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Examining the Role of Executive Functions in Focal Processing of Event-Based Prospective Memory

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EXAMINING THE ROLE OF EXECUTIVE FUNCTIONS IN FOCAL PROCESSING OF EVENT-BASED PROSPECTIVE MEMORY

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Prospective Memory (PM) refers to remembering an intention to be acted upon in the future. Such a memory may be triggered by an event (i.e., Event-based PM) where a specific cue reminds one of the previously encoded intention. PM can be assessed in a lab-setting by having subjects learn a baseline task, subsequently receiving a PM instruction, completing a distractor task, and then going through a test phase where the PM task (i.e., responding to PM cues) is embedded within the ongoing task. The multiprocess view (McDaniel & Einstein, 2000) posits that PM can be retrieved primarily using two different strategies: one can strategically monitor for the PM cue to keep the intention in mind or spontaneously retrieve the intention by coming across the cue.

The multiprocess view suggests that monitoring or spontaneous retrieval strategies are chosen based on whether one's current task is focal or non-focal to the nature of the PM task. When processing of the ongoing task stimuli and PM stimuli overlap (i.e., focal), spontaneous retrieval of the encoded intention is thought to occur more often. On the other hand, when processing of the PM stimuli is peripheral (i.e., non-focal) to the ongoing task, one may have to consistently monitor for the PM cue for successful task performance. Manipulation of PM task focality has shown a PM performance advantage in focal conditions (Einstein & McDaniel, 2005), confirming the focality effect posited by the Multiprocess view.

Past studies (e.g., Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013) have suggested that some aspects of executive function (EF) are involved in non-focal PM performance. However, according to the multiprocess view, spontaneous retrieval of the PM cue can occur when the ongoing task is focal to the PM task. Because subjects may not need to appropriate as many cognitive resources toward the PM task, EF might be unrelated to PM performance in focal tasks. The current study tested this idea by examining a sample of college-aged subjects on two event-based PM (category and syllable judgments) and two EF (inhibition and task-switching) tasks. Subjects were assigned to focal or non-focal conditions for the PM tasks. The prediction of a focal condition advantage was found for PM performance measures, particularly in the syllables task. No relationships were found between PM performance and EF measures for the focal condition, as predicted. However, most of the predicted relationships between PM performance and EF measures for the non-focal condition were not confirmed, with the exception of a correlation between inhibition and PM performance measures. Further, EF measures could not account for performance differences across focality conditions. These findings were evaluated in terms of current theories of PM and implications of the current study were addressed.

KEYWORDS: Executive Function, Prospective Memory

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Statement of the Problem

Forming intentions to complete a task at some point in the future, or in simple terms ‘remembering to remember’ (Harris, 1984; Smith, 2003), is fundamental to everyday human behavior. To be able to successfully execute such intended acts, one must utilize one’s memory for these delayed intentions – the multiple processes supporting the execution of intended behaviors that can only be fulfilled after performance of an interposed activity (Gilbert, 2015). Prospective Memory (PM; Brandimonte, Einstein, & McDaniel, 1996) seems to be the primary construct involved in carrying out these intentions. PM is exercised when retrieving a previously encoded intention of an act to be performed in the future (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000). For example, one may need to remember to deposit a check before a particular day in order to pay a certain bill on time. As such, remembering future intended acts is crucial and can have troublesome consequences (e.g., power is shutdown for not paying the bill).

One way that PM can be triggered is when one comes across a specific cue that reminds one of the action intended to be performed, a type of PM known as Event-based PM (Einstein & McDaniel, 1990). People’s experience of event-based PM can be studied both in natural and lab settings. In a natural setting, an experimenter might test individuals on whether or not they can successfully perform a specified act prompted by a PM task (e.g., mail a post card on the day they receive a text from the researcher). However, often times PM is studied in a laboratory setting where one can control for variables more precisely. In a laboratory task, PM may be measured by having subjects complete some ongoing (e.g., lexical decision) task where a PM task is embedded within the task. Participants complete some trials of the ongoing task, receive a subsequent PM task instruction (e.g., press a key when a particular target word appears), and then are tested on the PM task in a later ongoing task block. PM performance (i.e., pressing the correct key) corresponds to whether the subject retrieves and acts on that encoded future intention at the appropriate time (i.e., when the target word appears in the task) after a delay between the PM instruction and testing phase (Einstein, Smith, McDaniel, Shaw, 1997).

CHAPTER II

REVIEW OF RELATED LITERATURE

General literature review

Prospective Memory Frameworks

The current theoretical landscape largely centers around three prominent frameworks of PM: the Preparatory Attentional and Memory processes (PAM) view (Smith, 2003), the Multiprocess (MP) view (Einstein & McDaniel, 1990; McDaniel & Einstein, 2000), and the Dynamic Multiprocess (DMP) view (Scullin, McDaniel, & Shelton, 2013). These views generally concur on the conception of PM, but critically disagree on *how* delayed intentions are retrieved and acted upon.

The PAM view. Smith (2003) proposed the PAM view of PM, which looks at the dual-task nature of PM and how PM can have an influence on the ongoing task that the subject performs. This view concentrates on one's attentional capacity; in a dual-task paradigm, it is thought that one does not have as many attentional resources available when one's attention is divided between two tasks. Smith argued that there is a cost associated with the ongoing activity that had been largely overlooked in the traditional PM literature; past researchers (i.e., Einstein & McDaniel, 1990; McDaniel & Einstein, 2000) had adhered to the assumption that intentions are retrieved automatically when exercising event-based PM, in which case the only attentional cost to the subject is during the target event. One may infer, then, that the PAM view implies a dependency of PM performance on the subject's level of executive control as a function of working memory.

PM, therefore, is restricted by the bounds of one's conscious capacity, thus acting upon a previously encoded, delayed intention should not be automatic (Smith, 2003; Smith, Hunt, McVay, & McConnell, 2007).

Smith (2003) suggests that a portion of attention – in the form of preparatory attentional processes – is partitioned to monitor for imminent target events during a PM task. Because preparatory attentional processes are activated when a PM task is embedded within an ongoing task, fewer resources are available, thus performance on the ongoing task should suffer. This view would then posit that subjects' successful performance of the PM task is the result of increased monitoring at the expense of the ongoing task's performance. One can measure the cost that monitoring has by measuring response times (RTs) on the ongoing task trials; RTs on the ongoing task trials are increased when a PM task is performed simultaneously compared to trial blocks that only have ongoing task trials (Smith et al., 2007).

The culprit of the cost on ongoing task performance is suggested to be retroactive memory – remembering what the action is and when it should be executed – that consumes attentional resources; retroactive memory processes are controlled and are consistently present in order to distinguish target from non-target trials to recognize the PM cues as cues to perform the intended action (Smith, 2003; Smith et al., 2007). Constantly checking one's retrospective memory and monitoring for a PM cue can impose a cost upon one's attentional capacity (i.e., preattentional processes) during trials other than the target trial in an event-based PM task, meaning intentions are not simply retrieved automatically, but one must be prepared to retrieve them when completing non-target trials (Smith, 2003; Smith et al., 2007). Conversely, PM failure would occur when preattentional processes are not activated. Moreover, Smith et al. (2007) exhibited evidence in favor of involvement of preparatory attentional processes in the detection of PM cues as well as the intention retrieval that follows. They ran several experiments where a control group of subjects underwent a lexical decision (i.e., ongoing) task as well as an experimental group that performed the same ongoing task embedded with a PM task (i.e., press a key when they saw a pre-determined salient target such as the subjects' name). The results showed that the experimental group was slower on the ongoing task trials leading up to the target event than the control group, especially when there was more than one target event (Experiments 3 and 4). In sum, the PAM view suggests that PM retrieval is never automatic, and successful PM requires the activation of preattentional processes via monitoring. More focus should be put on cost of performing the ongoing activity in the presentence/absence, and resulting interference, of a supplemental PM task rather than just PM performance (Smith, 2003; Smith et al., 2007).

The MP view. Contrary to the PAM view (Smith, 2003), the Multiprocess (MP) view (Einstein & McDaniel, 1990; McDaniel & Einstein, 2000) proposes a more flexible conception of event-based PM that encompasses different cognitive processes that are involved in PM retrieval. The MP view allows for both automatic as well as attention demanding retrieval of an intention to be acted upon (Einstein & McDaniel, 2005). This framework does recognize that, depending on the nature of the task, individuals will monitor for the PM target; when the subject exercises monitoring, the executive system is active and processes stimuli more carefully (McDaniel & Einstein, 2000). However, the MP view rejects the idea that monitoring is the only process involved in PM retrieval.

The MP view argues that constantly using monitoring processes would be maladaptive, thus situations that warrant a less demanding and automatic processing in acting upon a delayed intention can be successful without monitoring processes (Einstein & McDaniel, 2005). Specifically, PM retrieval can happen spontaneously in an involuntary manner (McDaniel & Einstein, 2000). To justify this claim, the MP framework theorizes that an involuntary associative system (Guynn, McDaniel, & Einstein, 2001) may be involved in the automatic retrieval of intentions. This proposal, known as the reflexive-associative theory (Einstein & McDaniel, 2005), posits that an associative memory mechanism initiates when an intention for future action is formed. This system lies dormant while an individual undergoes an interposed unrelated task but reflexively activates when a target cue is encountered; the spontaneous recognition of the target's relevance to the PM task warrants an action depending on the strength of association of the cue at encoding. Involuntary retrieval of the intention via the proposed associative mechanism, therefore, can be robust to the demands imposed by the ongoing task, and seems functionally favorable, as it does not demand many cognitive resources (Brandimonte, Einstein, & McDaniel, 1996; Einstein & McDaniel, 2005). Thus, the MP view contrasts with the PAM view's proposal that successful PM is dependent on a strictly controlled monitoring since using such a strategy does not necessarily always dictate successful event-based PM performance.

Task focality. The MP view posits that specific factors trigger the different types of processing when simultaneously performing a PM and ongoing task (McDaniel & Einstein, 2000). In terms of PM retrieval, the MP view suggests focal processing to be a considerably influential factor in performance of PM tasks (Einstein & McDaniel, 2005).

Focal processing directs attention to the target along with the association between the PM cue and intended action that was processed at the time of encoding. Specifically, when the nature of the ongoing task requires focal processing of the PM cue (i.e., the PM task is focal to the ongoing task), one is more likely to spontaneously retrieve the previously formed intention (Einstein & McDaniel, 2010). For example, one may need to remember to pay a co-worker back the following day for covering one's lunch; thus one subsequently gets money from an ATM, and puts the money in an envelope stored away in his or her bag. However, other things (e.g., work, grocery shopping, doctor appointment, etc.) draw one's attention away from remembering to give the envelope to his or her co-worker. When one decides to organize the contents of the bag the next day, one sees the envelope and suddenly remembers that he or she needs to pay his or her co-worker back. In this case, the organizing ongoing task allowed one to process the key feature of the PM cue, the envelope containing the money, which prompted retrieval of the PM task. As mentioned above, the MP view would suggest that the individual in the example likely activated the associative memory system when encoding the intention to pay his or her co-worker back and seeing the envelope (i.e., focally processing the PM cue) triggered the association.

Alternatively, if a PM cue is not as readily accessible in relation to the ongoing task, it may be overlooked (McDaniel & Einstein, 2000). If the individual from the above example does not end up organizing the contents of the bag the next day, he or she would be less likely to remember his or her debt to the co-worker because they would not encounter the PM cue (the envelope of money) that prompts PM retrieval. The MP view would argue that because the individual's ongoing tasks that day did not involve looking through the bag, the PM cue (i.e., the envelope) was outside of his or her focal processing. Therefore, a monitoring strategy would have to be implemented in order to appropriate sufficient attention to the envelope to remember to give it to the co-worker.

The above example illustrates situations where a PM cue can be focal or non-focal to the ongoing task. This dualistic distinction of the focality of PM cues can be emulated in a lab setting by employing an ongoing task and manipulating the instructions such that the PM task will either be focal or non-focal to the ongoing task. For example, one could have subjects do a lexical decision task where a string of letters is presented on the center of the screen; subjects would decide whether the letters make up a word or non-word by pressing keys that correspond to each decision. The PM task would be embedded within this ongoing task as either focal or non-focal. A focal condition instruction may ask the subject to press a key (separate from the two keys indicating nonword/word) whenever they see a specific word (e.g., flower). In a non-focal condition, subjects could be instructed to respond whenever they see a word that represents an animal (e.g., dog, giraffe, etc.).

The MP view would suggest that because subjects are semantically processing the word stimuli, responding to a specific cue word (e.g., flower) would involve focal processing. However, if they were to respond to a peripheral cue (i.e., a word that represents an animal) focal processing would not be involved (McDaniel & Einstein, 2000). Research has found that in focal conditions, subjects do not show a cost – decline in performance on the ongoing task due to the interference of the PM task demands – in response time, while RTs in non-focal conditions exhibit a significant cost as compared to RTs in the block with the ongoing task trials only (Einstein et al., 2005; Scullin, McDaniel, Shelton, & Lee, 2010). These findings present support for the MP framework's conception that focal processing of the PM cue does not require monitoring and is robust to performance cost; one may rely on a spontaneous retrieval processes to perform well on the PM task (Einstein & McDaniel, 2005; Scullin et al., 2010). Whether spontaneous retrieval and monitoring are functionally independent processes remains unclear.

The DMP view. A third, and more recent, view – the Dynamic Multiprocess (DMP; Scullin et al., 2013) view – provides an update to the original MP view. DMP adds to the MP framework in that it considers PM performance in a more gradient manner where processes such as spontaneous retrieval and controlled monitoring can have reciprocal influence. The DMP view gives more consideration to naturalistic PM tasks where delays between intention formation and the target event can vary in scale (e.g., hours, days, weeks, etc.). Laboratory tasks are often constrained by time, and thus may not be able to accurately assess PM processes such as monitoring over the time range with which naturalistic PM tasks must be stored; what appears to be a consistent monitoring strategy could actually fluctuate when longer delays are interposed and retention of the intention becomes increasingly difficult. Moreover, the monitoring behavior could be discontinued if a cue indicating the target event is not encountered (Scullin et al., 2013). Scullin et al. (2013) suggest that rather than strategic processes (i.e., monitoring) being active consistently, they are recruited dynamically in relation to spontaneous retrieval. Spontaneous retrieval processes are thought to trigger monitoring when environmental cues or contexts reminiscent of the PM intention are encountered. Monitoring processes, then, would be crucial for the interim between when the spontaneous retrieval occurs and the execution of the intended act. This pattern was observed in findings that successful PM performance did not require a cost in response time prior to encountering the PM cue, but a consistent cost was observed for trials following successful retrieval/execution of the intended act.

The DMP framework allows for the possibility of monitoring to be disengaged, so PM performance is neither contingent on the engagement of, nor always affected by (i.e., incurs a cost), preparatory attentional processes. Concurrently, the DMP view does not simply assume spontaneous retrieval and monitoring as dichotomous processes restricted to specific instances; PM performance reflects a dynamic interplay among monitoring and spontaneous retrieval, among other processes, that can encompass many situations and contexts (i.e., contextual variability). One can infer, then, that the discrepancy in retrieval practices due to focality of the PM task, as proposed by the MP view, can be attributed to a dynamic process. For instance, focal PM tasks may be cases where monitoring would not be immediately engaged or would be engaged less often; high PM performance may be due to retrieval of the PM intention via a spontaneous retrieval process that prompts subsequent monitoring to enhance performance. In this case, PM retrieval is not simply automatic as the traditional MP view would posit, but rather the processes that prompt retrieval can be automatic, leading to dynamic activation of other processes (e.g., monitoring).

Executive Function in Prospective Memory Research

As previously mentioned, the MP view proposes that processing of non-focal PM cues within an ongoing task requires strategic monitoring (McDaniel & Einstein, 2000). Further, the update of this view, the DMP view, includes strategic monitoring as a component of the dynamic interplay of processes that support PM task performance. Executive control processes are thought to mediate this strategy because of the attentional demands that monitoring imposes (McDaniel & Einstein, 2000; Schnitzspahn et al., 2013; Smith, 2003). Such an assumption, therefore, warrants investigation of meaningful relations between tasks that test specific executive control processes of cognition and PM. The current study provided a test of this relationship within the context of the MP view's proposal regarding the processes involved in focal and non-focal tasks.

Tasks that test attentional control are thought to measure executive function (EF) – a cognitive construct thought to manage cognitive processes underlying the execution of complex tasks. One of the most prominent frameworks of EF by Miyake, Friedman, Emerson, Witzki, Howerter, and Wager (2000) explains EF in terms of a global construct encompassing a multitude of subcomponent processes modulating the control of various cognitive faculties. Modeling and differentiating subcomponent processes of EF epitomizes this line of research, which has lead to the conception of different approaches with different takes on EF. For instance, Diamond (2013) suggests that the core of executive function can be separated into three parts: inhibition, working memory, and cognitive flexibility. This framework emphasizes the reciprocal nature of EF: working memory and inhibition are supportive processes, both of which are required for cognitive flexibility.

Although most situations require these processes, using the proper instruments to measure each subcomponent process independently can help isolate which construct is important for different types of tasks (Diamond, 2013). Miyake et al. (2000) especially emphasizes this diverse nature of EF. Their framework, with the construct of EF rooted in the *Central Executive* component of Baddeley's (1986) model of working memory (WM), takes an individual differences driven approach and separates EF into three main facets: shifting – the ability to switch between different tasks or mental sets; updating – on-line monitoring and modification of WM representations; and inhibition – purposeful suppression of predominant responses. This comprehensive theory driven three-factor model provides a quantitative depiction of relations and differences among the chosen factors of EF. Though frameworks such as Diamond's (2013) and Miyake et al.'s (2000) have slightly different conceptions of EF, each can inform on the other. For example, Diamond (2013) posits that a Spatial Stroop task is a purer measure of inhibition, in comparison to many other representative tasks, because it minimizes memory demands. Thus, separate components of their framework can be taken into consideration when comparing and contrasting relations of these EF constructs to the construct of interest (i.e., PM).

CHAPTER III

RESEARCH DESIGN

Statement of the Problem

The current study drew considerable influence from a recent study by Schnitzpan et al. (2013) that conceptually focused on disentangling the role of EF facets in age-related PM performance. Using Miyake et al.'s framework of EF, they looked at the role of controlled attentional processes implicated in age-related PM performance by testing subjects on a battery of EF tasks. By doing so, they attempted to confirm previous findings of shifting and inhibition as predictors of PM performance (Martin et al., 2003), as well as disentangle the WM subcomponents of WM capacity and updating as separate constructs. The experimental procedure involved two event-based non-focal PM tasks (i.e., syllable and semantic tasks), two updating tasks (i.e., keep-track task and letter-memory task, Miyake et al., 2000), two inhibition tasks (i.e., antisaccade task, Miyake et al., 2000, and Simon task, Simon & Berbaum, 1990), and two shifting tasks (i.e., category switch task, Friedman, Miyake, Corley, Young, Defries, & Hewitt, 2006; Mayr & Kliegl, 2000, and color-shape task, Friedman et al., 2006). They additionally tested WM capacity and cognitive speed as control variables.

Schnitzpan et al.'s (2013) study revealed that EF facets were differentially related to non-focal PM performance. They found that both shifting and inhibition, but not WM, significantly predicted PM performance. These findings show the importance of being able to shift between the ongoing and PM tasks, as well as inhibiting the ongoing task, in order to successfully respond to the PM cue. Moreover, these results are consistent with the MP and DMP views' (McDaniel & Einstein, 2000) claims that multiple processes are involved in strategic monitoring, as opposed to a single global construct. Schnitzpan et al. (2013) concluded that further investigation using other EF tasks should be conducted in order to confirm that the cognitive factors implicated in their study can reliably predict PM performance and are not subject to change. They also indicated that testing differential involvement of EF with focal and non-focal PM tasks would be beneficial. The current study followed these suggestions.

Hypotheses

In the current investigation, I hoped to add to the literature examining EF's involvement in PM performance in order to further understand the processes underlying event-based PM. The current study aimed to extend Schnitzspahn et al.'s (2013) findings by testing whether the EF facets (i.e., shifting and inhibition) shown to closely relate to non-focal PM performance are also involved in focal PM performance. I hypothesized in terms of predictions from the MP and DMP views: Participants in the focal condition would perform more accurately on the PM task with less of a cost (i.e., in reaction time) than those in the non-focal condition when ongoing and PM tasks are performed simultaneously. In addition, EF performance for these constructs should show weak (or no) correlations to focal PM performance and strong correlations to non-focal PM performance. A replication of Schnitzspahn et al.'s findings for non-focal tasks would strengthen the argument that task-switching (i.e., shifting) and inhibition play an important role in strategic monitoring. Concurrently, I proposed from the MP and DMP view that there should be no relation between EF and focal PM performance, endorsing the role of spontaneous retrieval in focal processing of PM cues.

Current Project

The study design was a simplified version of Schnitzspahn et al.'s (2013) study design where subjects were tested on two PM tasks embedded within lexical decision ongoing tasks, one task-switching task, and one inhibition task. The PM tasks were adapted from Schnitzspahn et al's (2013) design and modified to include focal and non-focal versions of the PM task to test between-subjects. Notably, I used a different inhibition task than Schnitzspahn et al. (2013). Diamond (2013) suggested that some tasks (e.g., spatial Stroop) are purer measures of the construct of inhibition than others. Therefore, I included a task (i.e., the spatial Stroop task suggested) that heeded the aforementioned suggestion, as well as adhered to Schnitzspahn et al.'s (2013) call for replication of their findings with a different task. Replicating these findings with different tasks would support the development of a coherent argument for the involvement of these features of EF in PM tasks, while also giving consideration to more than one theoretical framework of EF (i.e., Miyake et al.'s, 2000, model).

Collection of the Data

Participants

Subjects consisted of undergraduate students from Illinois State University recruited through an online subject pool via the Department of Psychology in the spring semester. Participants were compensated with course credit. Participants completed a university IRB approved consent form upon arrival. Subjects were assigned to one of two focality (i.e., focal or non-focal) conditions for the PM tasks. I used G*Power software to perform an a priori power analysis to determine a suitable ample size. I estimated a need for *N* = 200 participants (i.e., *n* = 100 per between-subjects focality condition) based on the following criteria: $\alpha = 0.05$, power of 0.80 or higher, and an effect size (Cohen's *f*) of 0.20 (i.e., a small to medium effect size).[1]

Design and Procedure

The experiment was conducted on an iMac Desktop computer and executed via SuperLab (2015) software. Verbal stimuli across tasks were presented in size 36 Lucida Grande font. Each experimental session lasted approximately 30 min where subjects completed a series of two PM tasks and two executive function (i.e., inhibition and task-switching) tasks. Subjects were randomly assigned to one of two focality conditions (i.e., focal or non-focal) of the PM tasks. There was also a counterbalancing factor of list order – each PM task was always be followed by the same EF task, amounting to two orders of execution for each PM-EF task pair.

PM Tasks

Event-based PM was assessed using two different tasks, the categories and syllables tasks, adapted from Schnitzspahn et al.'s (2013) study. These tasks involved verbal and semantic reasoning. Stimuli for the Categories task were chosen using the Van Overshelde, Rawson, and Dunlosky (2004) category norms, which included category cue phrases (e.g., "a part of a building") and corresponding words (e.g., basement, floor, roof, wall, etc.). The category cue "a part of a building" was chosen as the PM cue to accommodate the non-focal PM task (i.e., respond to words with two of the same vowel in a row) because there were three words (i.e., door, floor, roof) listed under the category

[1] Given the limited subject availability via the subject pool, a post hoc power analysis was conducted to accommodate a smaller sample

that fit the task's criteria. Stimuli for the Syllables task were chosen, based on number of syllables (i.e., either two or four syllables), via the Paivio, Yuille, and Madigan Word List Generator (Friendly, 1996; http://www.datavis.ca/online/paivio/). Words were chosen for baseline and test phases and compared on Kucera-Francis (KF) word frequency, concreteness, meaningfulness, and number of letters: KF word frequency for the baseline phase (M = 15.43, SD = 16.00) was not significantly different from the test phase (M = 14.54, SD = 14.99), $t(102) = 0.28$, $p = 0.78$; concreteness for the baseline phase (M = 4.57, SD = 1.57) was not significantly different from the test phase (M = 4.61, SD = 1.59), $t(102) = 0.15$, $p = 0.88$; meaningfulness for baseline (M = 5.73, SD = 0.81) was not significantly different from the test phase (M = 5.78, SD = 0.85), $t(102) = 0.28$, $p = 0.78$; and number of letters for baseline (M = 7.83, SD = 1.73) was not significantly different from the test phase (M = 8.07, SD = 1.88), $t(102) = 0.65$, $p = 0.52$.

Each task consisted of a practice phase to acclimate the participants to the nature of the task, especially since each task had a different set of response keys. Both PM tasks involved decision-making that used two keys on opposite sides of the keyboard to hinder any interference. The key to make the PM response was located near the center of the keyboard equidistant from each of the ongoing task keys. PM phases for all three tasks were preceded by a 3 min distractor task (i.e., a Sudoku puzzle) in order to create enough of a time lapse between the PM instructions and the PM task to discourage monitoring for the PM cues.

The same stimuli as well as the same PM cue words were used for both the focal and non-focal PM conditions. Focality was determined by how focal the PM instruction was to the on-going task. In other words, the nature (i.e., focality) of the PM task either allowed (i.e., focal) subjects to process the same aspects (i.e., category or syllable) of the task stimuli in the ongoing task or not (i.e., non-focal). For example, in the current study, subjects made judgments of whether or not the presented word fit the category cue that it was presented with during the ongoing Categories task. Therefore, the PM task involving a response to items within a specific category (i.e., respond when you see a bird word) was focal to the ongoing task. However, the PM task involving an orthographic feature of the words (i.e., respond when you see a word with two vowels in a row) was non-focal to the ongoing Categories task.

The Categories task consisted of 6 trials of practice, 40 trials of the ongoing task for baseline performance measurement, and 63 trials of the test phase that contained 3 PM cues spread out across the trials (i.e., on trials 14, 40, and 62). The ongoing task involved presenting the participants with two words side by side and having them judge whether the word on the right fit in the category presented on the left. Subjects were asked to press the "s" key if the right-hand word fit in the category or the "l" key if it did not. Participants received the PM instruction following the baseline ongoing task phase. Subjects in the focal condition were told to press the "y" key whenever they saw a "word that described a part of a building" (e.g., floor). Subjects in the non-focal condition were told to press the "y" key whenever they saw a word with two of the same vowels in a row (e.g., floor). After the instruction, subjects (in both conditions) were asked, "When you think of these instructions, would you say you would think of specific examples or [focal – words that describes a part of a building; non-focal – words with two of the same vowels in a row] in general?" Depending on their answer, experimenters noted whether subjects encoded the PM cue as specific examples (e.g., floor; words that contain two consecutive vowels) or as a general category (i.e., a part of a building). The stimuli, across all phases, were presented for a maximum time of 3000 ms or until a response was made. Subjects advanced to the next trial once they made a key press; subjects also advanced to the next trial if they did not make a key press in 3000 ms of presentation.

The other ongoing task, the Syllables task, presented one word stimulus per trial in the center of the screen. The procedure consisted of 6 trials of practice, 40 trials of the ongoing task only for baseline, and 63 trials of the test phase with 3 PM cues spread out across trials. Subjects were instructed to judge whether each word had *more than* three syllables. The "w" key indicated that the word had less than three syllables, and the "o" key indicates that the word contained more than three syllables (there were no words that contained exactly three syllables). For example, if the subject was shown the word "runner", he or she should have selected the "w" key to indicate that the word had fewer than three syllables. Subjects were given the PM instruction upon completion of the baseline phase. Participants in the focal condition were told to press the "6" key whenever they saw a word that included the syllable "COM" (e.g., communicate); participants in the non-focal condition were told to press the "6" key whenever they saw a word that was a verb (e.g., communicate).

Inhibition Task

An adaptation of the Simon-Spatial Stroop hybrid task from Liu, Banich, Jacobson, and Tanabe (2004) was be used to assess Inhibition. The nature of the task allowed for a two-fold measurement of inhibition; Simon and Spatial Stroop trials were assessed separately in the analysis. Subjects underwent 20 practice trials where they learned to press the "1" key for an upward arrow and the "=" key for a downward arrow.

A fixation cross appeared for 500 ms in the center of the screen, which was subsequently be replaced by the arrow stimuli – arrows pointed upward or downward (See Figure 1). The arrow stimuli were present for up to 1500 ms or until a response was made; the trial was automatically marked incorrect if an answer is not made within the 1500 ms that the arrow was present. The subsequent test block, composed of 96 trials, presented the up/down arrows to the right, left, above, or below a fixation cross at the center of the screen. The fixation cross appeared by itself for 500 ms and then together with the arrow for 1500 ms. Participants had to input an answer while the arrow was present or else the trial was marked as incorrect and they automatically moved on to the next trial.

The spatial (i.e., left, right, above, below) and directional (upward or downward) orientation of the arrows was counterbalanced to equate conditions (i.e., Simon and Spatial Stroop) within the trial block. The order of their presentation within the trial block was also randomized.

The Spatial Stroop aspect of the task constituted the trials that presented the arrows above or below the fixation cross. The congruent trials presented the arrows in a spatially concurrent orientation – upward arrows presented above the fixation and downward arrows presented below the fixation. Conversely, incongruent trials required inhibition to resolve spatial dissonance; when an upward arrow was presented below the fixation cross, the subject had to inhibit the incorrect (down; press "=" key) response to make the correct response (up; press "1" key). Half of the Spatial Stroop trials were congruent and the other half was incongruent.

The Simon trials presented the arrows to the left and right of the fixation cross. These trials were deemed a Simon task because one had to inhibit pressing the key on the same side as the arrow stimulus. Liu et al. (2004) suggested that this would elicit a Simon effect when the spatial orientation of the arrow stimulus conflicts with the spatial orientation of the response keys; the subject had to overcome a *stimulus-response* conflict – when the stimulus was presented on the incongruent side (i.e., left or right) of the fixation cross compared to the directional position (i.e., left or right) of the hand used for the key press. In contrast, the subject did not have the added conflict for the Spatial Stroop task because the stimuli were presented on the vertical axis. Therefore, the only conflict, and ensuing Spatial Stroop effect, was contingent on the spatial placement (i.e., above or below the fixation cross) and directional attribute (i.e., upward or downward) of the stimulus (e.g., whether an upward arrow is presented above the fixation cross).

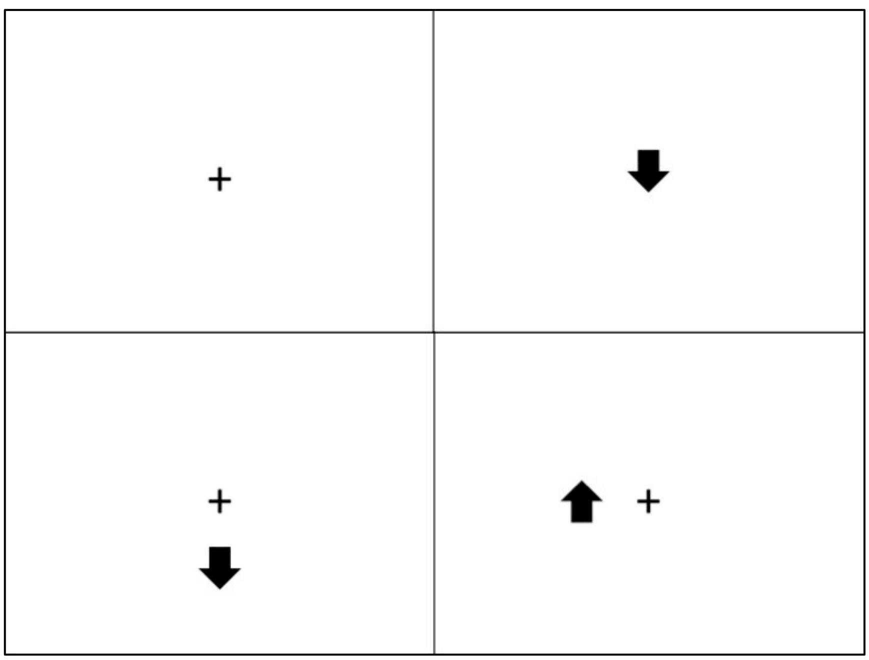

Figure 1. Simon Spatial Stroop Task Stimuli. Top left is the fixation-cross seen before practice/test trials. Top right is an arrow stimulus as seen in a practice trial. Bottom left is an example of a Spatial Stroop trial and bottom right is a Simon trial.

Task-Switching Task

A color-shape task (Friedman et al., 2006; Schnitzpan et al., 2013) was utilized to assess Task-Switching ability. The stimuli consisted of red/blue color blocks (205 × 205 pixels) and circle/triangle shape outlines (195 × 195 × 5 pixels; See Figure 2). For all trials, color and/or shape stimuli were presented in the center of the screen for up to 3000 ms or until a key press was made.

Subjects first underwent 10 practice trials where shapes and colors were presented individually. They were instructed to press the "q" key for the color blue and the circle shape and the "p" key for the color red and the triangle shape; thus each key was bivalent. Subjects then moved on to two single-feature blocks consisting of 26 trials where the shapes were superimposed on the colors. For each single-feature block, participants were asked to respond to either just the color or just the shape. The subsequent test block consisted of 88 two-feature trials that required switching between making judgments about the shape or the color of the object. For each trial, the color-shape stimuli were preceded by a cue word – either "COLOR" or "SHAPE." The cue word appeared for 1500 ms right above where the color-shape object subsequently appeared. Subjects were instructed to press the key that corresponded to the color or shape of the object based on the preceding cue word.

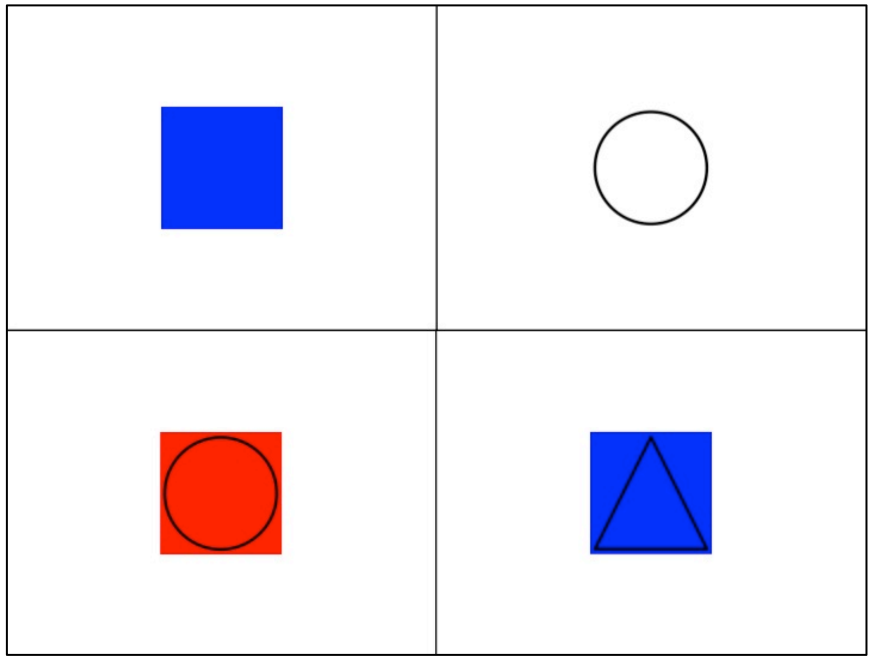

Figure 2. Color-Shape Task Stimuli. Top left and right quadrants are examples of color/shape stimuli presented individually as seen in practice trials. Bottom left and right quadrants are examples of shapes superimposed on the colors as seen in the single-feature and test blocks.

CHAPTER IV

ANALYSIS OF THE DATA

Of the subjects (*N* = 173) who participated in the study, 12 participants were excluded from analyses because of experimental error (*n* = 10), missing data (*n* = 1), and poor performance (i.e., less than 70% accuracy – *n*'s presented with each analysis) and misunderstanding of directions on more than one task (*n* = 1; i.e., subject pressed PM response key instead of ongoing task response key for the PM phase). If participants performed poorly on just one task, that task's data were excluded and performance on the other three tasks was still considered for analysis. One hundred and sixty one participants were included in the analyses; *n* = 80 participants were in the focal condition, and *n* = 81 were in the non-focal condition. The aforementioned total participants did not meet the criteria (i.e., *n* = 100 subjects for each focality condition) from the proposed a priori power analysis due to scarce subject availability. As such, a post hoc power analysis was conducted to entertain a slightly higher effect size (Cohen's *f*) of 0.25 (i.e., a small to medium effect size). The power analysis incorporated the analyzable subject count (*n* = 161) with two groups representing the focality conditions, which output a power of 0.88. Thus, sufficient power was present to test hypotheses regarding focal/non-focal differences.

PM performance was assessed in terms of PM response accuracy along with reaction times (RTs) for the baseline and test phases of the ongoing tasks. PM response accuracy was broken down into two components: overall PM response accuracy across the three targets (i.e., PM accuracy) and whether participants responded to the first PM cue (i.e., first PM response). PM block RTs were calculated excluding the critical PM trials and only for trials on which a correct response was made (i.e., excluding incorrect trials). RT data were also trimmed such that trials with RTs that exceeded 3 standard deviations from the mean were excluded from each participant's final average RT for both baseline and PM blocks. Analyses assessed whether performance was comparable across focality conditions in the baseline block, separately for the Categories and Syllables tasks.

Categories Task Analyses

For the Categories task, three subjects' data were excluded from analysis due to poor performance (i.e., less than 70% accuracy). Subjects in the focal condition were predicted to perform significantly more accurately (i.e., higher rate of PM accuracy and first PM response) and with less of a cost (i.e., lower RT score difference between PM and baseline phases) than the non-focal condition. Contrary to the MP view, PM accuracy (see Figure 3) for the focal condition (n = 79, M = 0.41, SD = 0.38) was not significantly different from the non-focal condition (n = 79, M = 0.54, SD = 0.42), $t(156)$ = 1.84, d = 0.32, with a mean trend in the opposite direction as predicted. The first PM response data (See Figure 4) were also inconsistent with predictions: the non-focal condition (n = 79, M = 0.57, SD = 0.50) resulted in a significantly higher response rate than the focal condition, (n = 79, M = 0.35, SD = 0.48), $t(156)$ = 2.76, d = .45.

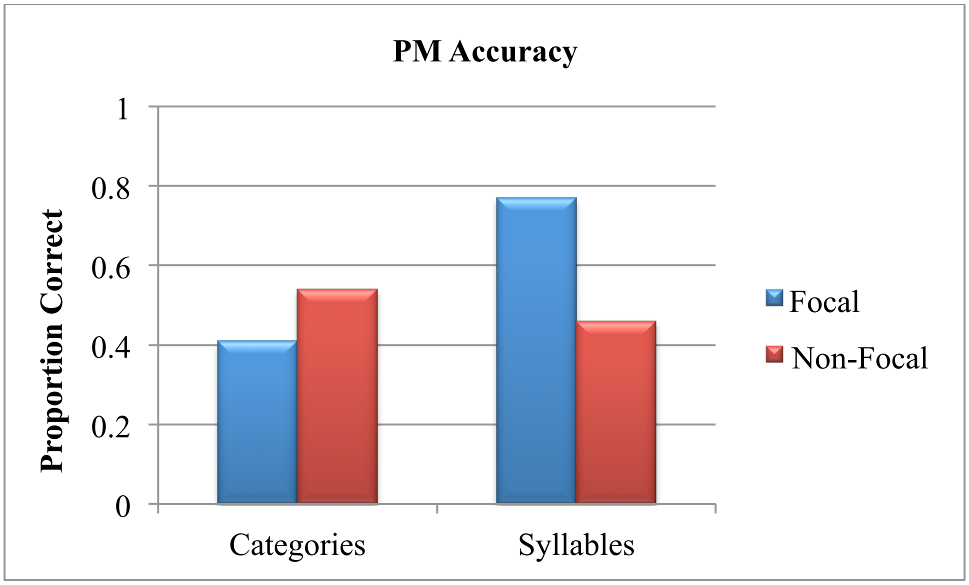

Figure 3. PM Accuracy. Overall accuracy for responses to the PM cue (i.e., PM Accuracy) across focality conditions for Syllables and Categories tasks.

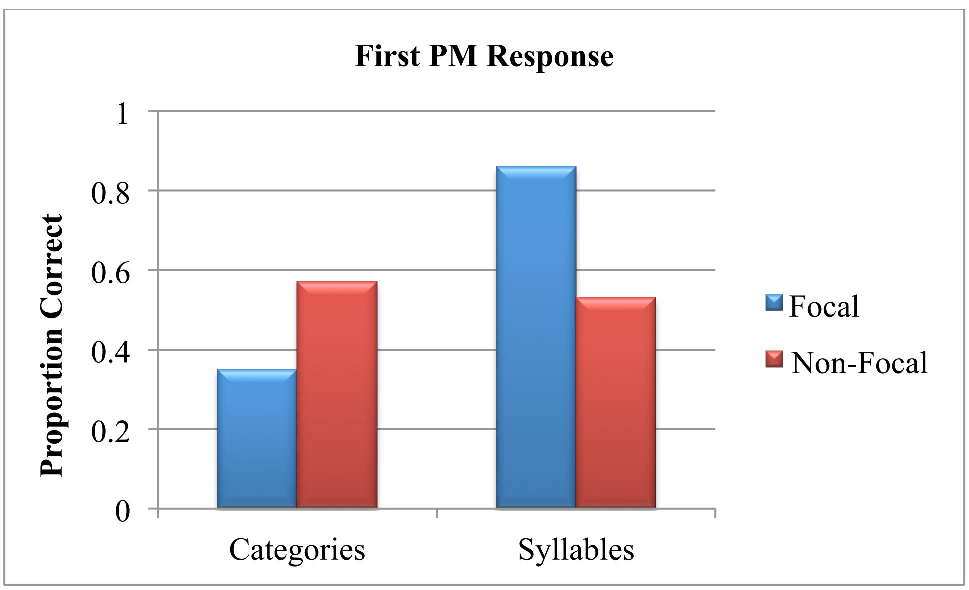

Figure 4. First PM Response. Response accuracy for the first PM cue (i.e., first PM response) across focality conditions for Syllables and Categories tasks.

To determine if PM cost could be evaluated from RT difference scores across blocks, the Baseline Block RTs were first compared. The focal condition (*n* = 79) participants' baseline RTs (*M* = 1509.80, *SD* = 393.52) were not significantly different from the non-focal condition (*n* = 79) participants' baseline RTs (*M* = 1512.11, *SD* = 332.40), *t*(156) = 0.40, *d* = 0.006; thus, a comparison of RT difference scores (PM block RT minus Baseline Block RT) was made for the focality factor. This comparison confirmed predictions: RT difference scores for the non-focal condition (*M* = 201.87, *SD* = 314.90) were significantly higher than for the focal condition (*M* = 5.62, *SD* = 276.46), *t*(156) = 4.16, *d* = 0.66, indicating a higher PM cost for the non-focal than the focal condition.

The findings for the Categories task's PM response accuracy (i.e., PM accuracy and first PM response) were contrary to my predictions. Indeed, the non-focal condition actually showed higher accuracy than the focal condition for both PM accuracy and first PM response, which is contrary to MP view predictions and results from past studies (e.g., Einstein et al., 2005). These results could be due to the PM task used in the focal PM task (i.e., respond to words that describe a part of a building). This task might have been more difficult for subjects to complete than the non-focal PM task (i.e., respond to words that have two of the vowels in a row) due to difficulty in understanding the category of the cues. Given this possibility, PM accuracy for this task is likely a poor measure of the effects of focality.

A follow-up analysis was conducted based on subjects' responses for how they encoded the PM task instructions; experimenters recorded whether subjects thought they encoded the PM task instruction either by thinking of specific exemplars (e.g., wall, roof, floor, etc.) or as a general category (i.e., a part of a building). This measure allowed for separation of specific exemplar vs. general category encoding subjects when analyzing across focality conditions. If a subject encoded a non-focal PM task instruction (e.g., respond to a word with two of the same vowels in a row) in terms of specific examples (e.g., roof, door, floor, etc.), a non-focal task could have become more focal in nature. In this case, subjects might have encoded specific exemplars and spontaneously retrieved the intention to respond when a PM cue was encountered rather than keeping the instruction in mind and monitoring for the PM cue (Scullin, Dasse, Nguyen, & Lee, 2015). Therefore, subjects' responses for whether they encoded categories as specific examples (i.e., category exemplars) or general categories were assessed.

In the focal condition, subjects who encoded specific exemplars had higher accuracy (n = 22, M = 0.47, SD = 0.41) than those who encoded as general categories (n = 56, M = 0.40, SD = 0.42), but this difference was not significant, $t(76)$ = 0.68, d = 0.17. In the non-focal condition, subjects who encoded specific exemplars had higher accuracy (n = 20, M = 0.57, SD = 0.45) than those who encoded as general categories (n = 58, M = 0.53, SD = 0.41), but this difference was not significant, $t(76)$ = 0.29, d = 0.09. The pattern of PM accuracies between specific exemplar and general category encoding styles was consistent with predictions but non-significant. Therefore, it is unclear whether encoding styles (i.e., specific or general category) can affect performance along with the focality of the PM task. However, these results could be due to the imbalance in sample sizes for the two groups. Because this was a self-report measure presented before undergoing the PM task, subjects may have responded without fully understanding the question; subjects may have naively answered that they encoded the PM task instruction as a general category even though they ended up thinking of specific examples during the PM task. This would explain why there were many more subjects in both conditions that reported that they encoded the PM instruction as the general category rather than specific examples. Given the inconsistency of these results with the inquiry, no further analyses were pursued for how subjects encoded the PM tasks.

Syllables Task Analyses

For the Syllables task, 7 subjects' data were excluded from analysis due to poor performance. Focal condition subjects were predicted to have superior PM performance than the non-focal condition. For this task, results for both PM accuracy (see Figure 3) and first PM response (see Figure 4) were consistent with predictions: Subjects in the focal condition (n = 79, M = 0.77, SD = 0.30) were significantly more accurate on the PM task than those in the non-focal condition (n = 76, M = 0.46, SD = 0.38), $t(152)$ = 5.61, d = 0.91, and those in the focal condition (n = 79, M = 0.86, SD = 0.35) responded accurately to the first PM target significantly more often than those in the non-focal condition (n = 75, M = 0.53, SD = 0.50), $t(152)$ = 4.72, d = 0.76. A lack of a difference in baseline RT scores was also confirmed: the focal condition (n = 79) participants' baseline RTs (M = 1479.11, SD = 599.57) were not significantly different from the non-focal condition (n = 76) participants' (M = 1524.27, SD = 557.05), $t(152)$ = 0.48, d = 0.08. This result warranted calculation and analysis of the RT difference scores (i.e., PM block RTs minus baseline RTs; see Figure 5). The RT difference score analysis results were also consistent with predictions and those from the categories task presented in the previous section: RT difference scores for the non-focal condition (M = 333.44, SD = 426.43) were significantly higher than those in the focal condition (M = 50.28, SD =

295.67), $t(152) = 4.81$, $d = 0.77$. Overall, accuracy on the PM task embedded in the Syllables task was as expected in terms of the focality predictions consistent with the MP view and past results. Thus, PM performance measures (i.e., PM accuracy and PM cost) for the Syllables task were the focus of further analyses.

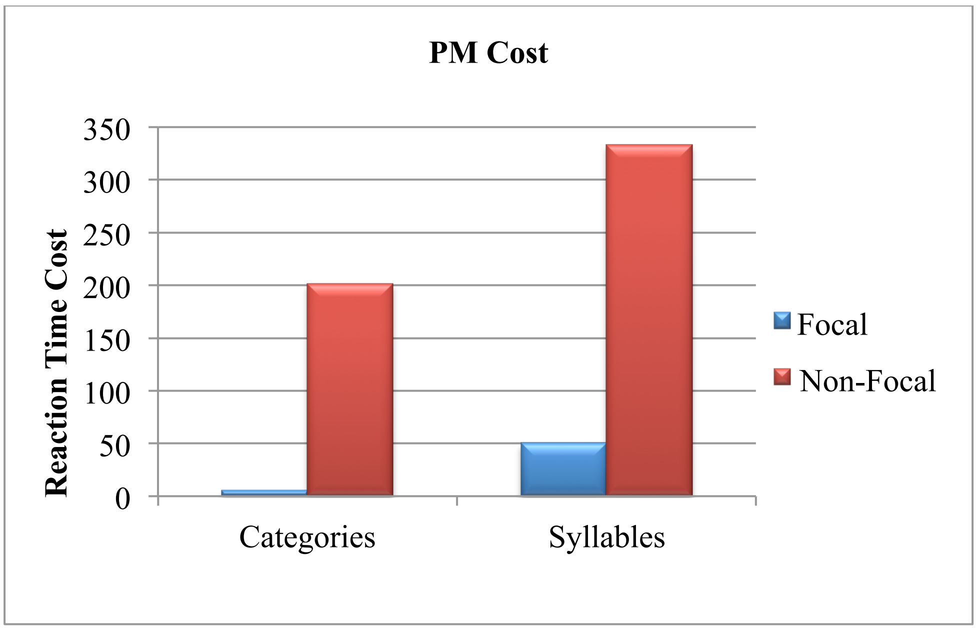

Figure 5. PM Cost. RT difference scores (i.e., PM Cost) across focality conditions for Syllables and Categories tasks.

EF Tasks Analyses

Performance on the Simon Spatial Stroop task and the Color-shape task (CS) were examined to test EF facets of inhibition and task-switching, respectively. For the Simon and Spatial Stroop (SS) task, one subject's data were excluded due to poor performance (i.e., less than 70% accuracy). RTs from Simon and SS trials were analyzed separately as measures of inhibition. Subjects had to execute congruent trials faster on average (i.e., lower RTs) than incongruent trials for these tasks to be considered measures of inhibition (i.e., inhibiting the incongruent aspect of the trial resulting in higher RTs). The results confirmed this expectation: Simon congruent trial RTs (n = 160, M = 615.58, SD = 112.47) were significantly faster on average than incongruent trial RTs (n = 160, M = 633.95, SD = 108.60), t(159) = 3.97, d = 0.17, and SS congruent trial RTs (n = 160, M = 597.07, SD = 112.62) were significantly faster on average than incongruent trial RTs (n = 160, M = 663.59, SD = 127.58), t(159) = 13.87, d = 0.55. Subsequently, RT difference scores (i.e., incongruency cost; congruent minus incongruent trials) were calculated and compared across inhibition tasks. The SS incongruency cost (n = 160, M = 66.52, SD = 60.67) was significantly larger than the Simon incongruency cost (n = 160, M = 18.37, SD = 58.56), t(159) = 7.84, d = 0.81. This finding indicates that perhaps the SS component may have required more inhibition than the Simon component. Therefore, SS incongruency cost was chosen as the primary measure of inhibition for further analyses concerning focality conditions.

Task-switching was measured by comparing RTs on baseline trials for the Color-only (i.e., color trials) and Shape-only (i.e., shape trials) phases against the CS test (i.e., switch trials) phase. Task-switching in this task is measured as higher RTs on the CS switch trials than the Color-only and Shape-only trials. Five subjects were excluded from analysis due to poor performance (i.e., less than 70% accuracy). Concerning baseline phases, Color trial RTs (n = 156, M = 687.97, SD = 310.30) were significantly higher than Shape trial RTs (n = 156, M = 598.39, SD = 140.37), t(156) = 3.75, d = 0.37. This was likely due to a practice effect because the color phase was always presented before the shape phase. Given this result, the shape trial RTs were chosen as the baseline counterpart to compare against the CS switch trial RTs, as the practice effect would still be present in the CS switch trials presented later in the procedure. This comparison showed a task-switching cost, such that switch trial RTs (n = 156, M = 838.81, SD = 299.32) were significantly higher than shape trial RTs, $t(156) = 3.75$, $d = 1.03$. RT difference scores between shape and CS switch trials (i.e., task-switching cost) were then calculated and used as the critical measure of Task-switching for further analyses comparing focality conditions.

Further analyses were carried out to investigate the effect of focality on PM performance with EF difference score measures as the covariates to remove error due to EF processes. These analyses looked at the variables of Syllables task PM performance (i.e., PM response accuracy and PM cost) as dependent measures and SS incongruency cost (inhibition measure), and task-switching cost as covariates. If the EF measures could account for slower and less accurate performance in the non-focal condition, then the focality effect should have disappeared in this analysis using these covariates. A MANOVA comparing PM performance measures (i.e., overall PM accuracy, first PM response, and PM cost) across focality conditions was significant, $F(2, 150) = 25.09$, $p < 0.001$, $\eta^2 = 0.33$. Subsequently, A MANCOVA comparing PM performance measures across focality conditions with SS incongruency cost and task-switching cost as covariates still showed a focality difference in PM performance, $F(2,142) = 23.04$, $p < 0.001$, $\eta^2 = 0.33$. This decrease in the F value from the MANOVA indicated that the covariates were accounting for some of the error term, although not enough to eliminate the focality effect between conditions. These findings suggest that EF processes cannot fully account for the focal advantage described in the previous section.

Analyses of Trials Near PM Cue

A supplementary analysis looked at RTs on the 10 trials immediately preceding the PM cues in the Syllables tasks to examine whether monitoring was present when the PM cue was presented in either of the task conditions (i.e., focal or non-focal). Consistent with the MP view, non-focal conditions were expected to produce a higher PM cost for the trials that immediately precede the PM cues due to monitoring. Further, the PM cost should have increased with each subsequent PM cue, indicating dynamic involvement of monitoring behavior, as posited by the DMP view. Therefore, RT differences scores were calculated by subtracting baseline trial RT averages from the average RTs for the 10 trials preceding the PM cue for each of the three PM cues. A 2 (focality) × 3 (first, second, and third PM cue) repeated measures ANOVA examining the RT difference scores revealed a significant main effect of focality, $F(2, 151) = 15.80$, $p < 0.001$, $\eta^2 = 0.09$, and PM cue, $F(2, 304) = 16.95$, $p < 0.001$, $\eta^2 = 0.10$, but the interaction between focality and PM cue was not significant, $F(2, 304) = 1.81$, $p = 0.17$, $\eta^2 = 0.01$. Subsequently, a follow up ANCOVA was conducted with SS incongruency and Task-switching costs as covariates. The EF covariates were expected to account for the focality differences in the RT differences scores (i.e., difference between baseline RT and the 10 trials preceding the three PM cues). Results still showed a significant main effect of focality for the RT difference scores for the three PM cues, $F(1, 144) = 14.64$, $p < 0.001$, $\eta^2 = 0.09$, although Task-Switching cost also explained as significant amount of the variance, $F(1, 144) = 8.59$, $p = 0.004$, $\eta^2 = 0.06$. The main effect of PM cue was again significant, $F(2, 288) = 6.50$, $p = 0.002$, $\eta^2 = 0.04$, and there was a significant interaction with SS incongruency, $F(2, 288) = 6.18$, $p = 0.002$, $\eta^2 = 0.04$. However, the interaction between focality and PM cue was once again not significant, $F(2, 288) = 1.67$, $p = 0.19$, $\eta^2 = 0.01$. These results implicate some involvement of EF processes in the anticipation of a PM cue across focality conditions, which would suggest that subjects might have monitored for the PM cue. Yet EF could not completely account for the focality effect (i.e., MP view) or the presence dynamic monitoring behavior (i.e., DMP view).

Correlation Analyses

Finally, correlations between PM performance and EF measures were conducted to examine relations among the variables to test the primary hypotheses of the study that correlations would be present between PM and EF measures for the non-focal, but not the focal, conditions. Focal and non-focal conditions were analyzed separately. Table 1 shows the correlations for the focal condition. The pattern of correlations was largely as predicted: PM performance measures, with the exception of the Categories PM cost, were not correlated with EF measures. These results are consistent with the MP view that focal PM is less cognitively taxing and therefore would not be correlated with measures of EF cost. On the other hand, the Categories task PM performance for the focal condition, as described in the Categories Task Analyses section, appeared to be idiosyncratic. Contrary to predictions, Categories PM cost and Task-switching cost were correlated, which suggests EF involvement. However, due to the limitations present with this task mentioned above, this result may be due to processes related to interpretation of the Categories PM task.

Further, PM performance measures (i.e., PM accuracy, first PM response, and PM cost) between Syllables and Categories tasks were expected to correlate. Although Categories PM cost was significantly correlated with Syllables PM cost as expected, neither PM accuracy nor first PM response was correlated with the corresponding Syllables PM performance measures. However, these results are again not fully interpretable given that the Categories task's non-focal condition unexpectedly had significantly higher accuracy than the focal condition. These findings further strengthen the notion that the Categories task behaved unexpectedly, rendering its results ambiguous. Overall, the prediction that PM performance would not be correlated with EF measures was confirmed through the Syllables task.

For the non-focal condition, results were expected to replicate Schnitzspahn et al.'s findings: PM performance measures were expected to correlate with EF measures. Contrary to predictions, correlations between PM performance and EF measures were largely absent in the non-focal condition (see Table 2). PM performance across PM tasks was not correlated with either task-switching or inhibition measures with the exception of the Syllables task PM cost: Cost significantly correlated with the SS incongruency cost (i.e., inhibition). However, the correlation was in the negative direction, which would indicate that higher SS incongruency cost was associated with lower PM cost. The additional RT accrued due to inhibiting an incorrect response (e.g., pressing the key corresponding to a downward arrow when the arrow stimulus is pointing upward) when the stimulus is spatially incongruent (e.g., an upward pointing arrow presented below the fixation cross) would then relate to exhibiting less of a performance cost due to the PM task for the Syllables task. That is, inhibition and non-focal PM tasks would impose opposing cognitive loads, which is a theoretically strange and unexpected result. Thus, there is some indication that inhibition processes may be related to non-focal PM but not in the way one would expect. Given that the remaining correlations between PM performance and EF measures were not significant, these findings were inconsistent with the notion that task-switching and inhibition are closely related to non-focal PM performance. This point will be discussed further in the General Discussion.

Table 1

Focal Condition Correlations for PM Performance and EF Measures

	1	2	3	4	5	6	7	8	9
1. Categories PM Accuracy		0.82**	0.23**	0.16	0.05	0.20	−0.10	−0.15	0.05
2. Categories 1st PM Response			0.14	0.19	0.07	0.12	−0.03	−0.08	0.15
3. Categories PM Cost				0.18	0.05	0.35*	−0.07	−0.12	−0.27**
4. Syllables PM Accuracy					0.62**	0.13	0.08	0.18	0.03
5. Syllables 1st PM Response						−0.12	0.07	−0.01	0.05
6. Syllables PM Cost							0.03	0.08	0.09
7. Simon Incongruency Cost								0.02	−0.29**
8. SS Incongruency Cost									0.20
9. Task-switching Cost									

Note: *** Significant at the 0.01 level (2-tailed); * Significant at the 0.05 level (2-tailed).*

Table 2

Non-Focal Condition Correlations for PM Performance and EF Measures

	1	2	3	4	5	6	7	8	9
1. Categories PM Accuracy		0.79**	0.46**	0.36**	0.43**	0.20	−0.15	−0.18	0.03
2. Categories 1st PM Response			0.42**	0.29*	0.40**	0.23	−0.12	−0.12	−0.01
3. Categories PM cost				0.15	0.25*	−0.02	−0.04	−0.03	0.11
4. Syllables PM Accuracy					0.62**	0.37**	0.03	−0.11	0.04
5. Syllables 1st PM Response						0.29*	0.03	−0.14	0.08
6. Syllables PM Cost							−0.14	−0.39	0.16
7. Simon Incongruency Cost								0.32	−0.03
8. SS Incongruency Cost									0.13
9. Task-switching Cost									

Note: *** Significant at the 0.01 level (2-tailed)*; ** Significant at the 0.05 level (2-tailed).*

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Research Problem, Method, and Findings

The MP view (McDaniel & Einstein, 2000) suggests there is a performance advantage (i.e., focality effect) when the ongoing task enables focal processing of the PM cue, whereas non-focal processing of the PM cue may not help in the way of focal processing and require executive attention. The focality effect is suggested to be due to differences in encoding and retrieval of the PM cues: Focal PM tasks may allow for spontaneous retrieval of the PM intention when encountering a PM cue, whereas non-focal PM tasks may require cognitively taxing methods (i.e., monitoring) to remember to respond to the PM cue. Past research (Einstein et al., 2005) has implicated increased involvement of executive control processes (i.e., EFs) in the execution of non-focal PM tasks. Schnitzspahn et al. (2013) employed Miyake et al.'s (2000) framework of EF to test which features of EF may have the closest ties to non-focal PM performance. They found that the EF constructs of inhibition and task-switching may have the closest ties to non-focal PM performance.

The current project aimed to respond to Schnizspahn et al.'s (2013) call for replication with consideration of both Miyake et al.'s (2000) and Diamond's (2013) EF frameworks. Such a theoretically inclusive approach was taken to supplement the developing understanding of EF features' involvement in PM tasks. Thus, the current study adapted Schnitzspahn et al.'s (2013) design, modified it to include focal and non-focal versions of the PM task tested between-subjects, and introduced a different inhibition task (i.e., Simon Spatial Stroop task; Liu et al., 2004).

Focality Effect on Prospective Memory

Consistent with the MP view, participants in the focal condition were predicted to exhibit superior PM performance (i.e., higher PM accuracy, more first PM responses, and lower PM cost) than the non-focal condition during the PM block of the PM tasks. A focal advantage in PM performance was found for the Syllables task, but the Categories task resulted in a contradicting pattern of results (see the Limitation section for further possible causes of this effect). In any case, only the Syllables task's PM performance outcomes were consistent with previous findings supporting the MP view. Accordingly, multivariate analyses revealed a significant effect of focality on the Syllables task's PM performance outcomes with the focal condition showing higher PM accuracy and lower PM cost than the non-focal condition.

Given the focal advantages seen in the results, EF measures were predicted to account for the focality effect, which would have supported the MP view's description of EF involvement in non-focal PM and extended Schnitzspahn et al.'s (2013) claims. EF measures chosen for the analyses represented the performance cost (i.e., RT difference score) incurred in task-switching (i.e., RT difference between baseline and task-switching trial RTs in the CS task) along with inhibition (i.e., RT difference between spatially congruent and incongruent trials in the SS task). These EF difference score measures were used as covariates to remove variability due to EF processes in further multivariate analyses of the effect of focality on PM performance. Although EF measures (i.e., SS incongruency cost and task-switching cost) accounted for some of the variation in PM performance between conditions, the significant focality effect between conditions remained. These results were contrary to the MP view prediction that EFs may fully account for the difference in PM performance depending on the PM task focality.

Executive Function and Prospective Memory

The primary prediction of the current study was a replication of Schnitzspahn et al.'s (2013) findings of features of EF (task-switching and inhibition) correlating with non-focal PM. Specifically, outcomes for task-switching and inhibition measures were hypothesized to correlate significantly with non-focal PM performance outcomes, but not with focal PM performance outcomes. Contrary to the above predictions, most correlations between PM performance measures and EF difference score measures were not significant (see Table 2). The only exception was that inhibition (i.e., SS incongruency cost – RT difference score between spatially congruent and incongruent trials) negatively correlated with Syllables task PM cost (i.e., RT difference score between PM and baseline blocks). One can infer from this result that non-focal PM incurs a converse cost in processing time as inhibiting a spatially incongruent stimulus. This indicates that there may be some processing overlap in non-focal PM and inhibition. Although this result was consistent with the strength in correlation (i.e., Inhibition: $r = 0.32$) between inhibition and non-focal PM found by Schnitzspahn et al. (2013), the direction of the correlation was opposite the positive correlations they found between inhibition and PM performance measures. Although inhibition was not correlated to the PM accuracy measures, PM cost is likely a finer measure of processes involved in PM; one would be more likely to see correlations between measures of performance cost (i.e., RT difference scores) rather than with a measure of accuracy. Thus, the current results obscure the proposed association between inhibition and non-focal PM.

Task-switching cost was not correlated to any of the PM performance measures, which is contrary to the prediction derived from Schnitzspahn et al.'s (2013) findings. Thus, in the current study there was no indication of task-switching's involvement in non-focal PM performance. This finding was particularly unexpected since the same task-switching task (i.e., the CS task) was used by Schnitzspahn et al. and they found it to significantly correlate with PM performance.

In adherence to the MP view, absence of significant correlations between PM and EF performance measures was predicted for the focal conditions. Accordingly, the Syllables task focal PM performance measures did not correlate with EF difference score measures. This result is consistent with the MP and DMP (Scullen et al., 2013) views' proposal of a cognitively less taxing process (i.e., spontaneous retrieval) being involved in focal PM tasks.

Implications for Prospective Memory Frameworks

Considering the PM frameworks previously discussed, the findings of the current study were most consistent with the MP view (McDaniel & Einstein, 2000), and possibly the DMP view, as opposed to the PAM view (Smith, 2003). The PAM view suggests that embedding a PM task within an ongoing task (i.e., a dual-task paradigm) would result in a cost to PM performance compared to when the ongoing task is done by itself. The MP view, on the other hand, suggests that when the PM cue is focal to the ongoing task, no such cost in performance is incurred. The current study supported this focality effect posited by the MP view such that focal condition participants did not show much of a cost (i.e., RT difference between baseline and PM task blocks), whereas non-focal participants exhibited a significant cost (see Figure 5). This finding also fits the DMP view (Scullen et al., 2013), which presents an interesting alternative to the MP view. The DMP view proposes a focal effect but does not attribute the focal advantage to spontaneous retrieval exclusively. Instead, PM performance is considered a product of various processes being dynamically recruited, activated, and or deactivated across longer time scales as may be seen in natural settings. For instance, PM intention could be spontaneously retrieved after a long delay (e.g., day, week, month, etc.) and trigger monitoring for the PM cue. Thus, one could conceivably assess whether features of EF are differentially involved across different time scales of a PM task. However, the current project had limited time and resources for data collection, which constrained each study to a 3 min maximum delay for the PM tasks. Moreover, the results of the analyses of the RT of the 10 trials prior to the PM cue did not support the dynamic interplay of processes predicted by the DMP view. Therefore, the current study's design did not allow for a thorough assessment of the DMP view.

Prospective Memory Retrieval

MP, PAM, and DMP views critically disagree on how encoded intentions are successfully retrieved and acted upon after a delay. The MP view suggests that intentions can be spontaneously retrieved when PM cues are encountered in focal PM tasks, whereas non-focal PM tasks require a cognitively taxing method of retrieval such as monitoring for the PM cue. The PAM view suggests that preattentional processes are activated when the intention is encoded, and these processes prompt successful retrieval of the intention. In this scenario PM is restricted to one's conscious capacity (i.e., by monitoring for upcoming cues), thus retrieving a previously encoded, delayed intention could not happen automatically (Smith, 2003; Smith et al., 2007). The DMP view proposes a more dynamic theory where spontaneous processes may remind one of the PM task and trigger one to strategically monitor for some time after that realization. Successful PM performance can therefore result from a dynamic interplay of processes.

The current study found that focal condition participants in the Syllables task accurately responded to significantly more first PM cue trials and had significantly higher overall PM response accuracy compared to non-focal condition participants. The focal advantage found in the current study along with previous studies (Einstein et al., 2005; Scullen et al., 2010) provides a strong case that PM retrieval can be enhanced or hindered by the focality of PM cues, which favors the MP and DMP theories that allow for automatic retrieval of delayed intentions in focal PM tasks. However, this finding alone cannot discount the possibility of preattentional processes.

In the MP view, focal PM tasks do not require cognitively taxing behaviors (i.e., monitoring) for successful PM performance. Conversely, EF (i.e., task-switching and inhibition) has been shown to predict non-focal PM performance (Schnitzspahn et al., 2013). Therefore, one would expect focal PM task performance measures to be unrelated to measures of task-switching or inhibition costs. The current study indeed found no correlation between focal condition PM performance measures (in the Syllables task) and EF cost measures (see Table 1). However, the only significant relation found between non-focal PM performance and EF cost measures (see Table 2) was a negative correlation between inhibition and PM cost (i.e., RT difference score between baseline and PM blocks). EF cost measures, when used as covariates, also could not account for the variation in PM performance across focality conditions. To further investigate potential monitoring immediately before the presentation of each PM cue, in the current study I looked at the RT difference between the 10 trials preceding each PM cue and baseline trials. The effect of focality was significant, however, no interaction was found between focality condition and which PM cue was considered in the 10-trial RT difference scores. EF cost measures again could not fully account for the focality difference. These findings not only obscure the role of EF in non-focal PM, but also do not indicate whether EF activation can be attributed to the conception of monitoring in either the MP or PAM views.

Limitations

The current study presented some limitations that affected results interpretations. Participants in the focal condition of the Categories task performed less accurately on the PM task (see Figure 3) and were significantly worse at responding to the first PM cue compared to the non-focal condition (see Figure 4). Strangely, the focal condition still showed a significantly lower cost in RT due to the PM task (see Figure 5). These findings may have been due to the focal PM task being more demanding than the non-focal task. Subjects had to interpret a category phrase (e.g., “a part of a building”) and look for words (e.g., floor, roof, etc.) that fit that category, which was focal to the ongoing task of judging whether a word fit in the category described by the left hand phrase. There is a possibility that the category phrase was interpreted in a manner that made the task more difficult. For instance, the category phrase could have been confusing enough that the intention was not well encoded and led to overlooking PM cues. This would explain why the focal PM condition performance was less accurate in this task. Conversely, the non-focal task (i.e., respond to words with two of the same vowels in a row) may have been less confusing to interpret and easier to recall. Whatever the case, these results were ambiguous enough that the task's measures were excluded from follow up analyses. Note that the current study took descriptive category phrases for ongoing and PM tasks directly from the word norms (Van Overshelde, Rawson, & Dunlosky, 2004) that the stimuli were chosen from. There is a possibility that the PM target category (i.e., a part of a building) may have been more difficult to interpret than other simpler categories (e.g., a type of fruit).

Another limitation was the disparity in RTs across color-only and shape-only blocks of the CS task. Subjects took longer on average to respond to the color-only trials than the shape-only trials. This was likely due to a practice effect and the fact that the color-only block always came before the shape-only block. Researchers would be wise to counter-balance the order of these blocks between-subjects.

Conclusions

In the current study, I attempted to gain a better understanding of how event-based PM is processed cognitively. The findings in this study were not entirely consistent with Schnitzspahn et al.'s (2013) findings, especially since there was no indication of task-switching's association to non-focal PM. However, there was some indication of a role for inhibition in non-focal PM performance, although opposite direction than expected. Critically, among the inhibition measures, the SS task measure (i.e., SS incongruency cost) had more definitive findings than the Simon task measure (i.e., Simon incongruency cost). This finding is important given that the task was chosen based on recommendations in Diamond's (2013) EF framework that suggests that SS tasks are a purer measure of inhibition than Simon tasks. Future studies may look to further investigate this distinction by presenting SS and Simon tasks separately rather than in the hybrid task used in the current study. Note, the current study and Schnitzspahn et al.'s study were conducted in different countries and sampled from different age groups: Schnitzspahn et al. looked at older adults while the current study looked at undergraduate university students. Also, both studies based predictions and designs on the MP view; future studies should consider a design that would accommodate the DMP view, given it is an extension of the MP view. Overall, the current study shows that more studies of this kind need to be conducted in order to clarify the role of EF in event-based PM performance differences based on task focality.

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