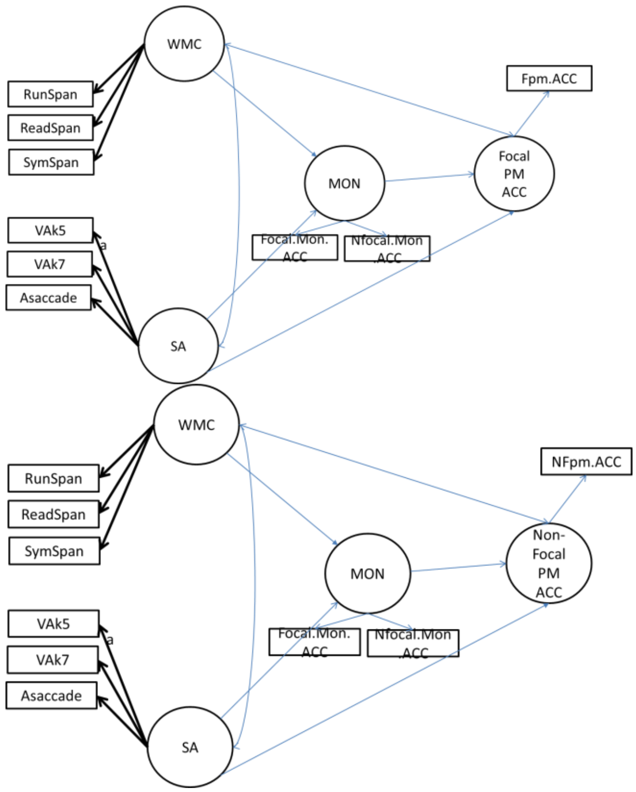


Figure 5. Example of the division of the previous combined model into the distinct focal and non-focal prospective memory performance conditions (see Table 5 for model values).

Interestingly, this model showed no relationship between WMC and monitoring or a general prospective memory performance factor. However, this combined model does not reflect the possible strategy differences between a more and less resource demanding task condition. The model was next divided to assess the relationship between the latent factors and monitoring respective to performance on the focal and non-focal tasks independently, in order to identify insignificant paths for the next step, where I fit a full event-based model with separate focal and non-focal prospective memory factors.

This division also allowed me to compare model fit with and without monitoring as a mediating variable across task conditions (focal and non-focal). The monitoring factor once again contained the ongoing task accuracy difference for both the focal and non-focal conditions as the change in reaction time was not informative. Table 5 summarizes model fit for the models with a combined event-based prospective memory performance factor, with and without monitoring as a mediating variable, as well as the fit for just the focal and non-focal conditions with and without monitoring.

Table 7. Model values for mediation vs non-mediation models. *Note:* The above models are for the event-based condition. Combined PM factor refers to the combining of prospective memory performance in the focal and non-focal conditions into a single combined factor. Focal or non-focal refer to models with only that condition's prospective memory performance as the performance factor. Models with mediation included monitoring (change in accuracy) whereas 'NoMediation' models had those paths set to zero.

Model fit with a without a mediation factor.

Model	χ2	df	χ2/df	RMSEA	SRMR	NNFI	CFI	AIC
1) Combined PM factor No Mediation	32.72	14	1.71	.09	.06	.93	.96	4.72
2) Combined PM factor Mediation	73.53	34	2.22	.09	.06	.92	.95	5.53
3) Focal No Mediation	19.50	21	1.49	.09	.06	.94	.98	3.50
4) Focal Mediation	36.94	36	2.43	.08	.06	.93	.97	2.95
5) Non-Focal No Mediation	28.07	21	1.74	.12	.06	.89	.96	12.07
6) Non-Focal Mediation	44.83	17	1.75	.10	.06	.90	.95	10.83

Figure 6 shows the final event-based model, with isolated focal and non-focal prospective memory performance factors included. Once again, the paths that are set to zero were found to be not significant in a focal or non-focal 'only' model.

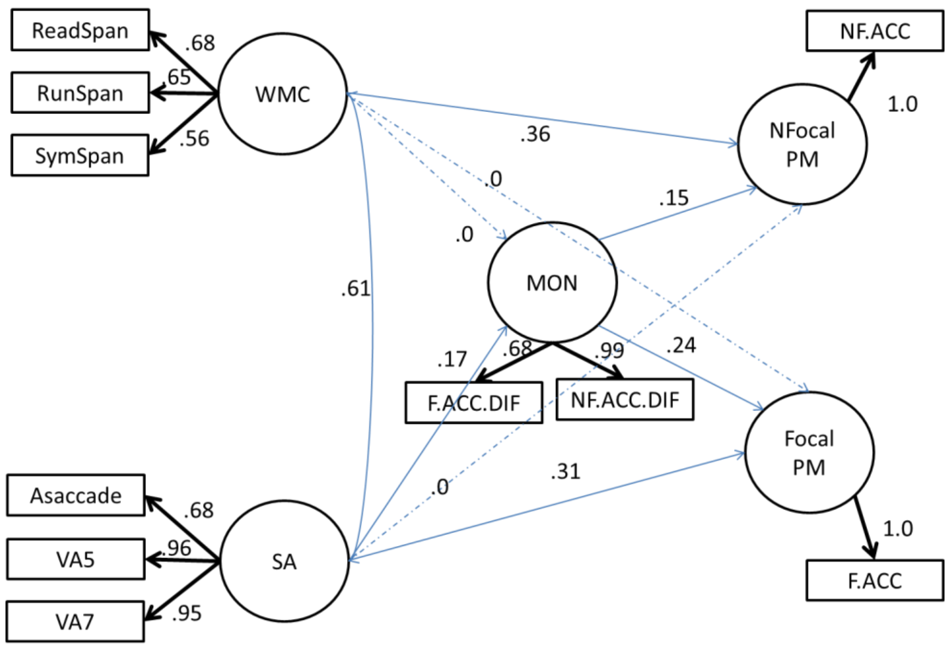
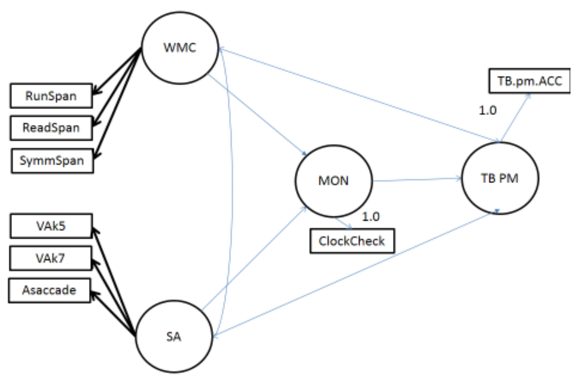


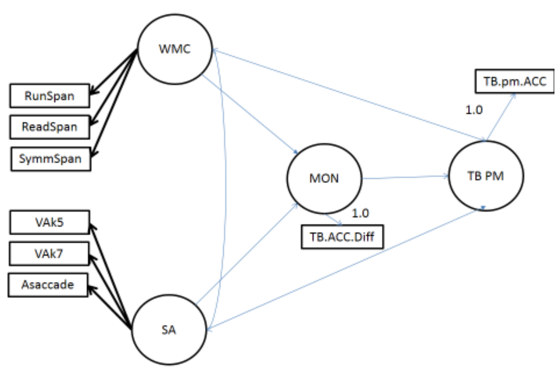
Figure 6. Full event-based model with monitoring. *Note:* Model fit: $\chi^2 = 50.97$, df =34, p<.05; RMSEA = .09; CFI = .95; NNFI = .90; AIC = 8.97; SRMR = .06

With the paths from WMC to Focal PM performance, from SA to non-focal performance, and from WMC to monitoring fixed to zero (based on previous models finding no significant relationship between these factors), we see the different relationships between WMC and SA, and the other factors. Namely, higher WMC was directly related to higher performance on the non-focal PM task, but not monitoring or performance on the focal PM task. Alternately, SA was directly related to focal PM performance, and to monitoring. Finally, the paths from monitoring were significant for both the Focal and non-focal prospective memory tasks, such that individuals with more efficient monitoring (less interference to the ongoing task) showed increased performance on both prospective memory tasks (monitoring was revered scored in these models).

In the time-based condition, two sets of models were run, one, using clock checking as our measurement of monitoring (as I had anticipated due to the literature), and a second post-hoc model, where the monitoring factor was comprised of the lexical decision task accuracy difference score (between time-based and control) as done in the event-based conditions.

My base time-based model, for both types of monitoring, is the same as the single condition event based models in Figure 5.





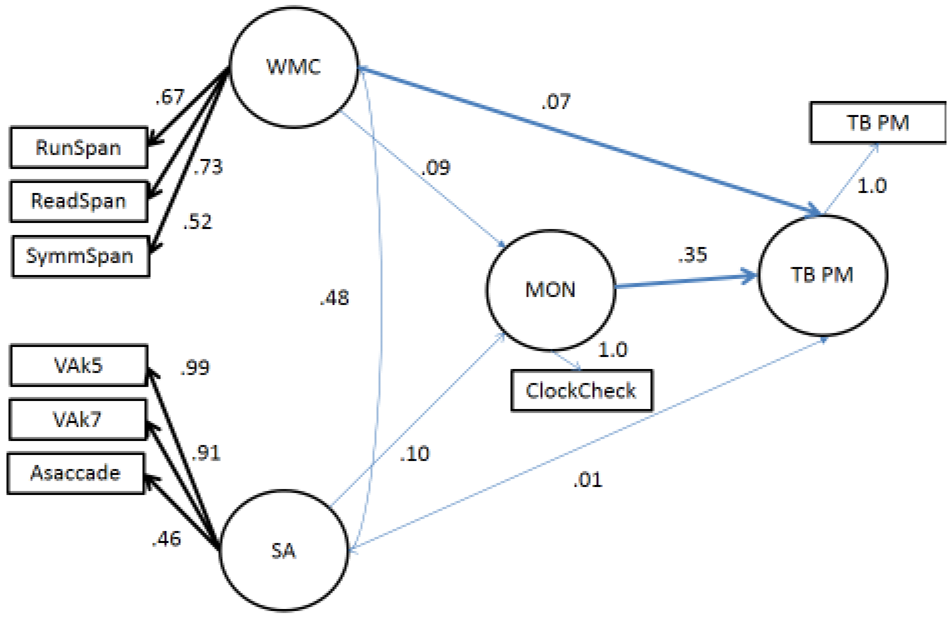


Figure 7. Top: Sample models above for the time-based condition. Bottom: Model showing the best fit for the time-based condition. *Note:* Model fit: χ^2 = 48.49, df = 12, p<.05; RMSEA = .15; CFI = .90; AIC = 21.49; SRMR = .09

Here, the path between working memory capacity and prospective memory performance was significant, as was the path from monitoring to prospective memory performance. There was no significant path between either working memory capacity or selective attention and monitoring (clock checking) as would be anticipated based on previous literature. Furthermore, when the model did not include monitoring, there were no significant paths. Finally, when this model was run using change in accuracy as our measurement of monitoring, in order to compare the underlying performance factors between the time-and event-based conditions, none of the paths in this model, were significant (Model fit: χ^2 = 35.77, df = 12, p<.05; RMSEA = .12; CFI = .93; AIC = 11.77).

Finally, because the accuracy difference score and the clock checking and change in lexical decision reaction time, reflected different factors, we explored the possibility of a relationship between these variables (see figure 8).

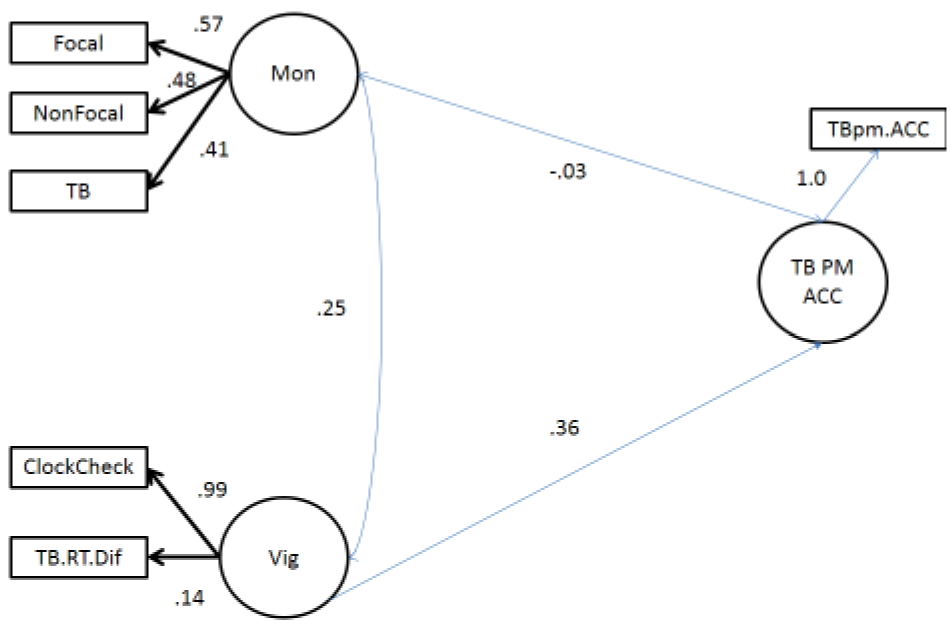


Figure 8. Time-based model examining the relationship between monitoring defined as a change in accuracy, vs number of clock-checks and difference in reaction time. *Note:* Model fit: χ^2 = 50.97, df = 12, p<.05; RMSEA = .13; CFI = .89; AIC = 8.97.

Although no paths were significant, the path from the time-based monitoring factor to the time-based PM performance reflected a stronger relationship. As the model fit was good, and the relationship was in the direction we would expect theoretically, it was included as a significant path in the final model combining the event and time-based prospective memory outcomes.

The model above shows an integrated model including both the event and time-based monitoring outcomes and performance factors. In this model, the path from selective attention to monitoring was marginally significant, as was the path from working memory capacity to clock-checking (not shown).

CHAPTER 4

DISCUSSION

This study sought to reconcile discrepant findings regarding the relationship between prospective memory performance and executive control measures by reevaluating the role of monitoring and its relationship to both performance and cognitive control measures. Predictions were made regarding the idea that monitoring may serve as a mediating variable between working memory capacity, selective attention, updating, and prospective memory performance. I hypothesized, first, that working memory capacity would have a significant impact on performance on the time-based and non-focal prospective memory tasks, but not the focal prospective memory task, in accordance with the Multi-Process theory of prospective memory. Second, I hypothesized the presence of an inverse relationship between working memory capacity and updating level of monitoring (proactive control), with high working memory capacity individuals relying less on monitoring than those with low working memory capacity and/or updating in the non-focal and time-based conditions (McDaniel & Einstein, 2000). Third, I hypothesized a significant relationship between selective attention and updating and prospective memory performance on the time, focal and non-focal prospective memory tasks. Finally, I anticipated that these relationships would be significant in models including monitoring as a mediating variable, and that the fit for these models would be better than when no mediating factor was included.

I would first like to address the issue of the 'unique' monitoring measure used in this study, as it is particularly relevant to the conclusions that follow. What was unusual about this study was that reaction times did not increase when the prospective memory intention was added in either the focal or non-focal conditions. Typically, the accuracy during the lexical decision task stays relatively stable, with the reaction time changing across task conditions, I essentially found the opposite effect. Here, the reaction times for the ongoing task *decreased* slightly with the addition of the focal prospective memory intention, but then did not increase from the focal condition to the non-focal condition. Alternately, the accuracy during these tasks is what changed, decreasing from the control to the focal, and from the focal to the non-focal condition. Subsequently, I will argue that this difference in accuracy is reflective of coping with proactive control, with individuals who are able to disengage from stimuli maintaining performance in the face of ongoing task interference. As we will see, this may actually be reflective of not only differences in proactive and reactive control as anticipated, but also of variance associated with fluid intelligence (Gf) beyond that captured by working memory span tasks.

Event-based discussion

Consistent with previous literature on the relationship between working memory capacity and prospective memory performance (McDaniel & Einstein, 2000), results revealed significant positive correlations between our measures of working memory capacity and prospective memory performance in the non-focal, but not the focal condition. Selective attention also correlated with performance in the non-focal condition, but not as consistently with performance in the focal condition. The updating measures were not correlated with prospective memory performance, and not significantly correlated with one another, or with working memory or selective attention measures. Thus, a principal components analysis was performed to decide what factor constructs would be included in the final model. This analysis revealed two strong factors: working memory, comprised of the span tasks as originally intended, and a selective attention factor, comprised of the two visual arrays tasks and the anti-saccade task (and excluding the flanker task).

Due to the strong correlation between prospective memory performance in the focal and the on-focal conditions, prospective memory was first looked at as a factor combining performance on both the focal and the non-focal prospective memory tasks. This combined factor also allowed for an examination of the role of monitoring more generally across event-based prospective memory task conditions. In this event-based model with focal and non-focal performance comprising a single performance factor, the fit improved when monitoring was included as a mediating variable. In fact, all event-based models (combined, focal, and non-focal) that included a mediating factor of monitoring, provided adequate whereas those without it did not, suggesting that 'monitoring' is relevant across both focal and non-focal task conditions. However, the single latent factor memory model did not show a significant path between monitoring and prospective memory performance. According to the predictions of the Preparatory Attention Model, if monitoring were essential for prospective memory execution, regardless of task condition, then this path would have been significant for a combined construct.

Continuing on, using a more Multi-Process theory framework, the single prospective memory performance factor was split into its constituent focal and non-focal condition outcome variables. In this model, the path between selective attention and focal prospective memory performance was significant, as was the path between selective attention and monitoring; however, the paths between selective attention and non-focal prospective memory performance were not significant (also, when a single model comprised of only the non-focal outcome variable, the path from selective attention to monitoring also lost significance). This pattern suggests that the previous relationship between selective attention and monitoring, seen in the unitary construct model prospective memory, was driven primarily by the role of selective attention in monitoring in the focal task condition. Although the strength of the path from selective attention to monitoring is reduced somewhat in this model, we do see the anticipated relationship between monitoring and performance in the non-focal condition. Unexpectedly, a significant path from monitoring to performance on the focal task also emerged when both focal and non-focal prospective memory factors were included as independent outcome variables. This link between monitoring and performance in the focal prospective memory performance was particularly contrary to our hypothesis, and the argument made by the Multi-Process theory.

Time-based discussion

In the time-based prospective memory condition, as anticipated, the path from working memory capacity to prospective memory performance was significant (such that individuals with high working memory capacity had higher prospective memory accuracy scores), as was the path from the mediating variable of monitoring (clock checking in this task) to prospective memory performance. Contrary to expectations, however, there were no significant direct paths from working memory capacity or selective attention to monitoring. Additionally, a post-hoc model was run in order to compare performance between the event-and time-based tasks. This model used change in accuracy as the measure of monitoring as was done in the event-based models; note that principal components analysis revealed that change in accuracy in the time-based condition held together with change in accuracy in the event-based conditions. However, when this model was run, no paths were significant, and the model fit decreased (in the time-based condition, there were significant differences in both reaction time and accuracy between the prospective memory blocks and the control condition; however, accuracy was selected for comparability with the event-based data). Thus, it is possible that time and event based tasks are governed by similar constructs (proactive and reactive control), but that those constructs differ in their manifestation, as change in accuracy did not account for performance in the time-based condition as it had in the event-based conditions.

In summary, the pattern of results obtained aligned with the Multi-Process Theory, that is, for the most part, the anticipated relationship between working memory capacity and performance in the non-focal and time-based conditions was present in the models (arguably reflecting individual differences in proactive and reactive control strategies in the evened-based tasks: Individuals with lower working memory capacity, who presumably are more prone to interference, are more likely to use proactive rather than reactive strategies), and model fit was improved when a mediating variable of monitoring was included. Unexpected findings included that the mediating variable was captured by a change in accuracy rather than reaction time, and was governed by selective attention alone, with no relationship to an individual's working memory capacity. Finally, although this change in accuracy in both the time and event-based conditions held together as a single factor (arguably reflecting the same construct) the only factor related to performance was the original measure of monitoring that we had included (number of clock checks).

Possible Explanations

According to Fukuda and Vogel (2009), the aspect of selective attention captured by the visual arrays tasks used here, is reflective of the ability to disengage from no longer relevant stimuli, rather than the ability to maintain relevant information in the face of interference. Because there is still interference in the focal condition, albeit it not as much so as in the non-focal condition, it follows that the ability to disengage from the attention capture of the no longer relevant information would still be necessary. Subsequently, it is possible that when monitoring is evaluated in terms of decreases in accuracy, rather than increases in reaction time, the factor is more reflective of an overall reflexive process providing a benefit against added, or prolonged proactive task interference. Thus, it is not so much an issue of whether proactive control, or attention allocation, is necessary across task conditions, as much as the degree to which disengagement from no longer relevant information impacts performance when there is not another, less effortful way to maintain the intention (i.e., maintain more easily in the face of interference when working memory capacity is high). This explanation would also clarify why the path from selective attention to the focal performance variable is significant, but the path from selective attention to the non-focal performance variable is not, as a reflexive process such as this is less beneficial when task-target processing is not congruent. This incongruency leads to a greater buildup of proactive interference, ultimately leading to an advantage for individuals high in working memory capacity who are less impacted by the proactive interference of the non-focal condition, and subsequently better able to proactively maintain the prospective memory intention. .

The division between the maintenance of the prospective memory intention, evidenced by individuals with high working memory capacity, and the disengagement seen in the selective attention and monitoring factors, is a dynamic that is congruent with recent arguments by Shipstead, Harrison, and Engle et al. (submitted) regarding the relationship between working memory capacity and fluid intelligence. According to Shipstead et al., although working memory tasks and fluid intelligence tasks have been shown to be highly correlated with working memory capacity (captured by span tasks) does not fully explain fluid intelligence. Further, Shipstead et al. argue that this is due to a difference in function (albeit it complimentary) between working memory capacity and fluid intelligence, such that working memory capacity is reflective of the ability to maintain information or quickly retrieve it from memory in the face of interference (proactive control), and that fluid intelligence is related to the ability to disengage from no longer relevant information (reactive control). Furthermore, the visual arrays tasks used here are the same as those used to argue for this aspect of disengagement (Fukuda & Vogel, 2009; 2011; Shipstead et al, 2014). Thus, it may be the case that the selective attention variable, and by proxy the monitoring factor, may be capturing individuals' ability to disengage, similar to the findings in Shipstead et al. While individuals high in working memory capacity are able to maintain both intentions in the face of the increased interference of the non-focal task condition, when interference is reduced in the focal condition, successful performance is influenced by the ability to disengage from previous stimuli, and move on to the next assessment, a reactive control process that may be reflecting differences in fluid intelligence (Gf). Finally, Hutchison et al. argue that changes in accuracy, rather than reaction time, are most reflective of proactive control, and that, when proactive control is reduced, then we being to see other aspects of fluid intelligence (Hutchison et al., 2011) (the same pattern of results seen here from the non-focal to the focal condition). Thus, I argue that the monitoring construct captured by change in accuracy is ultimately related to a reduced use of, or ability to efficiently use, proactive control, and is more reflective of a reactive control strategy related to the ability to disengage from one trial to the next.

CHAPTER 5

CONCLUSIONS

In summary, this study attempted to further our understanding of the role of monitoring as it relates to performance, how it is influenced by other cognitive factors, and ultimately help explain discrepancies in the literature to date by evaluating the use of a mediational model in order to explain the relationship between working memory capacity, cognitive control factors, monitoring, and prospective memory performance across different task designs. My findings both replicated and diverged from existing literature, in that they supported a multi-process view of prospective memory performance, but also extend the theory behind the role of monitoring into the realm of proactive and reactive control. Furthermore, these findings are, for the most part, consistent with the theoretical position that there are two distinct processes related to proactive control, one relating to working memory capacity as evidenced by the ability to simultaneously maintain two intentions, and the other reflective of selective attention and ultimately a part of Gf, reflecting the ability to disengage from stimuli. Subsequently, in addition to replicating findings by Shipstead et al. (2014; submitted), it provides a new language and theoretical base with which to more critically, and accurately, evaluate the processes involved in prospective memory performance. This is an important conclusion in that it suggests that this type of prospective memory study yields results similar to dual task paradigms evaluating the use of proactive and reactive control. I would argue that this is a positive for this type of memory evaluation in that, when executing prospective memory intentions in the real world, we are typically already performing other tasks when the need to act arises.

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