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Meta-Prospective Memory Accuracy in Healthy Older Adults Compared to Older Adults with Suspected Mild Cognitive Impairment (sMCI)

by

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List of Abbreviations

DSM	Diagnostic and Statistical Manual of Mental Disorders
EF	Executive Function
GMT	Goal Management Training
iADLs	Instrumental Activities of Daily Living
MCI	Mild Cognitive Impairment
MPM	Multiprocess Model
PAM	Preparatory Attentional and Memory process
PFC	Prefrontal Cortex
PM	Prospective Memory
PPE	Personal Protective Equipment
sMCI	Suspected Mild Cognitive Impairment

Abstract

This study examined if the relationship between generalized and task-specific appraisals of one's prospective memory (PM) and actual PM performance (i.e., meta-PM accuracy) differed between healthy and suspected Mild Cognitive Impairment (sMCI) older adults. Older adults recruited included 50 healthy and 31 sMCI participants from the community and an outpatient neuropsychology clinic. Data collected consisted of self-reported appraisals and task-specific predictions/postdictions of PM performance, objective PM performance, and executive functioning (EF). The sMCI group had significantly lower scores on objective PM tasks and EF measures related to simple and complex task-switching. Moreover, sMCI participants displayed lower task-specific meta-PM accuracy in the direction of overconfidence, but they displayed relatively equivalent generalized meta-PM accuracy when compared to the healthy group. Notably, the sMCI group's task-specific inaccuracies became non-significant in relation to the healthy group on the final long-term PM tasks after exposure to metacognitive reflection on the first two PM tasks. Despite lower scores on EF measures, EF performance did not explain task-specific meta-PM differences between groups beyond neurocognitive status, utilizing hierarchical regression. Based on these data, sMCI patients may be better assisted by metacognitive calibration strategies, EF protocols, and the implementation of general compensatory memory strategies as targets for early intervention and prevention of neurocognitive decline.

Keywords: prospective memory, metacognition, aging, mild cognitive impairment, executive function

CHAPTER ONE
Prospective Memory

Prospective memory (PM) is a sub-facet of memory that entails having to remember an intention in the future (Harris, 1983; Kvavilashvili, 1992). This cognitive ability is vital to our success in several domains that aid our ability to develop, pursue, and maintain autonomy, including occupational, social, and physical aspects of functioning. For instance, PM is highly implicated in medication adherence, and its working condition impacts our health and can ultimately determine if we live or die. Unfortunately, PM is subject to failure in a number of circumstances, particularly in older adulthood (Rabin et al., 2014). Given the importance of successful PM function, researchers have facilitated our understanding of these processes and highlighted potential areas for intervention. However, the current literature does not address metacognitive considerations for PM intervention among older adults with and without memory decline, or whether executive function (EF) may serve as a mediating mechanism to these processes.

There are four intention phases necessary for successful PM-task completion and the current study prioritized the fourth phase, intention execution. The four intention phases of PM consist of the following: intention formation, intention retention, intention initiation, and intention execution (Ellis & Kvavilashvili, 2000; Martin et al., 2003). The intention formation phase is the moment in which the intention is consciously planned, such that this phase represents the intention-related stimuli exposure (e.g., the doctor says one should take their medications twice daily; Kliegel et al., 2002). The second phase, intention retention, is the period in which the intended task is retained in memory while one goes about other activities in their day (Kliegel et al., 2002). According to Kliegel and colleagues (2002), the third phase, intention initiation, begins at the initiation of intention execution (e.g., one walks into the bathroom to get their medication). Finally, intention execution, the fourth and final phase of PM task completion, is the actual execution of the intended action based on the original intention plan (e.g., taking the medication; Kliegel et al., 2002). When the four phases are executed, one is thought to have intact PM ability. The current study focused on the final phase of PM, intention execution, as it is the most observable and measurable PM phase; however, understanding of intention phases highlights the complexity of PM as a memory process, and why PM is susceptible to decline in older age.

Successful PM may further be impacted by the type of PM stimuli and the type of environment in which the PM task is to occur. Researchers have distinguished between two categories of stimuli in the intention phases: time-based and event-based stimuli (Einstein et al., 1995; Einstein & McDaniel, 1990). Time-based stimuli require individuals to conduct the intended task at a specific time, such as taking a medication at 5 o'clock. Event-based stimuli rely on the PM task to be coupled with a specific event, such as taking a medication with a meal. Previous research has found that older adults often rely on event-based stimuli, such as close others serving as a reminder, resulting in a lower probability of successful PM execution, with more immediate health-related dangers (Costa et al., 2011). Additionally, some studies have shown that older adults perform more poorly on *laboratory*-based PM tasks but perform better than younger counterparts on *naturalistic*-based PM tasks, suggesting PM initiation and execution may rely on different task-environments (Costa et al., 2011). PM has also been found to be impaired in healthy older adults on time-based tasks, above and beyond that of event-based tasks (Henry et al., 2004). However, healthy older adults have outperformed younger adults in naturalistic-based PM settings compared to laboratory-based settings (Henry et al., 2004). Therefore, although event-based cues are more unreliable in one's environment, research shows that PM tasks that occur in naturalistic settings and are dependent on event-based stimuli have a better chance of success in execution among the older adult population, though it is unclear if these event-based, naturalistic measures are either an under- or over-estimation of older adults' true PM abilities. Given older adults tend to anchor their PM tasks to events in naturalistic settings, there is more opportunity for failure when those events do not occur or something within the naturalistic setting changes. For example, if an older adult has paired their medication routine with a call from her daughter, and her daughter does not complete the call, it is likely that the medication routine could be taken late or could be forgotten altogether. Thus, group differences in PM performance could depend on the stimuli and context in which it was studied. Given these findings, the current study utilized a measure that captured event-based, time-based, naturalistic, and laboratory conditions to provide a holistic understanding of PM function when comparing healthy older adults to older adults who exhibit cognitive impairment.

Prospective Memory in Older Adults

Older adults are known to display a greater frequency of PM failure (Rabin et al., 2014), resulting in potentially life-threatening implications, such as inadequate medication adherence, among other social, occupational, and physical difficulties. More specifically, the older adult population is likely to have numerous health diagnoses obtained from a variety of providers (e.g., primary care physicians, cardiologists, etc.), resulting in an assortment of medications that must work in combination and in isolation to address each diagnosed medical condition (Wooten, 2015). The management of these medications proves difficult, even for cognitively healthy older adults, as the number of older adults admitted to the hospital for inappropriate medication use continues to increase in the United States (Wooten, 2015). Therefore, research regarding PM processes in older adults is essential to informing appropriate management of medications and other potentially dangerous tasks associated with PM failure.

Although current research has contributed to our understanding of PM processes in normal aging, research regarding PM processes in the context of abnormal neurocognitive decline is essential given the likelihood of progressing to a form of cognitive impairment tends to increase with age (Farias et al., 2009). Neurocognitive decline further has been shown to impact several elements of independent activities of daily living (iADLs), given most iADLs require successful PM function (Rabin et al., 2014). Therefore, studies focused on older adults with Mild Cognitive Impairment (MCI) are crucial for understanding PM decline, as this population generally displays intact iADLs yet significant complaints of PM failure. Moreover, an MCI diagnosis often precedes the onset of a full dementia diagnosis (also known as Major Neurocognitive Disorder per DSM-5 criteria; American Psychiatric Association, 2013), and is hallmarked by subjective and objective memory impairment that is abnormal for one's age, without significant impairment in iADLs (Petersen, 2004; Schoenberg & Duff, 2011). Considering the features of this population, researchers have found strong evidence that PM is impaired in older adults with MCI (Costa et al., 2011; Spíndola & Brucki, 2011), and that there is no significant difference in PM functioning between those with MCI and those with dementia (van den Berg et al., 2012). More specifically, Van Den Berg and colleagues (2012) posited that PM problems may serve as a marker of future decline to a dementia diagnosis. As a result, the current study examined PM failures in those with *suspected* MCI (sMCI) in an effort to provide better indicators of future decline and to facilitate areas for intervention by addressing whether PM failures in older adults are affiliated with metacognitive function, executive function (EF), or simply impaired objective PM performance.

Researchers have also examined PM strategies that older adults with MCI may employ in order to maintain their function and independence. One group found that those with MCI were more likely to rely on close others as a mechanism of PM retrieval, initiation, and execution rather than to rely on external strategies to aid in PM performance, such as writing a reminder note or setting a notification on a device (J. Crawford et al., 2003). As such, this type of reliance on others has the potential to create burden for others and subtracts from the individual's ability to form new mechanisms of PM cues. Additionally, this type of reliance on others may lead these close others to evaluate their loved one's memory abilities more often than one evaluates their own memory abilities, creating a potential for more objective reports, if formally assessed. Multi-informant memory reports have served as a better estimate of memory ability, showing more substantial correlations with formal objective measures of memory compared to self-reports (Hickox et al., 1992; Sunderland et al., 1984). Given these findings, the proposed study assessed informant-reported PM to examine if there are differences in self- versus other-reported difficulties when compared to objective PM functioning. This study objective aided in the understanding of self-perceived versus other-perceived PM, and provided a guide for intervention and communication about PM problems in older adults with and without memory decline. Previous studies have found that informant-reported impairments of patients' PM abilities are generally more accurate and predictive of future neurocognitive decline, particularly in early Alzheimer's Disease populations, compared to self-reported PM impairments (Hsu et al., 2014). Therefore, the addition of informant reports in this study served as an extension of previous literature by investigating whether informant reports are more accurate in those with less severe neurocognitive decline, such as sMCI.

Metacognition's Role in Prospective Memory

Not only is successful PM important to maintain autonomous living in older adults, but so is the ability to *accurately* judge one's PM. Metacognition, a term coined by Flavell in 1979, is the awareness and thoughts of one's personal cognitions and includes the ability to monitor and control cognitions (Maki et al., 2009). Nelson and Narens (1990) constructed a model of metacognitive activity that describes two levels of any cognitive task: an object level and a meta-level (see Figure 1). Most cognitive tasks occur at the object level, but when one starts to monitor said task, is when the information from the object level is transitioned to the meta-level. It is at the meta-level that one can make judgments about the task at hand to subsequently regulate behaviors or cognitions at the object level. For example, remembering to turn off the oven is a cognition that happens at the object level; however, the monitoring of the remembering to turn the oven off (e.g., "I am good at remembering to turn off the oven, so I don't need a reminder") is related to the meta-level of processing. Similarly, metamemory has been a commonly studied aspect of the metacognition literature and aims to explore one's thoughts and controlled behaviors regarding memory performance. Taken together, appraising one's memory performance is referred to as metamemory monitoring (Nelson & Narens, 1990), which was used in the current study to evaluate differences in meta-PM in older adults.

Metacognitive judgments are crucial to metacognitive monitoring because they affect behaviors exhibited during a specific task, such as a PM task. During PM tasks, metacognitive judgments can determine whether to form an intention, initiate an intention, or execute an intention (Kliegel et al., 2008a). These judgments can be measured through confidence judgments, widely used throughout metamemory research, to assess the level of confidence one feels in their performance on a memory measure (Shimamura, 2008). Regarding PM, one study found that those who performed better on event-based PM tasks believed their PM was under their internal control, as compared to those who performed worse on event-based PM tasks who reported lower beliefs of metacognitive control (McDonald-Miszczak et al., 1999). More generally, Meeks and colleagues (2007) found that individuals have basic awareness of their PM functions but are vastly inaccurate in their predictions of objective PM performance, much like other facets of metacognition (Dunlosky & Lipko, 2007). In their study, their sample was approximately 20% underconfident in their PM abilities, for which the authors suggest could have been an adaptive strategy in an effort to be more accurate in daily PM tasks (Meeks et al., 2007). However, Meeks and group (2007) argued that the accuracy component is likely a large predictor of PM success, because those with accurate perceptions of their PM abilities are more likely to choose appropriate strategies for intention formation, initiation, and execution, whereas those with lower awareness may be more susceptible to PM failure. Therefore, if older adults with and without memory impairment are able to form accurate representations of their PM ability, they may be more likely to successfully execute a PM task.

Prospective Memory & Executive Function

A theoretical debate has continued in the literature regarding the cognitive processes underlying the initiation and execution of the intended action in PM. The first well-known theory of PM is the Preparatory Attentional and Memory (PAM) process theory, which posits that PM requires attentional preparatory processes for successful intention formation, retention, initiation, and execution (R. E. Smith, 2003; R. E. Smith et al., 2007; R. E. Smith & Bayen, 2004, 2005, 2006). The PAM theory is rooted in the Morris et al. (1977) assumption of transfer appropriate processing. The assumption is that limited cognitive resources must be partially devoted to an ongoing evaluation of the environment (attentional monitoring) and responses in the environment to recognize a target time or event in which a PM task is to occur (R. E. Smith, 2008). Therefore, preparatory attentional processes and continuous attentional monitoring are thought to be engaged during every component of ongoing activities where the PM task is not at the forefront of importance, and the retrospective memory component (remembering things from the past) is engaged upon PM target detection via preparatory attentional processes (Guynn, 2008). These cognitive processes are part of what is called executive function (EF), which includes but is not limited to working memory, set-shifting (i.e., multi-tasking), goal setting, problem-solving, organization, cognitive flexibility, inhibition, and attention (Best & Miller, 2010; Meltzer, 2018; Miyake et al., 2000; Miyake & Friedman, 2012). Given that EF represents a global term for multifaceted cognitive processes that underlie goal-driven behaviors, according to PAM theory, PM relies on one's EF ability.

This is because PAM theory posits that one must attend to ongoing tasks in addition to continuously monitoring the environment for the PM cue, utilizing EF mechanisms of attention, response inhibition when a PM cue is salient, and set-shifting to the PM task.

Other authors have suggested an alternative framework of PM that encompasses Smith's (2003) attentional monitoring component, with the addition of the possibility of spontaneous retrieval and automatic processing components (Einstein & McDaniel, 2005; Kliegel et al., 2002; McDaniel et al., 2004). This framework is referred to as the Multiprocess Model (MPM), which posits that PM retrieval may depend on the context in which a PM intention is formed and executed, relying on automatic processes in certain situations and strategic processes in others (Guynn, 2008). For example, in the MPM framework, attentional monitoring has been implicated when the PM task is of high importance, when the PM target is not salient, when the connection of the target event and the PM task has not been established prior to intention formation, and when the focus of attention in the ongoing task does not align with the focus of attention for the PM target (Guynn, 2008). Therefore, EF also plays a large role in the MPM, as attentional monitoring and set-shifting are largely implicated in PM execution and task completion. Thus, the point of theoretical divergence between the Multiprocess Model and the PAM process theory is that PAM requires constant attentional monitoring, utilizing substantial cognitive resources; whereas, the MPM does not require continuous attentional monitoring, as it requires spontaneous retrieval and is dependent on various task factors. Both theories highlight the need for functional attentional components of EF to be successful in PM performance; however, the MPM directly accounts for additional EF mechanisms, such as inhibition and set-shifting, that are not explicitly accounted for by

PAM theory. As such, the current study is in alignment with the MPM and hypothesized that EF aides in the explanation of significant group differences in PM performance, which would further support the MPM as a better theoretical explanation of PM processes, particularly in populations with neurocognitive decline.

The development of EF is necessary for successful completion of tasks involving PM (McDaniel et al., 1999), given that PM is thought to develop alongside frontal lobe functions and EF is largely dependent on the frontal lobe (Kliegel et al., 2008b). Best and Miller (2010) found that EF matures alongside frontal cortex development and is the first area of decline in older adults (Cepeda et al., 2001; De Luca et al., 2003; Zelazo et al., 2004). Additionally, those with MCI display higher bilateral frontal lobe atrophy rates compared with healthy older adults, contributing to the decline of EF in this population (McDonald et al., 2012). Therefore, significant age differences have been apparent in intention formation, intention initiation, and intention execution phases of PM, which generally rely on executive control processes (Kliegel et al., 2002, 2004; Martin et al., 2003). As such, it could be argued that the decline of EF may substantially contribute to a decline of PM performance in older adults with and without neurocognitive decline.

Given that aspects of memory function have been correlated with the decline of EFs in later development (Cepeda et al., 2001), it is critical to examine the role of EF as an indicator for clinical levels of memory and metamemory impairment. Previous research found that both subjective memory reports and objective memory performance have been mediated by EF (Mäntylä et al., 2010), and other authors have discovered that deficits in EF were found several years prior to a clinical diagnosis of Alzheimer's Disease with a large effect (d = 1.07; Bäckman et al., 2005). Therefore, the investigation of EF's role in declining PM processes in older adulthood provides an important target area for intervention. More specifically, the current study investigated the role of EF in meta-PM accuracy with objective PM performance. Knowledge about whether deficits in EF may relate to one's generalized and task-specific perceptions of PM ability has the potential to inform clinical interventions at the level of objective PM through memory strategies, meta-PM processes through metacognitive calibration/awareness training, or EF through goal management practices.

In addition to general memory decline, EF has also been found to surpass age in the prediction of PM function on more complex tasks (Martin et al., 2003), meaning individuals with impaired EFs are more likely to display difficulty with PM performance. Previous research has suggested that the inhibition and set-shifting components of EF tend to be the most prominent factors in successful PM (Schnitzspahn et al., 2013). Kliegel and colleages (2008b) tested a complex PM task across the developmental lifespan (e.g., testing children, young adults, and older adults) in which the researchers manipulated whether individuals were required to interrupt an ongoing task in an effort to switch attention to the PM task, which relied on the inhibition component of EF. They found a replication of the inverted U-shaped developmental trajectory across groups, with children and older adults displaying the greatest amount of difficulty on intention execution when ongoing tasks were interrupted (Kliegel et al., 2008b), which implies that inhibition may be widely implicated in successful PM function. As such, PM difficulties have been found in individuals with disorders that tend to rely heavily on EF processes near the end of the developmental lifespan (e.g., dementia, mild cognitive impairment, etc.; Schmitter-Edgecombe et al., 2009). Given these findings, the current study proposed that EF would partially or mostly account for the relationship between groups' meta-PM accuracy differences, above and beyond neurocognitive status alone.

In alignment with study aims, previous researchers have discovered a significant relationship between metacognitive processes and PM, and they have found that EF plays an important role in these processes. As the Nelson and Narens (1990) model implies, metacognitive monitoring maintains a top-down process of information regulation, which is thought to be heavily influenced by EF processes, such as task-switching, attention, and working memory (Shimamura, 2008). As such, Shimamura (2000) proposed the dynamic filtering theory to account for neural mechanisms implicated in Nelson and Narens (1990) framework, such as prefrontal cortex (PFC) involvement with posterior cortical circuits. Therefore, using this theoretical framework, object-level information is dispersed in posterior cortical regions and is then subsequently controlled in PFC regions by meta-level processors. Thus, Shimamura (2000) posited that metacognitive control is implemented by PFC functions via selection and suppression of appropriate and inappropriate signals (i.e., dynamic filtering). As such, dynamic filtering theory then provides evidence that metacognitive control and metacognitive monitoring of PM processes are affected by normal age-related decline and impaired neurocognitive functioning at a circuitry level (i.e., in those with dementia) due to the decline in EF capacity (discussed above), which is controlled by neural networks associated with the PFC and posterior cortical regions (Gilbert & Burgess, 2008). Moreover, Mäntylä and colleagues (2010) found that participants who reported more PM complaints displayed poorer performance on EF measures, suggesting a link between metacognitive processes and EF processes. Furthermore, they found that objective memory performance was significantly related to EFs (Mäntylä et al., 2010), meaning if there is a link between metacognition and EFs in addition to a relationship between EFs and memory performance, it is likely that EF has the potential to influence both metacognitive processes and successful PM performance, making it a potential target for intervention in older adults.

Aims of the Current Study

The purpose of the current study was to investigate if differences exist between healthy older adults and those with sMCI in meta-PM accuracy as measured with both generalized perceptions of PM and task-specific judgments of PM compared with objective PM performances. The current study was a replication and extension of Thompson and colleagues (2015) work, in which the researchers compared older adults with cognitive impairment (MCI and dementia) to older adults who are healthy on self-report and performance-based PM measures. Thompson and group (2015) also looked at informant-report differences in these populations. They specifically aimed to compare MCI, dementia, and healthy older adults on self- and informant-rated versions of prospective and retrospective memory function, while they further investigated the association between self- and informant-reported symptoms with actual PM performance. Their group collected data on 138 participants between the ages of 64 and 92 and utilized the self- and proxy-versions of the Prospective and Retrospective Memory Questionnaire (PRMQ), the Mini Mental Status Examination (MMSE), and an objective measure of PM, the Virtual Week Test (Thompson et al., 2015). They found that the dementia group performed significantly more poorly on the Virtual Week Task compared to the MCI group and controls, and the MCI group also performed significantly worse on this task than controls (Thompson et al., 2015). Self- and informant-reports were not significantly different between all three groups, but findings indicated that the correlation between self-reported PM and objective PM performance was not significant for any of the groups, meaning that all groups were inaccurate (Thompson et al., 2015). Results of the study were in opposition to previous findings in which informant reports of PM were more highly correlated with actual performance on neurocognitive measures (Hsu et al., 2014). Given these mixed findings between Thompson 's (2015) group and Hsu's (2014) group, the hypotheses for the current study align more with that of Hsu's (2014) research. Moreover, task-specific accuracy discrepancies using predictions and post-dictions between self-reported PM and laboratory PM tasks have not been studied in the sMCI population, which is how the current study extended Thompson and colleagues' (2015) work. Additional work incorporating the role of EF in metamemory reported that those with EF impairment, such as those with neurocognitive disorders, display worse metamemory accuracy compared to those without EF impairment (Souchay et al., 2003). However, the investigation of the role of EF in generalized and task-specific meta-PM function in the older adult population has yet to be uncovered. This research is essential, because it allows a better understanding regarding PM (e.g., if the failures occur at the meta-level, object-level, or due to EF), which better facilitates individualized targets for intervention, improving functional living for older adults with and without neurocognitive impairment.

Understanding older adults' beliefs about their PM performance, and the accuracy of these thoughts, would provide insight into the areas that could be targeted for individualized treatment. Specifically, if differences exist between generalized meta-PM and objective PM performance and/or task-specific meta-PM and objective PM performance, clinicians would be able to target metacognitive means of calibration to increase overall meta-PM accuracy. If individuals are fairly accurate in their generalized thoughts and predictions regarding their PM performance, then objective PM behaviors could be the potential targets for effective treatment, rather than PM-related cognitions. Additionally, individuals must be able to provide an accurate assessment of their functioning before the regulation of behavior can occur in treatment; thus, understanding the ways in which older adults with sMCI view their generalized PM performance compared with actual PM performance, informant reports, and immediate pre- and post-dictions provides a comprehensive synopsis of the metacognitive accuracy associated with PM. The measurement of predictions and postdictions in PM is necessary for a number of metacognitive regulation reasons. Specifically, predictions provide a measurement of one's confidence in their ability to complete a PM task, and this will affect regulation of behavior (i.e., deciding whether or not to set reminders or use reliable cues; Meier et al., 2011). PM postdictions, which occur after having experience with PM task stimuli, are based on more information, which helps individuals update whether they need to implement changes to behavior to successfully accomplish PM tasks in the future (Correa et al., 1996). Therefore, measuring both predictions and postdictions in this study provides two measures of task-specific beliefs. Altogether, the set of measures employed in the current study provides researchers an opportunity to derive whether or not there are areas for intervention at a task-specific level, requiring behavioral modification to ensure successful PM task completion.

Primary Hypotheses

Hypothesis 1 (H_1): The sMCI group would have significantly lower meta-PM accuracy than healthy older adults.

H1a: Self-reports of PM complaints in the sMCI group would be significantly higher than the healthy older adult group, given the literature surrounding perceived self-efficacy in aging memory populations which posits low memory self-efficacy with onset and awareness of memory deficits (West et al., 2008).

H1b: Objective PM task performance in the sMCI group would be significantly lower than the objective PM task performance in the healthy older adults, as previously seen in the literature (Costa et al., 2010).

H1c: Generalized meta-PM will be more accurate for the healthy group compared to the sMCI group, due to the sMCI group displaying more subjective PM complaints (West et al., 2008) and worse objective task-performance in the sMCI group (Costa et al., 2010). Although the sMCI group would display worse objective task-performance compared to the healthy group, the sMCI group's generalized PM beliefs would be significantly underconfident compared to their performance, making them more inaccurate (West et al., 2008).

H1d: Task-specific predictions for the sMCI group were expected to be significantly more overconfident in their predictions compared to the healthy group, whereas postdictions between groups were not expected to significantly differ. This is because predictions are thought to be impacted by impaired EF (Souchay et al., 2003), but there is a tendency for calibration after utilizing the task/activity as a cue of performance (Halamish et al., 2011) for all groups being compared.

H1e: Informant reports of PM problems would be significantly higher in magnitude for the sMCI group compared to the informant reports for the healthy controls, since informant reports often correlate more with actual impairment (Hickox et al., 1992; Sunderland et al., 1984).

H1f: Informants would be more accurate regarding meta-PM performance for the sMCI group compared to healthy controls, given previous findings that informant reports are more predictive of memory performance than self-reports of memory functioning (Hickox et al., 1992; Sunderland et al., 1984).

Hypothesis 2 (H_2): Executive functioning capabilities were expected to be significantly more impaired in the sMCI group compared to the healthy older adult group (Mäntylä et al., 2010).

Hypothesis 3 (H_3): The difference in meta-PM and objective PM performance between groups would be explained by impaired EF capabilities given the substantial literature regarding the significant relationships between EF and objective PM function, as well as metamemory awareness (Mäntylä et al., 2010; Schmitter-Edgecombe et al., 2009; Souchay et al., 2003).

CHAPTER TWO

Method

Participants

Participants aged 60 to 90 were recruited from an established database through the Laboratory of Aging Science and Health, in addition to community-posted flyers and hospital-based referrals from an outpatient neuropsychology office. A total of 99 older adults participated in the study, but 14 participants were omitted from analysis due to incomplete participation or insufficient data. Specifically, one participant had an upset stomach and asked to end their participation early, and two participants experienced technological difficulties with the Wisconsin Card Sorting Test (WCST) program. The remaining 11 participants that were omitted from analysis were omitted during data-screening procedures described below. As a result, 81 participants were included in the final analysis, and all demographic data for the participants can be found in Table 1, below.

Table 1
Participant Demographics

	Full Sample	Healthy	sMCI
Sample Size	81	50	31
Mean Age (*SD*)	71.05 (5.2)	70.30 (5.2)	72.26 (4.9)
Gender			
Men	34	20	14
Women	47	30	17
Self-Identified Race			
American Indian	2	2	--
Asian	1	1	--
Hispanic/Latinx	1	1	--
Mixed	4	4	--
White/Caucasian	73	42	31
Mean Education Years (SD)	15.12 (2.4)*	15.56 (2.5)	14.42 (2.3)
<12	1	--	1
12	15	8	7
13-15	21	10	12
16	23	19	4
17-19	17	10	7
>20	3	3	--
MMSE Performance (SD)	26.56 (3.1)**	28.30 (1.8)	23.74 (2.7)
18	1	--	1
19-24	21	--	21
25-29	8	31	8
30	51	19	1

Note: * denotes $p < .05$; ** denotes $p < .001$; An MMSE score at or below a 24 was used for a cutoff of community-recruited participants; however, some participants meeting criteria for sMCI were recruited with confirmed diagnoses of MCI made by a clinical neuropsychologist and were therefore categorized as sMCI for the purposes of the study.

Participants were divided into respective "healthy" and "sMCI" groups based on scores obtained from a dementia screener, the Mini Mental State Examination (MMSE; Folstein et al., 1975) administered in the laboratory. Participants who scored at or below a 24 on the MMSE were classified in the sMCI category for purposes of the study. Participants could also be considered a part of the sMCI group if they were diagnosed with MCI or a Minor Neurocognitive Disorder after independent evaluation by a neuropsychologist. Given an *a priori* power analysis using hierarchical regression in G-Power, a total of 68 participants (34 in each group) was the target recruitment number to detect a medium effect size when employing a .80 power approximation (Cohen, 2013). Although the targeted recruitment number was 68 and our sample exceeded that number, there were only 31 participants that comprised the sMCI group, while there were 50 participants that comprised the healthy group, given both the community and hospital-based recruitment strategy. For group comparisons using ANCOVA, the *a priori* power analysis indicated a total sample size of 52 (26 participants per group) to detect a large effect as seen in recent older adult literature (Rabin et al., 2014), which our sample exceeded. Individuals who had prior neurocognitive diagnoses, with the exception of Mild Cognitive Impairment (MCI)/Minor Neurocognitive Disorder, were excluded from the study. Participants who were colorblind were also be excluded from the study. All other psychiatric and health-related diagnoses were controlled for during analyses.

Notably, informant data collection was attempted for the entirety of the sample; however, only 58 informants (n = 22 sMCI; n = 36 healthy) completed the required questions for participants, and therefore resulted in an underpowered informant group.

Materials

Mini Mental State Examination (MMSE). The Mini Mental State Examination (MMSE; Folstein et al., 1975) is a commonly used dementia screening when considering neurocognitive diagnoses according to the Diagnostic and Statistical Manual of Mental Disorders (DSM). It is a paper-based exam with a minimum score of 1 and a maximum score of 30. Lower scores generally indicate greater severity of cognitive dysfunction, while higher scores >24 are representative of normal cognitive function. The MMSE has shown adequate sensitivity (0.87) and specificity (0.82; Creavin et al., 2016). For this study, participants that scored at or below a 24 on the MMSE were categorized into the sMCI group for analysis, based on Lopez and colleagues recommended cutoff (Lopez et al., 2005).

Prospective and Retrospective Memory Questionnaire (PRMQ). The Prospective and Retrospective Memory Questionnaire (PRMQ; G. Smith et al., 2000) is a 16-item self-report questionnaire asking about prospective and retrospective memory failures. Participants are asked to rate how often each item happens to them on a 5-point Likert scale ranging from ‘very often’ (5) to ‘never,’ (1), resulting in maximum and minimum total scores of 80 and 16. Crawford and group (2003) reported Cronbach’s alpha values of 0.89, 0.84, and 0.80 for the Total scale, Prospective scale, and Retrospective scale, indicating good reliabilities for all subscales. For our dataset, Cronbach’s alpha values were 0.90, 0.84, and 0.80 for the Total scale, Prospective scale, and Retrospective scale, indicating excellent and good reliabilities, respectively. Further, the PRMQ was developed to capture memory problems related to both normal aging and those with neurocognitive decline, including dementia and as such, has been used in older adult populations (G. Smith et al., 2000). The PRMQ has been used in both older adult and younger adult populations, as well as older adult clinical populations (Crawford et al., 2003; Thompson et al., 2015).

Prospective and Retrospective Memory Questionnaire Proxy (PRMQ-Proxy). The Prospective and Retrospective Memory Questionnaire (PRMQ-*Proxy*; G. Smith et al., 2000) is a 16-item self-report questionnaire asking about prospective and retrospective memory failures, rated by an informant for a participant. Informants are asked to rate how often each item happens to their loved using the same scale as above. Crawford and group (2006) reported acceptable Cronbach's alpha values of 0.92, 0.87, and 0.83 for the Total scale, Prospective scale, and Retrospective Scale, indicating excellent and good reliabilities, respectively. For our dataset, Cronbach's alpha values were 0.96, 0.94, and 0.92 for the Total scale, Prospective scale, and Retrospective scale, indicating excellent reliabilities. When used in older adult populations, G. Smith and colleagues (2000) found that informant reports only differed significantly from older adults with Alzheimer's Disease, whereas caregiver reports were not statistically different from healthy older adults and younger controls.

Royal Prince Alfred Prospective Memory Test (RPA Pro-Mem). The Royal Prince Alfred Prospective Memory Test (RPA; Radford et al., 2011) is a behavioral measure consisting of four items designed to assess objective prospective memory functioning. The measure consists of two time-based and two event-based PM tasks to be completed either within the session or up to a week following the administration. Each item receives a score out of three points, with a maximum score of 12. If a participant recalls the task content correctly at the appropriate time or the appropriate environmental cue, they receive full credit/points for that particular item. Standardized administration of this measure requires adequate time-checking allotment/availability, as well as permission of memory aid use. This measure has shown excellent inter-rater reliability (ICC = .97), and good ecological validity when compared with self-reported prospective memory complaints (Radford et al., 2011). The RPA was also found to have satisfactory alternate form reliability (r = .71; Radford et al., 2011). When tested between controls and neurological patient groups, the RPA revealed significant differences with large effects, indicating that the RPA was able to distinguish healthy controls from those with neurocognitive impairment (Radford et al., 2011).

Wisconsin Card Sorting Test (WCST). The Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) is a measure designed to assess abstract reasoning, perseveration, and set-shifting. The measure is capable of both computer and manual administration, and it consists of four stimulus cards and 128 response cards with different shapes (circle, triangle, star, cross), numbers (one, two, three, or four), and colors (red, blue, green, and yellow). On the computerized version, utilized in the current study, the four stimulus cards are displayed near the middle of the screen and a response card is displayed on the bottom of the screen. The participant is instructed to match the response card to one of the stimulus cards based on a rule of shape, number, or color. The program gives the participant either “correct” or “incorrect” feedback so the participant can adjust the rule they utilize accordingly. After 10 consecutive rule-matches, the sorting principle shifts without warning or the participant's knowledge and proceeds until all three possible sorting categories have been completed twice (Fortuny & Heaton, 1996a). This task has been used in neurocognitive evaluations for impairment to determine more complex set-shifting abilities and complex problem solving in clinical populations, but it has also been used for research in various populations (Fortuny & Heaton, 1996b).

Stroop Color-Word Test. The Stroop Color-Word Test (Golden, 1978) was designed to measure inhibitory control by assessing the ability of the participant to suppress reading a word and instead name the color ink in which the word is printed. The word-sets consist of color names on a card printed in different color ink (incongruent) or color words in the same ink color (congruent). The task requires participants to name the color of ink the words are printed in as quickly as possible. The Mayo Older Americans Normative Studies (MOANS) age- and education-matched norms will be used for scoring (Ivnik et al., 1996).

Trail Making Task (Parts A & B). The Trail Making Task is part of the Halstead-Reitan battery (Reitan & Wolfson, 1986) and measures psychomotor speed and simple set-shifting. For this task, the participant traces numbers and letters as quickly as they are able, and their time as well as number of errors is recorded. The Trail Making Task has demonstrated high forms of reliability between .78 to .92 (Bowie & Harvey, 2006), and it has been found to represent an index of frontal lobe integrity (Reitan, 1958; Spreen & Strauss, 1991). Moreover, it has been used in an abundance of populations ranging from normal cognitive functioning to those with neurocognitive impairment (Bowie & Harvey, 2006).

COVID-19 Personal Protective Equipment. The study was conducted during the middle of the COVID-19 pandemic, and therefore, personal protective equipment (PPE) was used to protect the researchers and the older adults being studied. PPE included surgical face masks, hand sanitizer, and disinfectant. Face masks or coverings were required at all points during data collection for both researchers and participants. Researchers were additionally trained on how to appropriately wear their masks, as well as how to facilitate participant mask-wearing. Moreover, hand sanitizer was readily available during data collection, and it was encouraged to be utilized by both the participant and researcher before, during, and after data collection. Disinfectant was used to sanitize desks, keyboards, doorknobs, pens/pencils, and all hard surfaces with which participants and researchers came into contact. If a participant had their own mask they wanted to wear, they were permitted to do so, as long as it met the requirements of covering their nose and mouth. Surgical face masks were available for participant use if they did not have their own.

Procedure

Prior to presenting to the laboratory, participants were contacted via phone to first answer screening questions related to the study and the COVID-19 pandemic. During the phone screening, they were asked their name, age, number of completed years of education, if they have been diagnosed with any dementia-related illnesses, if they were taking medications to help their memory, if they were color-blind, and if they had COVID-19, had been in contact with someone who had COVID-19, as well as if they had experienced any respiratory symptoms that are similar to that of COVID-19. If participants had any recent exposure or had any symptoms of COVID-19, participants were re-contacted four weeks later to try to schedule when they were healthy and non-contagious.

Upon arrival to the laboratory, participants were instructed to wear a face mask during the entirety of data collection and were encouraged to use hand sanitizer before, during and after data collection as a result of the COVID-19 pandemic. After PPE and sanitation procedures were explained, participants were given a description of the study and had the opportunity to ask questions. Once understanding of procedures was ensured, participants signed all necessary informed consent paperwork. Next, participants were administered the MMSE to determine group status (i.e., healthy vs sMCI). However, due to the nature of the population being assessed and the danger of impaired cognition, it was imperative appropriate resources are given when needed. Therefore, those scoring at or below an 18 out of 30 on the MMSE were utilized for the study but received a referral to their general practitioner for facilitation of a neuropsychological evaluation to discuss cognitive decline, based on Crum and colleagues severity ratings of MMSE scores (Crum et al., 1993).

After screening, participants were then given the first two prompts of the RPA (objective PM measure), which outlined two short-term PM prompts that consist of one time-based task and one event-based task and required completion within the context of the laboratory experience. Participants were required to predict their scores on the first two presented tasks of the RPA, and they were also required to postdict their scores upon task-completion (if completed or if time had expired for these tasks). Next, participants completed a demographic questionnaire which collected information relative to participants' age, gender, ethnicity, race, and years of education to allow for appropriate normative comparisons. After completing the demographic questionnaire, participants were administered the PRMQ to measure their generalized beliefs about their own PM functioning in daily life. Upon completion of the PRMQ, participants completed a memory aid usage questionnaire as an exploratory component beyond the aim of the current project. Next, participants engaged in the EF tasks. Order of EF tasks differed dependent on the time-delay of the RPA tasks, due to the variation of participant response times for the demographics and PRMQ surveys. Therefore, research assistants had to scaffold appropriately. However, the Stroop, TMT Parts A&B, and WCST were all administered during the laboratory time. When necessary, a distractor task (i.e., a verbal fluency task) was implemented to standardize the time-delay of the RPA across subjects. After administration of all EF measures, the researchers presented the final two long-term PM tasks from the RPA. After their presentation, participants were asked to predict their scores for their abilities to complete the tasks.

Once all laboratory tasks were complete, informant contact information was solicited from the participant, as discussed with the participant in the informed consent process. The participant was made aware that the informant will be asked to complete the PRMQ-proxy, either in person or by phone administration. Once the appropriate information was obtained, participants were thanked for their time and were entered into the drawing database for a $50 gift card as compensation for their participation.

Data Analytic Plan

All data was analyzed in R-Studio. Data were screened for accuracy and missingness. Approximately 14 participants had greater than 5% missing data (as described above). These participants were omitted from analyses. All participants with between 0% and 5% missing data were replaced using multiple imputation practices with the MICE feature of R Studio (Tabachnick & Fidell, 2012). The full sample data was not screened for multivariate outliers, as this dataset was expected to encompass participants that would be considered outliers by nature of neurocognitive status; however, analyses aimed at detecting outliers within groups were conducted with Mahalanobis distance scores, and results revealed that there were no outliers within healthy and sMCI groups. Data also met the assumptions for multivariate additivity, linearity, normality, and homogeneity.

Group differences in subjective PM reports on the PRMQ and objective task performance on the RPA were conducted using *t*-tests from the MOTE Package of R Studio with Cohen's *d* effect sizes to provide additional evidentiary support. Additionally, *t*-test calculations were supplemented with Bonferroni correction analyses to control for inflation of Type I error. Group differences in EFs and pre/postdiction performance were also tested using *t*-tests. Generalized meta-PM accuracy for each group was calculated using Pearson correlations between performance on the PRMQ and RPA. To test group differences in generalized meta-PM accuracy, a Fisher's *Z* test was conducted, as it allowed for difference testing between correlations. Task-specific meta-PM accuracy was derived by comprising an overall difference score between predicted performance and actual performance on the RPA. Moreover, a *t*-test with a Bonferroni correction was utilized to test group differences in task-specific meta-PM accuracy. The same statistical methods to determine informant meta-PM accuracies were used.

A hierarchical regression approach was utilized for each individual EF measure to test whether EF accounted for variance above and beyond that of group status alone for differences in task-specific meta-PM accuracy. This was preferential as opposed to a summary EF score acting as a mediator due to each measure's assessment of different domains of EF. This was completed using the Baron and Kenny (1986) four-step approach to mediation. With this approach, we tested if there were significant relationships between group status and task-specific meta-PM accuracy, group status and EF measures, and EF measures and meta-PM accuracy, before testing the overall hierarchical model. Given the relationship between group status and each EF measure, the relationship between task-specific meta-PM accuracy and group status was re-examined to detect if the relationship changed with the addition of the EF variable.

Lastly, ANCOVAs were conducted with covariates of education, psychological diagnoses, psychiatric medications, and total number of health conditions for all main dependent variables of the study. ANCOVA results were compared to ANOVA findings for all DVs to detect if the inclusion of these covariates changed the statistical outcomes.

CHAPTER THREE

Results

Self-Reported and Objective Prospective Memory

As hypothesized in H1a and as displayed in Table 2 below, the sMCI group had significantly higher self-reported PM failures on the overall PRMQ ($t(79) = -2.68$, $p = .01$), in addition to both the prospective ($t(79) = -2.40$, $p = .02$) and retrospective ($t(79) = -2.59$, $p = .01$) memory subscales. Moreover, in alignment with H1b, the sMCI group performed significantly worse on the objective PM measure, the RPA overall score ($t(79) = 5.37$, $p < .001$), and on all four RPA subscales including time-based ($t(79) = 4.03$, $p < .001$), event-based ($t(79) = 3.83$, $p < .001$), short-term ($t(79) = 5.72$, $p < .001$), and long-term ($t(79) = 2.16$, $p = .03$) subscales, with medium to large effects. Notably, *p*-values were unaffected by the addition of Bonferroni correction analyses.

Table 2
Group Means and Standard Errors by Measure

	Healthy (n = 50)		sMCI (n = 31)		
Measures	*M*	*SE*	*M*	*SE*	*d-value*
MMSE	28.30	0.26	23.74	0.48	2.08**
PRMQ Total	37.40	1.25	42.84	1.60	0.61*
PRMQ Prospective	19.94	0.64	22.55	0.92	0.55*
PRMQ Retrospective	17.46	0.70	20.29	0.81	0.59*
RPA Total	9.08	0.26	6.19	0.54	1.23**
RPA Item 1 (short-term, time-based)	2.28	0.13	1.26	0.22	0.98**
RPA Item 2 (short-term, event-based)	1.96	0.16	0.87	0.22	0.93**
RPA Item 3 (long-term, event-based)	2.56	0.13	2.19	0.21	0.36
RPA Item 4 (long-term, time-based)	2.28	0.11	1.87	0.23	0.41
RPA Time-Based (Items 1 &4)	4.56	0.19	3.13	0.34	0.92**
RPA Event-Based (Items 2 & 3)	4.52	0.21	3.06	0.35	0.88**
RPA Short-Term (Items 1 & 2)	4.24	0.21	2.13	0.32	1.31**
RPA Long-Term (Items 3 & 4)	4.84	0.18	4.06	0.36	0.49*
Stroop Word Condition (*T*-scores)	43.60	1.71	34.52	1.75	0.81**
Stroop Color Condition (*T*-scores)	43.50	1.47	34.94	1.34	0.91**
Stroop Color-Word Condition (*T*-scores)	47.56	1.38	40.71	1.47	0.75*
Stroop Interference (*T*-scores)	45.88	1.23	43.03	1.57	0.33
Trails A Time (Raw seconds)	27.84	1.23	33.10	1.96	0.55*
Trails A Errors	0.20	0.09	0.32	0.11	0.19
Trails B Time (Raw seconds)	70.02	3.53	124.32	17.02	0.88**
Trails B Errors	0.52	0.13	1.00	0.29	0.39
WCST Total Errors (*T*-scores)	56.46	1.63	43.97	1.88	1.12**
WCST Perseverative Errors (*T*-scores)	57.78	1.39	47.84	1.98	0.96**
WCST Non-Perseverative Errors (*T*-scores)	52.76	1.93	40.55	2.09	0.94**
WCST Categories Completed (Raw)	5.20	0.22	3.26	0.42	1.03**

Note: * denotes $p < .05$; ** denotes $p < .001$.; MMSE = Mini Mental State Examination, PRMQ = Prospective and Retrospective Memory Questionnaire; RPA = Royal Prince Alfred Prospective Memory Test, Stroop = Stroop Color Word Test; Trails = Trail Making Test; WCST = Wisconsin Card Sorting Test

Generalized and Task-Specific Meta-Prospective Memory Accuracy

To test differences in generalized meta-PM accuracy, the relationship between reported PM failures on the PRMQ and actual performance on the RPA had to be determined utilizing Pearson's *R*. There was a significant correlation between the overall PRMQ score and RPA total score for the full sample ($r = -.38$, $p < .001$) and the healthy group ($r = -.46$, $p < .001$), but not for the sMCI group ($r = -.12$, $p = .51$). All correlations between measures can be seen in Tables 3, 4, and 5. Despite significant group differences on objective PM and higher reported PM failures in the sMCI group, there were no significant differences in generalized meta-PM accuracy between groups (Fisher's $Z = 1.55$, $p = .12$) which is in opposition of H1c.

Table 3
Correlation of Measures for the Full Sample

Measure	1	2	3	4	5	6
1. MMSE	--					
2. PRMQ	-.35*	--				
3. RPA	.61**	-.38**	--			
4. Stroop	.21	.03	.16	--		
5. Trails A	-.29*	.19	-.30*	-.02	--	
6. Trails B	-.59**	.28*	-.44**	-.26*	.46**	--
7. WCST	.43**	-.34*	.23*	.12	-.23*	-.47**

Note: * denotes $p < .05$; ** denotes $p < .001$; PRMQ = PRMQ total score, RPA = RPA total score, Stroop = Stroop Interference score, Trails A = Trails A Time score, Trails B = Trails B Time score, and WCST = Wisconsin Card Sorting Test Total Errors

Table 4
Correlation of Measures for the Healthy Group

Measure	1	2	3	4	5	6
1. MMSE	--					
2. PRMQ	-.31*	--				
3. RPA	.07	-.46**	--			
4. Stroop	.10	.12	.03	--		
5. Trails A	.02	.15	.03	.12	--	
6. Trails B	-.22	.39*	-.16	-.33*	.44*	--
7. WCST	.00	-.21	.06	-.03	-.08	-.43*

Note: * denotes $p < .05$; ** denotes $p < .001$; PRMQ = PRMQ total score, RPA = RPA total score, Stroop = Stroop Interference score, Trails A = Trails A Time score, Trails B = Trails B Time score, and WCST = Wisconsin Card Sorting Test Total Errors

Table 5
Correlation of Measures for the sMCI Group

Measure	1	2	3	4	5	6
1. MMSE	--					
2. PRMQ	-.12	--				
3. RPA	.63**	-.12	--			
4. Stroop	.18	-.00	.16	--		
5. Trails A	-.30	.08	-.39*	-.13	--	
6. Trails B	-.60**	.16	-.35*	-.10	.50*	--
7. WCST	.32	-.29	-.13	.19	-.17	-.42*

Note: * denotes $p < .05$; ** denotes $p < .001$; PRMQ = PRMQ total score, RPA = RPA total score, Stroop = Stroop Interference score, Trails A = Trails A Time score, Trails B = Trails B Time score, and WCST = Wisconsin Card Sorting Test Total Errors

Notably, though, the sMCI group displayed significantly lower task-specific accuracy compared to the healthy group on the overall RPA ($t(79) = -3.89$, $p < .001$), indicating that H1d was met (see Table 6). More specifically, the sMCI group was over-confident on item 1 ($t(79) = -2.74$, $p = .008$) and item 2 ($t(79) = -2.52$, $p = .01$), which are lab-based tasks. However, there were no significant differences in performance on item 3 ($t(79) = -1.71$, $p = .09$) and item 4 ($t(79) = -0.92$, $p = .36$), which are home-based tasks. Also, as hypothesized in H1d, both groups displayed calibration at test, as evidenced by non-significant differences in overall postdiction accuracies ($t(79) = -0.42$, $p = .68$). Similarly to above, *p*-values were unaffected by the addition of Bonferroni correction analyses.

Table 6
Group Means and Standard Errors in Task-Specific Meta-PM Accuracy

	Healthy (n = 50)		sMCI (n = 31)		
Measures	*M*	*SE*	*M*	*SE*	*d-value*
RPA Item 1 Prediction	0.40	0.14	1.06	0.20	0.63*
RPA Item 2 Prediction	0.34	0.20	1.13	0.24	0.58*
RPA Item 3 Prediction	0.40	0.14	0.81	0.21	0.39
RPA Item 4 Prediction	0.60	0.12	0.84	0.27	0.21

RPA Total Prediction	1.74	0.30	3.84	0.48	0.89**
RPA Item 1 Postdiction	0.36	0.12	0.45	0.15	0.10
RPA Item 2 Postdiction	0.08	0.12	0.10	0.20	0.02
RPA Total Postdiction	0.44	0.15	0.55	0.23	0.09

Note: * denotes $p < .05$; ** denotes $p < .001$; Prediction refers to the task-specific prediction accuracy; Postdiction refers to the task-specific postdiction accuracy; RPA = Royal Prince Alfred Prospective Memory Test

Executive Function Group Differences

Differences between groups on all EF measures and sub-scales were tested (see Table 2). H2 was partially supported, with the sMCI group displaying significantly more impaired EFs on certain measures compared to the healthy group. Specifically, the sMCI group displayed significantly worse performance on the Stroop Word ($t(79) = 3.52$, $p < .001$), Color ($t(79) = 4.00$, $p < .001$), and Color-Word ($t(79) = 3.26$, $p = .002$) conditions; however, there were no significant differences between groups on the overall Stroop Interference score ($t(79) = 1.43$, $p = .16$). The sMCI group also displayed slower processing speed based on Trails A raw performance ($t(79) = -2.40$, $p = .02$), but there were no group differences in errors made on this subtest ($t(79) = -0.84$, $p = .40$). Simple set-shifting, as measured by Trails B, was significantly worse in the sMCI group ($t(79) = -3.85$, $p < .001$), but similarly to Trails A, there was no difference in the number of errors made on this subtest ($t(79) = -1.71$, $p = .09$). Finally, complex set-shifting, as measured by the WCST, was significantly more impaired in the sMCI group. This level of impairment was displayed for the total number of errors ($t(79) = 4.91$, $p < .001$), perseverative errors ($t(79) = 4.21$, $p < .001$), non-perseverative errors ($t(79) = 4.13$, $p < .001$), and the total number of categories completed ($t = 4.50$, $p < .001$), all with large effect sizes. Notably, p-values were unaffected by the addition of Bonferroni correction analyses.

The Role of Executive Function in Task-Specific Accuracy

To test whether impaired EF performance explained the group differences in task-specific meta-PM accuracy, three separate two-stage hierarchical regressions were employed with task-specific meta-PM accuracy as the dependent variable, group status as the independent variable, and various measures of EF (WCST total errors, Stroop interference score, and Trails B time to complete) that reflect different EF domains as the additive variables. Prior to conducting the hierarchical multiple regressions, the relevant assumptions of this analysis were tested and met (Tabachnick & Fidell, 2012). Group status was entered first for all models to control for the effects of neurocognitive status with task-specific meta-PM accuracy as the dependent variable. Each EF variable was entered at stage two. The first hierarchical regression indicated that at stage one, Group Status contributed significantly to the regression model ($F(1, 79) = 15.14$, $p < .001$) and accounted for 16% of the variation in task-specific meta-PM accuracy. Introducing the WCST Total Errors variable did not explain any additional variation, resulting in a non-significant change in R^2 ($F(1, 78) = 0.0001$, $p = .99$). The second two-stage hierarchical regression was conducted with task-specific meta-PM accuracy as the dependent variable and Stroop Interference entered at stage two of the regression. Introducing the Stroop Interference variable did not explain any additional variation, resulting in a non-significant change in R^2 ($F(1, 78) = 0.26$, $p = .61$). The third and final hierarchical regression was conducted with task-specific meta-PM accuracy as the dependent variable, and Trails B Time was entered at stage two. Introducing the Trails B Time variable explained an additional 1% of the variation in task-specific meta-PM accuracy; however, this additional variation accounted for still resulted in a non-significant change in R^2 ($F(1, 77) = 1.39$, $p = .24$). Therefore, contrary to H3, measures of EF did not explain the group differences in task-specific meta-PM accuracy above and beyond group status alone. Further, because no significant difference in generalized meta-PM accuracy was displayed between groups, the models were not conducted with generalized meta-PM accuracy as a dependent variable. All hierarchical regression data are reported in Table 7.

Table 7
Summary of Hierarchical Regression Analysis for Group Status and Executive Function Measures Predicting Task-Specific Meta-PM Accuracy

Variable	b	t	sr^2	R^2	ΔR^2
Step 1				.16	.16
Group Status (b_1)	2.10	3.89**	.16		
Step 2				.16	.00
Group Status	2.10	3.38**	.12		
WCST Total Errors (b_2)	0.00	-0.001	.00		
Step 2				.16	.00
Group Status	2.05	3.74**	.15		
Stroop Interference (b_2)	-0.02	-0.51	.00		
Step 2				.18	.01
Group Status	1.82	3.11*	.10		
Trails B Raw Time (b_2)	0.01	1.18	.01		

Note: * denotes $p < .05$; ** denotes $p < .001$; all b estimates are unstandardized.

Covariates for a Complex Population

Given the complex nature of an older adult participant group (e.g., large variation in education, greater number of medical diagnoses, more medication use, etc.), difference tests were re-analyzed using ANCOVA to control for the influence of education, psychotropic medication use, and number of health conditions as covariates. When controlling for education as a covariate for group differences in all dependent variables, there were mostly no significant changes in the data from the original *d*-test outcomes reported previously (Table 2). However, one outcome did differ with ANCOVA analyses controlling for education as a covariate. Previously with ANOVA, processing speed, as measured by performance on Trails A, was significantly different between groups, with the sMCI group performing at a slower pace than the healthy group ($F(1, 79) = 4.64$, $p = .03$). Utilizing ANCOVA with education as a covariate, there were no significant differences between groups in processing speed performance on Trails A ($F(1, 78) = 3.49$, $p = .07$). There were no other changes in dependent variable outcomes between the sMCI and healthy groups when using ANCOVA to control for psychological diagnoses, psychiatric medications, and number of health conditions as covariates.

Heterogeneity in Hospital- Versus Community-Recruited sMCI

Given that the sMCI group was recruited through both a neuropsychology hospital clinic and through community volunteerism, it is important to consider that group differences may be present in the sMCI group dependent on between recruitment avenues. As such, group difference tests were conducted to determine if the hospital-recruited sMCI participants significantly differed from community-recruited sMCI participants on the main measures of the study. Notably, there were 14 hospital-recruited and 17 community-recruited sMCI participants, creating slightly underpowered groups to conduct group difference testing. Even so, using *t*-test analyses, there were significant group differences in which the hospital-recruited sMCI group performed worse on the MMSE ($t(29) = -2.22$, $p = .04$, $d = .80$), RPA total scale ($t(29) = -2.60$, $p = .02$, $d = 0.94$), RPA time-based scale ($t(29) = -4.74$, $p < .001$, $d = 1.71$), and the RPA short-term scale ($t(29) = -2.85$, $p = .008$, $d = 1.03$). However, there were no significant differences between hospital and community sMCI participants on the PRMQ, EF measures, or in generalized meta-PM accuracy, task-specific meta-PM accuracy, and postdiction accuracy.

Informant-Reported Prospective Memory

Finally, informant reports were taken into consideration for this population, given that most older adults presenting in outpatient neuropsychological settings have a collateral report of memory functioning, as anosognosia often accompanies several neuropsychological disorders. A correlation between informant reported PM difficulties on the PRMQ and participant-reported difficulties was conducted to see if reports were similar to one another. There was a significant correlation between PRMQ scores reported by informants and scores reported by participants ($r = .53$, $p < .001$). Also in alignment with participant data and H1e, informants reported significantly more generalized PM failures for the sMCI group compared to the healthy group ($t(79) = -5.69$, $p < .001$, $d = 1.30$) and data were unaffected by Bonferroni correction. To test H1f, several analyses were conducted. To examine the difference between generalized meta-PM accuracy for informants and participants, informants' reports of generalized PM failures on the PRMQ-Proxy were significantly correlated with participants' actual performance on the RPA ($r = -.59$, $p < .001$), with greater memory difficulties reported by the informant, reflecting lower overall performance on the RPA. To test if there was a significant difference between informants and participants in their generalized meta-PM accuracy, a Fisher's Z test was conducted, and results revealed that there were no significant differences between informants and participants regarding generalized meta-PM accuracy (Fisher's Z = -1.61, p = .12), partially in contradiction to H1f.

Although generalized meta-PM accuracy did not differ between informants and participants, task-specific meta-PM accuracy between informants and participants was examined. Informants' task-specific meta-PM accuracy for participants was not significantly different from the full sample ($t(79) = 1.62$, $p = .11$, $d = .37$). However, when data were split to compare task-specific meta-PM accuracy between informants and the sMCI group alone, there were significant differences, in which informants were more accurate (or less overconfident) than participants for task-specific predictions of PM performance ($t(51) = -4.40$, $p < .001$, $d = 1.23$). Notably, the data did not follow the same pattern for the healthy group, wherein there were no group differences ($t(84) = -1.02$, $p = .31$, $d = 0.22$). Notably, p-values were unaffected by the addition of Bonferroni correction analyses. These results conclude that informants may provide more accurate and less overconfident task-specific appraisals of PM performance compared to self-reported task-specific appraisals from those with sMCI.

CHAPTER FOUR

Discussion

This study examined the performance of healthy older adults and older adults with sMCI with regard to several facets of PM and EF, in addition to generalized and task-specific meta-PM accuracy. These results provide unique evidence that healthy older adults and sMCI older adults are equivalent in their generalized meta-PM accuracy but not in their task-specific accuracy. However, in alignment with previous literature, the sMCI group displayed significantly greater self-reported PM difficulties, while performance was significantly lower on objective measures of PM and several sub-facets of EF compared to the healthy group. For task-specific meta-PM accuracy, the sMCI group was significantly over-confident in predicting performance, though they calibrated their postdictions based on their perceptions of their objective performance. Interestingly, despite worse performance on several measures of EF and the significant difference in task-specific meta-PM accuracy between groups, our study revealed that EF did not account for the difference in meta-PM accuracy between groups above and beyond that of neurocognitive status alone. This study was the first to compare both generalized and task-specific meta-PM accuracy between healthy and sMCI groups, as well as the first to examine how different aspects of EF related to task-specific meta-PM accuracy. In doing so, the results suggest that older adults with sMCI have several cognitive processes that could serve as targets for early intervention in hopes of preventing neurocognitive decline and functional difficulties.

A Replication and Extension

Since this study was a replication and extension of Thompson and colleagues (2015) work, a comparison of our findings to this study is essential. Thompson and group (2015) compared older adults with cognitive impairment (MCI and dementia) to healthy older adults on measures of self-reported and performance-based PM and RM, in addition to examining informant-reported differences in these populations. They found their hypothesized spectrum of performance on the objective PM measure, in which the dementia group performed the worst, the MCI group performed in the middle, and the healthy control group performed the best out of all groups. There were significant differences between groups at each level, suggesting that each level of neurocognitive status was distinctly different from one another on PM performance (Thompson et al., 2015). Moreover, Thompson's (2015) group reported no significant differences between self and informant reports of PM function, and there was no significant correlation between self-reported PM, informant-reported PM, and objective PM performance for any of the groups, indicating that generalized meta-PM was inaccurate for all participants, regardless of neurocognitive status. These findings are in opposition to Hsu and colleagues (2014), from which findings revealed high correlations between informant-reported PM with objective neurocognitive performance. The current study addressed a gap in the Thompson and group (2015) research by measuring task-specific meta-PM accuracies, in addition to generalized meta-PM accuracy, and by examining the role of several EFs in generalized and task-specific meta-PM accuracy.

The current study's findings are in alignment with Thompson and colleagues' (2015) study with regard to performance on the objective PM test, wherein our sMCI group displayed significantly worse overall PM performance. The current study's results also echo Thompson and group's (2015) work with regard to informant reports, as our study similarly found no significant difference in informant reports of PM problems compared to participants. The current study and Thompson and colleagues' (2015) study diverge on the findings related to generalized meta-PM accuracy. In alignment with Hsu and group (2014), the current study found that as self-reported PM difficulties increased, objective PM performance decreased. Informant reports followed the same pattern in the current study, wherein greater informant-reported PM problems were significantly negatively correlated with poorer performance on a measure of objective PM. However, this pattern was not detected for the sMCI group, as their data indicated no significant correlation between subjective PM and objective PM performance. Importantly, this lack of correlation for the sMCI group may have influenced the non-significant differences in generalized meta-PM accuracy between participants and informants, as the sMCI group's non-significant data likely reduced the overall participant data for generalized meta-PM, making it more difficult to detect significance between overall participants and informants.

The current study extended Thompson and colleagues' (2015) work by examining task-specific accuracies in meta-PM via confidence predictions and postdictions of objective PM performance. Eliciting task-specific predictions and postdictions of PM performance provided data on confidence levels in participants' ability to complete each PM task and on participants' ability to update their judgments after having experience with PM task stimuli. These task-specific predictions promote regulation strategies when approaching future PM tasks (Meier et al., 2011). For example, an individual should judge if a PM task is considered difficult (predictions) to determine the need for a reminder or reliable cue, providing metacognitive regulation of PM task behaviors and ultimately, PM success. Once a PM task has been either completed or forgotten, reflection upon behaviors related to the PM task (postdictions) aides in updating future strategies when approach similar PM task demands (Correa et al., 1996).

In alignment with hypotheses, the current study found that the sMCI group displayed lower task-specific accuracy compared to the healthy group for the overall measure of PM performance, in addition to performance on the first two items of the objective PM measure. Also as predicted, the lower task-specific accuracy for the sMCI group further trended in the direction of over-confidence, wherein the sMCI group believed they would perform better than they did on an objective PM measure. Notably, there were no significant differences in task-specific meta-PM accuracy on the last two items of the objective PM measure, indicating that the first two items' significant differences likely influenced the overall measure differences between healthy and sMCI groups. Additionally, all groups had more accurate postdictions of their performance, displaying the universal metacognitive trend of calibration once familiarity and experience with the PM tasks were had.

The Nuance of Task-Specific Meta-Prospective Memory

Interpretation of item-level PM data is crucial in this study, given that significant item-level differences in task-specific meta-PM accuracies and item-level differences PM performances were observed between groups. As such, the objective PM measure utilized in this study, the RPA, was selected because it targets the various contexts and environments in which PM has been studied (Radford et al., 2011). Specifically, the RPA requires participants to engage in tasks that are short- and long-term, time- and event-based, and in laboratory and naturalistic settings, all of which have had merit when determining PM success in older adults. On the RPA, item 1 is a short-term, time-based task, item 2 is a short-term, event-based task, item 3 is a long-term, event-based task, and item 4 is a long-term, time-based task. In the current study, the healthy group outperformed the sMCI group on laboratory items 1 and 2 of the RPA, but not on naturalistic items 3 and 4, which was in alignment with the sMCI group's overconfidence in their predictions of their PM performance on items 1 and 2. Due to the variation in types of task environment and cue type (Ellis & Kvavilashvili, 2000), there are several avenues for interpretation as to why the sMCI group performed significantly worse on items 1 and 2, as well as why the sMCI group displayed overconfidence on these items.

Items 1 and 2 on the RPA represent time- and event-based PM tasks, respectively, and as previously discussed, older adults generally have exhibited greater difficulty on time-based tasks when compared to event-based tasks (Costa et al., 2011; Troyer &

Murphy, 2007). Despite these findings, the literature has been mixed for the MCI population. Prior studies have reported that time-based PM tasks provide greater sensitivity in discrimination between MCI and healthy control participants (Costa et al., 2015), but a meta-analytic report noted that PM impairments for MCI groups were comparable between time- and event-based tasks (van den Berg et al., 2012). In the current study, the sMCI group displayed significantly worse performance on both time-based and event-based tasks compared to healthy controls, confirming meta-analytic reports, and suggesting that cognitive impairments in those with sMCI may compromise all systems of PM encoding and retrieval (Costa et al., 2011), regardless of PM cue-type.

Moreover, Items 1 and 2 on the RPA are laboratory-based, short-term PM tasks that were presented to the study participants after completing initial informed consent paperwork. Therefore, the timing and presentation of these tasks as the first instructions for the experiment could have impacted the way in which participants approached intention formation for PM task completion, with the sMCI group being less prepared to shift attention to PM task instruction. Furthermore, prior studies have found that older adults have more difficulty in laboratory environments compared to naturalistic environments for PM task completion (Henry et al., 2004); however, cognitively impaired older adults have displayed substantial PM difficulty regardless of PM environment (Will et al., 2009). In the current study, the sMCI group was only significantly outperformed by the healthy group on the laboratory tasks, suggesting that task environment could serve as a significant variable in PM task performance for those with decreased neurocognitive status. Likewise, the sMCI group in the current study only displayed significant overconfidence in predictions of PM performance for items 1 and 2 of the RPA. It is probable that providing task-specific predictions of PM task performance reflected a novel idea and experience for the participant group as a whole, but due to potential decreased awareness of objective PM performance in the sMCI group (Vannini et al., 2017), they reported over-confidence in their task-specific PM abilities. Notably, instructions for items 3 and 4 of the RPA were administered after the completion or forgetting of items 1 and 2, which also required the experimenter to elicit postdictions of PM performance. Providing postdictions for items 1 and 2 likely served as an opportunity to calibrate and regulate prediction scores for items 3 and 4, given the metacognitive trend to update cognitive valuations and implement changes to behavior to successfully accomplish tasks in the future (Correa et al., 1996).

The Role of Executive Function

The theoretical debate between spontaneous retrieval through automatic processing (McDaniel & Einstein, 2011) and methods of strategic monitoring in PM (Arnold et al., 2015; R. E. Smith & Bayen, 2004) sparked the current study's expansion of previous PM literature in healthy and sMCI populations by including several neuropsychological measurements of EF. The EFs that are in alignment with theories of spontaneous retrieval or strategic monitoring are that of response inhibition and set-shifting, because whether one spontaneously retrieves or is engaging in strategic monitoring, one must stop what they are doing in an ongoing task (inhibition), and shift to behaviors needed to complete the PM task. Therefore, response inhibition and set-shifting are necessary processes, despite which theory of PM is employed. In the current study, the sMCI group performed significantly below healthy older adults in the domains of simple and complex set-shifting paradigms. However, with regard to response inhibition, results were more nuanced. Specifically, the sMCI group performed worse on the Word-Reading, Color, and Color-Word conditions of the Stroop Test; however, the score that is thought to be most representative of response inhibition (Ivnik et al., 1996), the Interference score, was non-significantly different between groups. This non-significant difference for the Interference score could represent the discrepancy in processing speed between groups, with the sMCI group performing significantly worse on measures that tapped into processing speed more than response inhibition. As such, if the sMCI group displayed lower processing speed on the Stroop task for all conditions (e.g., not completing as many items in all conditions within the allotted timeframe), and the Interference score is derived from the discrepancy between prior Word and Color conditions and the Color-Word condition, then the Interference score would not be significantly lower within the group if performance across all conditions was lower. Moreover, it could be hypothesized that the age- and education-adjusted normative data comparisons for the Interference score led to a better statistical fit and did not underrepresent the sMCI group. Therefore, hypotheses regarding poorer EF performance in the sMCI group were partially met, with the exception of the Stroop Interference score.

The current study further sought to understand the role of EF and meta-PM *accuracy*. It was hypothesized that EF would account for differences displayed in meta-PM accuracy between healthy and sMCI groups, due to the abundance of literature suggesting a strong connection between EF performance and memory and metamemory success (Bäckman et al., 2005; Mäntylä et al., 2010; Martin et al., 2003; Souchay et al., 2003). Contrary to hypotheses, EF in this study did not account for differences in task-specific meta-PM accuracy above and beyond that of neurocognitive status alone. This was expected for our measure of inhibition (Stroop Interference), as the groups did not significantly differ in performance on this measure. However, taking into consideration the significant differences in both simple (Trails B) and complex (WCST) set-shifting measures, this finding was a surprise. The failure of EF to explain the relationship between group status and task-specific meta-PM accuracy could be due to sampling bias. More specifically, our sMCI group was comprised of hospital-recruited participants with a diagnosis of MCI in addition to community-recruited participants who were determined to fall into the MCI category by use of a cognitive screener rather than a full neuropsychological battery. Given the various ways the sMCI group was constructed for this study, as well as the recommended sample size based on a priori power estimates, post-hoc analyses were conducted. Post-hoc power was equal to 0.91 with the total sample size of 81 participants, detecting a medium effect ($f^2 = 0.17$). Given these results, it is likely that there is no clear effect to detect regarding EF's role in task-specific meta-PM accuracy. Nevertheless, because simple and complex set-shifting and PM performance were significantly associated with neurocognitive status, these cognitive processes represent important targets for assessment and intervention.

Neuropsychological Utility of PM & Meta-PM

This study's findings provide an abundance of clinical and neuropsychological utility. First and foremost, it is not currently standard clinical practice to assess PM within the context of a neuropsychological evaluation because the purpose of a neuropsychological evaluation is typically to determine the diagnosis of an underlying neurodegenerative condition (Kinsella et al., 2018). As it stands, there is not sufficient evidence for PM failures to play a diagnostic role in determining differential diagnoses between neurodegenerative disorders. Moreover, measures of PM to date have lacked comprehensive norms for a general population, as well as advanced age groups with neurodegenerative conditions. Notably though, most older adults with memory concerns initially consult their medical providers because of PM complaints (G. Smith et al., 2000), and PM is one of the largest predictors of medication adherence in the older adult population (Zogg et al., 2012). These factors alone make the construct of PM a fruitful neuropsychological domain for consideration in assessment and early intervention.

Moreover, the assessment of PM may provide an early indicator of neurocognitive decline. The diagnosis of MCI traditionally refers to the presence of a subjective cognitive complaint and objective impairment in one or more cognitive domain that is abnormal for one's age without functional impairment (Petersen, 2004). As such, individuals may qualify for an MCI diagnosis without the presence of objective retrospective memory impairment, in opposition to our societal view of neurodegeneration with memory impairment as a hallmark symptom. However, the inclusion of PM measures in neuropsychological evaluation may better capture the real-world experiences that patients tend to report to their primary care providers and shed light on another domain that could be a marker for MCI. This inclusion may also aide in the sensitivity of detecting functional decline, such as difficulty with medication adherence, which is more congruent with a major neurocognitive disorder or dementia diagnosis (Zogg et al., 2012). The current study highlighted the utility and sensitivity of the RPA as a performance-based PM measure that could distinguish between healthy older adults and older adults with sMCI to be used in neuropsychological evaluations.

The addition of informant reports of PM functioning should also be considered an important aspect of neuropsychological evaluation. The current study found that informants' reports of generalized PM functioning was significantly related to objective PM performance, and informants had more accurate task-specific PM predictions for the sMCI group. These findings highlight that informant reports may show greater sensitivity, specifically for task-specific PM, compared to reliance on self-reported functioning in cognitively impaired groups, which is largely in alignment with prior literature (Hickox et al., 1992; Sunderland et al., 1984). Additionally, the field of neuropsychology has valued a collateral source for initial intake interview in typical neuropsychological evaluations, making it feasible to add a short questionnaire to administer to these collateral sources, either by phone or in-person prior to the completion of a neuropsychological assessment. Therefore, the inclusion of the informant report with the addition of performance-based PM measures would provide a complementary and comprehensive view of PM functioning in a neuropsychological population (Sugden et al., 2021).

Beyond the realm of neuropsychological assessment, the current study's findings of impaired PM performance, impaired set-shifting performance, and impaired task-specific meta-PM accuracies compared to a healthy older adult population provide several targets for intervention. The idea that cognitive training can protect or enhance neurocognitive function stems from the idea of neuroplasticity, which entails utilizing environmental factors to change the physical structure and function of the brain (Hertzog et al., 2008; Stern, 2009). A recent meta-analysis revealed a modest effect of cognitive training in improving older adults' cognitive function in more than 200 randomized control trials, with a small-sized net-gain in cognition for healthy older adults ($g = 0.28$; Basak et al., 2020). Moreover, in this same meta-analysis, authors reported that training a single cognitive ability reliably benefited the trained ability in future tasks of a similar cognitive domain (i.e., near transfer effect); however, training of a single cognitive ability did not result in the benefit of cognitive domains beyond the one that was trained (i.e., far transfer effect; Basak et al., 2020). Therefore, cognitive remediation targeting several aspects of cognition including PM, EF, and meta-PM in the MCI population may result in better transfer effects to functional living than by providing training in PM alone.

Various targets for intervention should be considered for sMCI groups, as the current study found significantly lower performance on PM as a whole, but also on subcomponents of PM, such as time- and event-based PM, as well as on short-term laboratory-based PM tasks. Therefore, targets for intervention related to PM could include implementation of spaced retrieval practices, visual imagery, memory diaries, and digital calendars (Andrewes et al., 1996; Ozgis et al., 2009), which balance compensatory and restorative strategies. Moreover, a popular approach to PM intervention has been with implementation intentions, which represent an encoding method that requires verbal or visual repetition of intentions (i.e., “if situation X is encountered, then I will initiate Y goal-directed behavior”; Gollwitzer & Sheeran, 2006). One meta-analytic review found that implementation intentions had a medium to large effect size on PM performance (Chen et al., 2015), but far transfer effects have yet to be detected. Notably, one prior study aimed to enhance PM performance through executive control training (task-switching training), but they found no transfer effects to a real-life prospective memory task (i.e., blood pressure monitoring; Brom & Kliegel, 2014). The only PM-specific training paradigm that has shown evidence of improvement in PM and transfer effects to PM in real-world contexts was in a large RCT utilizing integrated restorative and compensatory approaches (Henry et al., 2021).

A small number of studies have been conducted in clinical populations that target executive dysfunction as an area for intervention in PM. Most commonly, Goal Management Training (GMT; Levine et al., 2000) has been the gold standard intervention for EF deficits, as it teaches participants step-by-step strategies to monitor their actions, describe their goals, narrow their goals, and action their narrowed goals. Using this paradigm, participants are taught to interrupt an ongoing task in order to implement the action necessary for PM execution, as well as engage in repetition of goals periodically to maintain PM intentions (Fine et al., 2021). However, findings related to the effectiveness of GMT for PM have been mixed, especially in older adult populations (Henry et al., 2021). More specifically, this is likely a function of the heterogeneity of community-dwelling older adults, as well as the heterogeneity of older adults with an MCI diagnosis. For example, some individuals with an MCI diagnosis have more executive dysfunction than others with the same diagnosis, meaning that EF training could be helpful for PM success in some but unhelpful in others. Although the sMCI group in the current study displayed significantly worse EF performance compared to the healthy group, EF training, such as GMT, should be considered a target for PM intervention.

The final viable target for intervention, meta-PM accuracy, highlights the novel finding of this study. The current study revealed no difference in generalized/overall perceptions of PM function between healthy and sMCI groups but showed that there are important task-specific meta-PM inaccuracies in the sMCI group. The interpretation of this finding is also more nuanced, as the sMCI group performed more accurately on the final two prompts of the RPA, after having to provide postdictions and reflect on one's performance on the first two prompts of the RPA. This performance pattern could reflect metacognitive calibration from having to reflect on performance for the first two RPA prompts before providing predictions for the last two RPA prompts, or a function of the first two PM tasks being lab-based and the last two being naturalistic. However, given Will and colleagues' (2009) findings that naturalistic and lab-based PM tasks are generally equivalent in cognitive impaired older adults, metacognitive intervention may provide a great benefit to this population.

The calibration that occurred from prediction to postdiction performance, as well as between the first two items and the last two items of the PM task suggest that metacognitive training may increase the likelihood of selecting appropriate compensatory strategies to better aide in future PM success. Moreover, metacognitive training does not have to require formal structure and could be combined with psychoeducation on compensatory strategy use. For example, clinicians could guide patients presenting for early intervention to be more reflective on their success in their PM tasks from day to day, recording on a Likert scale how well they did for each PM task throughout their day. Alternatively, patients could be given the directive to predict performance and postdict performance on daily PM activities, such as medication adherence. There are more formal structures of metacognitive training (e.g., "Goal, plan, do, review," etc.); however, introducing simple metacognitive techniques to existing psychoeducation about memory processes in a neuropsychological feedback setting would provide immediate access to and knowledge of ways in which patients can start making real-time changes to their existing routines and boost their functional PM outcomes.

Limitations & Future Directions

There are several limitations associated with the design of the current study that should not be overlooked. First and foremost, the study sample was derived from a rural, primarily white sample, rendering results potentially only generalizable to rural America. It is also imperative to discuss that these data were collected at the height of the COVID-19 pandemic with an at-risk population. Therefore, those who chose to participate in this study at that time may represent a different demographic than those who declined participation due to safety. As a result, this particular sample of both healthy and sMCI older adults may be restricted in generalizability to populations who have higher risk tolerance, and it is unclear how this demographic would generalize nationally. Moreover, as a result of the COVID-19 pandemic, the sample size for the sMCI group was four participants short of meeting criteria obtained from the *a priori* power analysis, leaving this group potentially underpowered. However, given the large effect sizes of most of the findings, the addition of the final four participants may not have substantially changed the results. Notably, the effect size for the sMCI group on generalized meta-PM accuracy findings was non-trivial, and if the effect was in fact small, the sMCI group may have been underpowered to detect this effect. Similarly, informant participation was likely underpowered, as the response rate from informants were substantially less than the number of participants in the study, therefore, requiring caution when interpreting informant results. However, significance was found with the informant group, and therefore may represent reliable results.

Importantly, many of the hospital-recruited older adults with existing MCI diagnoses had a significant amount of time between their neuropsychological evaluation that resulted in their diagnosis and the point at which they completed the study. While a large percentage of individuals remain in the MCI diagnostic range for several years or revert to a normal cognitive status, some patients with MCI, particularly of the amnestic type, have a higher risk to progress to more functionally impaired diagnoses, such as Alzheimer's Disease (Albert et al., 2011). Moreover, a distinction between amnestic and non-amnestic forms of MCI was not obtained, leading to less study specificity. Although it's crucial to acknowledge that the current study's sMCI participant group was largely characteristic of most MCI groups with heterogeneous cognitive presentations, results may have differed if the sMCI group was broken into amnestic, non-amnestic, and mixed, as literature has indicated that amnestic MCI is more related to objective impairments in all cognitive domains with higher probability of conversion to dementia, while non-amnestic MCI groups may only display impairment in a singular domain, such as EF (Espinosa et al., 2013).

Given the heterogeneous recruitment of the sMCI sample, it was also imperative to consider that differences could exist between the sMCI participants that were hospital-recruited versus community-recruited. Given this concern, our analyses suggested that the hospital-recruited sMCI group performed significantly worse on the MMSE and functional PM tasks measured by the RPA (though not all subscales of the RPA). Conversely, the hospital and community-recruited sMCI groups performed equivalently on all aspects of self-reported PM, EF measures, and on generalized and task-specific measures of meta-PM accuracy. These data suggest that the hospital-recruited sMCI group may be slightly more functionally impacted in areas of PM; however, EF and meta-PM abilities were not functionally different than the community-recruited sMCI participants. These patterns of performance may highlight the important distinction between those who feel their memory is poor enough in their daily lives to seek medical attention and those that are not yet observing substantial of memory impairment in their daily lives, even though functional differences were still apparent when compared to a healthy population. Though this was not a target of the current study, more work determining the spectrum of sMCI presentations would be beneficial to explore.

Measure-based limitations also existed within the current study in a variety of ways. First, although neurocognitive status was a top priority of the study, the MMSE was used for differentiation of healthy versus sMCI status in community-recruited older adults, even though the MoCA would have been a more sensitive cognitive screener to detect MCI (Wojtowicz & Larner, 2017). The MMSE was utilized in this study due to it being the measure of choice in the overarching database from which the community-recruited participants were drawn. Moreover, the current study did not administer a full neuropsychological battery, therefore limiting knowledge on how the current study's sMCI sample fared in comparison to other MCI samples.

To add to assessment limitations, the current study could have included psychological screeners in the design to account for state-based symptom presentation and how current psychological symptoms may have influenced the study's results. Nevertheless, the presence of psychological diagnoses and histories were obtained on the demographics questionnaire, and analyses revealed that the presence of psychological comorbidities did not change the results of the study's findings. Furthermore, the current study did not measure retrospective memory performance, beyond that of which was self-reported, limiting the ability to compare PM and retrospective memory processes in these populations. Additionally, the RPA, the measure of objective PM functioning, allows participants to utilize "any method" to help them remember to complete the PM tasks being assessed. Although this is reflective of real-world PM contexts, the use of written notes and reminders could have influenced the study findings via the healthy group utilizing their resources more efficiently than the sMCI group. Though this is diagnostic in and of itself, the restriction of such external aide usage could have led to more pure memory comparisons between groups. Lastly, the study's results were most significant for lab-based items which may not represent more naturalistic, real-world performance and may over-pathologize the sMCI group. Literature has indicated that lab-based and naturalistic designs of PM are often comparable (Will et al., 2009), but it is a factor for which caution should be taken.

Future studies in meta-PM accuracy in these populations should attempt to address the limitations listed above. Additionally, the current study collected data on memory aide usage and self-efficacy. Since these variables were not a primary aim of the study, a follow-up study incorporating these variables will be pursued. Moreover, the inclusion of retrospective memory measures would clarify the study results and provide more concrete conclusions. However, as it stands, these data could be utilized to inform a randomized clinical trial of a metacognitive intervention using predictions and postdictions for PM performance as a means of early intervention. It is suggested that a longitudinal design be implemented to track progression of MCI status, informing if metacognitive training could potentially prolong the onset of cognitive decline.

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Appendix A

Nelson & Narens' (1990) Model of Metacognition

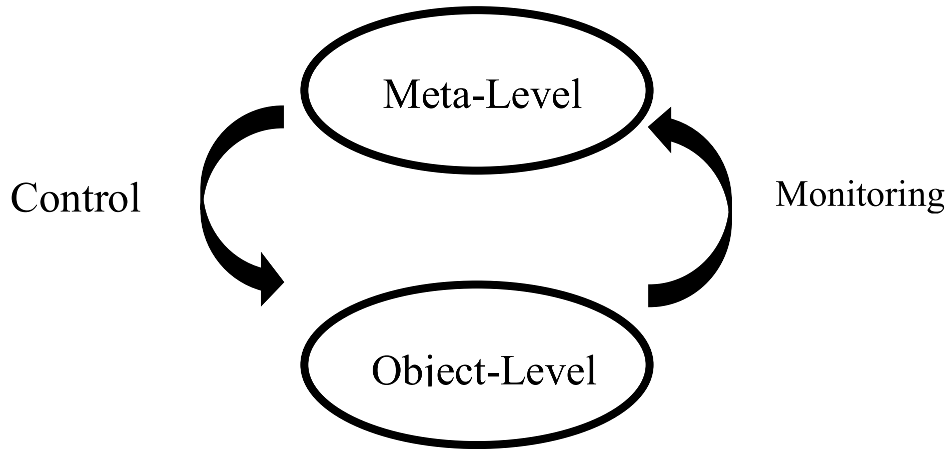


Figure 1. Model of cognitive monitoring and control proposed by Nelson & Narens (1990).

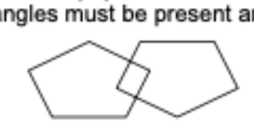
Appendix B

Mini-Mental State Examination (MMSE)

Mini-Mental State Examination (MMSE)

Patient's Name: ______________________________ Date: __________

Instructions: ***Ask the questions in the order listed. Score one point for each correct response within each question or activity.***

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ________
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

(Adapted from Rovner & Folstein, 1987)

Appendix C

Prospective and Retrospective Memory Questionnaire (PRMQ)

REMEMBERING TO DO THINGS

Prospective-Retrospective Memory Questionnaire as described in:

Smith, G., Della Sala, S., Logie, R.H. & Maylor, E.A. (2000). Prospective and Retrospective Memory in Normal Aging and Dementia: A Questionnaire Study. *Memory*, 8, 311-321.

In order to understand why people make memory mistakes, we need to find out about the kinds of mistakes people make, and how often they are made in normal everyday life. We would like you to tell us how often these kind of things happen to you. Please indicate by ticking the appropriate box.

Please make sure you answer all of the questions on both sides of the sheet even if they don't seem entirely applicable to your situation.

Please provide the following details about yourself.	Age ________	Male/Female ________	
How many year of formal education have you had?	________		
Have you suffered from brain or head injury resulting in hospitalisation (Y/N)		________	
Please give brief details ________			

Please answer all of the questions as accurately as possible.

	Very Often	Quite Often	Sometimes	Rarely	Never
Do you decide to do something in a few minutes' time and then forget to do it?	☐	☐	☐	☐	☐
Do you fail to recognise a place you have visited before?	☐	☐	☐	☐	☐
Do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?	☐	☐	☐	☐	☐

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	Very Often	Quite Often	Sometimes	Rarely	Never
Do you forget something that you were told a few minutes before?	☐	☐	☐	☐	☐
Do you forget appointments if you are not prompted by someone else or by a reminder such as a calendar or diary?	☐	☐	☐	☐	☐
Do you fail to recognise a character in a radio or television show from scene to scene?	☐	☐	☐	☐	☐
Do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?	☐	☐	☐	☐	☐
Do you fail to recall things that have happened to you in the last few days?	☐	☐	☐	☐	☐
Do you repeat the same story to the same person on different occasions?	☐	☐	☐	☐	☐
Do you intend to take something with you, before leaving a room or going out, but minutes later leave it behind, even though it's there in front of you?	☐	☐	☐	☐	☐
Do you mislay something that you have just put down, like a magazine or glasses?	☐	☐	☐	☐	☐
Do you fail to mention or give something to a visitor that you were asked to pass on?	☐	☐	☐	☐	☐
Do you look at something without realising you have seen it moments before?	☐	☐	☐	☐	☐
If you tried to contact a friend or relative who was out, would you forget to try again later?	☐	☐	☐	☐	☐
Do you forget what you watched on television the previous day?	☐	☐	☐	☐	☐
Do you forget to tell someone something you had meant to mention a few minutes ago?	☐	☐	☐	☐	☐

Appendix D

Prospective and Retrospective Memory Questionnaire Proxy (PRMQ-Proxy)

Remembering Things To Do

In order to understand why people make memory mistakes, we need to find out about the kinds of mistakes people make and how often they are made in normal everyday life. We would like you to tell us how often these kinds of things happen to your loved one. Please make sure you answer all of the questions, even if they don' seem entirely applicable to your loved one's situation.

1. Do they decide to do something in a few minutes time and forget to do it?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

2. Do they fail to recognize a place they have visited before?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

3. Do they fail to do something they were supposed to do a few minutes later even though it is there in front of them, like take a pill or turn off the kettle?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

4. Do they forget something they were told a few minutes before?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

5. Do they forget appointments if they are not prompted by someone else or by a reminder such as a calendar or diary?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

6. Do they fail to recognize a character in a radio or television show from scene to scene?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

7. Do they forget to buy something they planned to buy, like a birthday card, even when they see the shop?

   ☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

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8. Do they fail to recall things that have happened to them in the last few days?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

9. Do they repeat the same story to the same person on different occasions?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

10. Do they intend to take something with them, before leaving a room or going out, but minutes later leave it behind, even though it is there in front of them?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

11. Do they mislay something that they have just put down, like a magazine or glasses?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

12. Do they fail to mention or give something to a visitor that they were asked to pass on?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

13. Do they look at something without realizing they have seen it moments before?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

14. If they tried to contact a friend or relative who was out, would they forget to try again later?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

15. Do they forget what they watched on television the previous day?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

16. Do they forget to tell someone something they had meant to mention a few minutes ago?

☐Very Often ☐Quite Often ☐Sometimes ☐Rarely ☐Never

Appendix E: Royal Prince Alfred Prospective Memory Test (RPA)

RPA-ProMem

Royal Prince Alfred Prospective Memory Test

FORM 1

ID__________

Date__________

Instructions: "As I mentioned before, today we will be doing some tasks to test certain areas such as your memory and attention. Firstly, I am going to ask you to remember to do some things at a later stage of the assessment. You can use any techniques that you think might help you remember these things."

START TIME: ____________________________

Part 1 and Part 2

"I am going to leave this clock here where you can see it. **In 15 minutes time**, I would like you to tell me it's time for a coffee break. Do this as close to 15 minutes' time as you can. The other thing I would like you to do, **at the end of our session** today, is to ask me for an information sheet on note-taking strategies." *(Place digital clock in subject's direct view).*

- *Verify encoding of instructions and repeat if necessary*

Part 1 (Short-term, Time-based)

SUBJECT'S RESPONSE: ____

____ TIME: ________________________

Part 2 (Short-term, Event-based)

TIME OF TARGET EVENT: ____________________ *(i.e., time session ends; time alarm or phone rings)*

SUBJECT'S RESPONSE: ____

____ TIME: ________________________

Part 3 and Part 4

Instructions [administered at end of session]: "I am going to ask you to do some more things after we are finished today. You can use any method that will help you to remember to do the things I ask you to do. It is important that you try your best to remember".

"Firstly, when you arrive home today, I want you to phone and leave a message on my voice mail, telling me **what the weather is like**. The number is [*insert appropriate #*]. The second thing I would like you to do this week is to return this postcard to me on [date to be posted, one week from now] with your name and the word **HAWAII** written on the postcard. Will you be able to do this on that day? *[If not, plan another day]" (Make sure it is already stamped, addressed and labelled with participant ID code).*

- *Verify encoding of instructions and repeat if necessary*

Part 3 (Long-term, Event-based)

TIME OF TARGET EVENT: ____________________ *(i.e., approximate time expected to return home)*

SUBJECT'S RESPONSE: ____

____ TIME: ________________________

Part 4 (Long-term, Time-based)

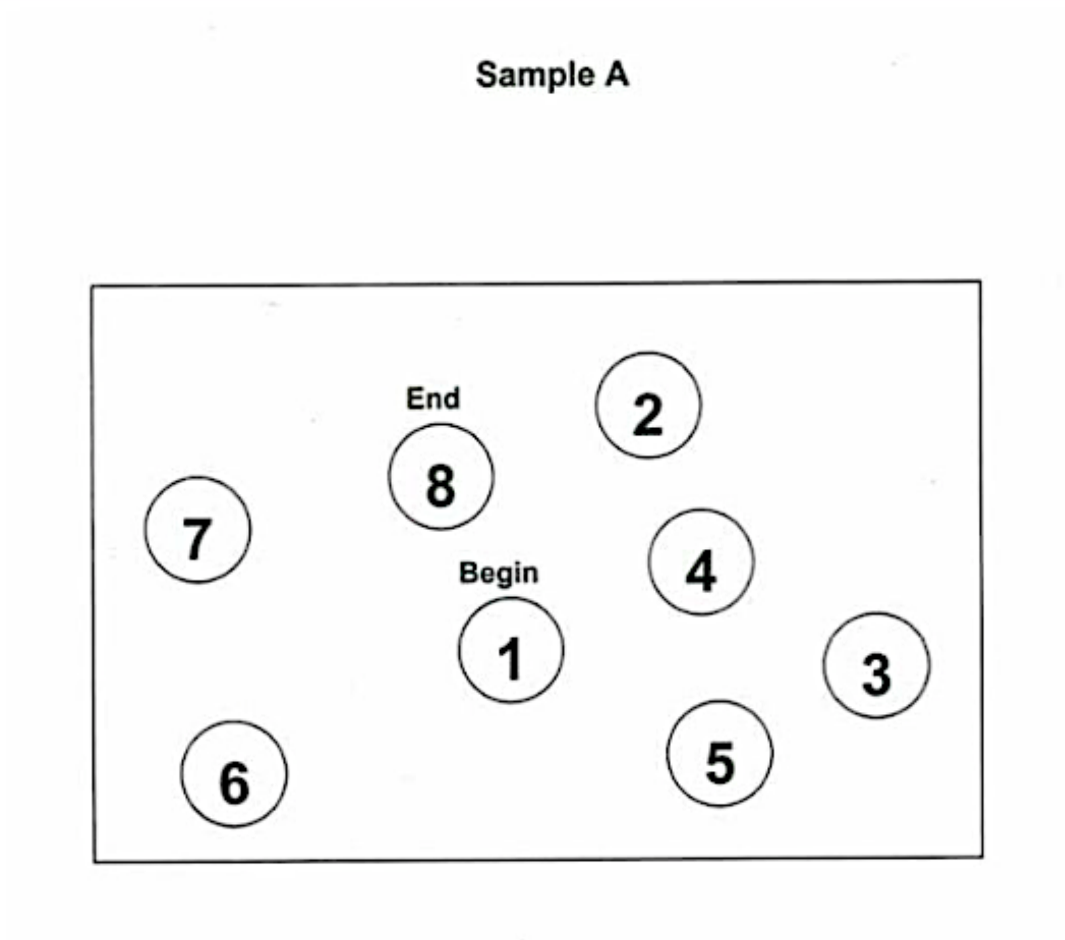
TIME OF TARGET EVENT: ____________________ *(i.e., date one week from assessment session)*

SUBJECT'S RESPONSE: ____

____ DATE: ________________________

Comments:

Appendix F: Trail Making Test



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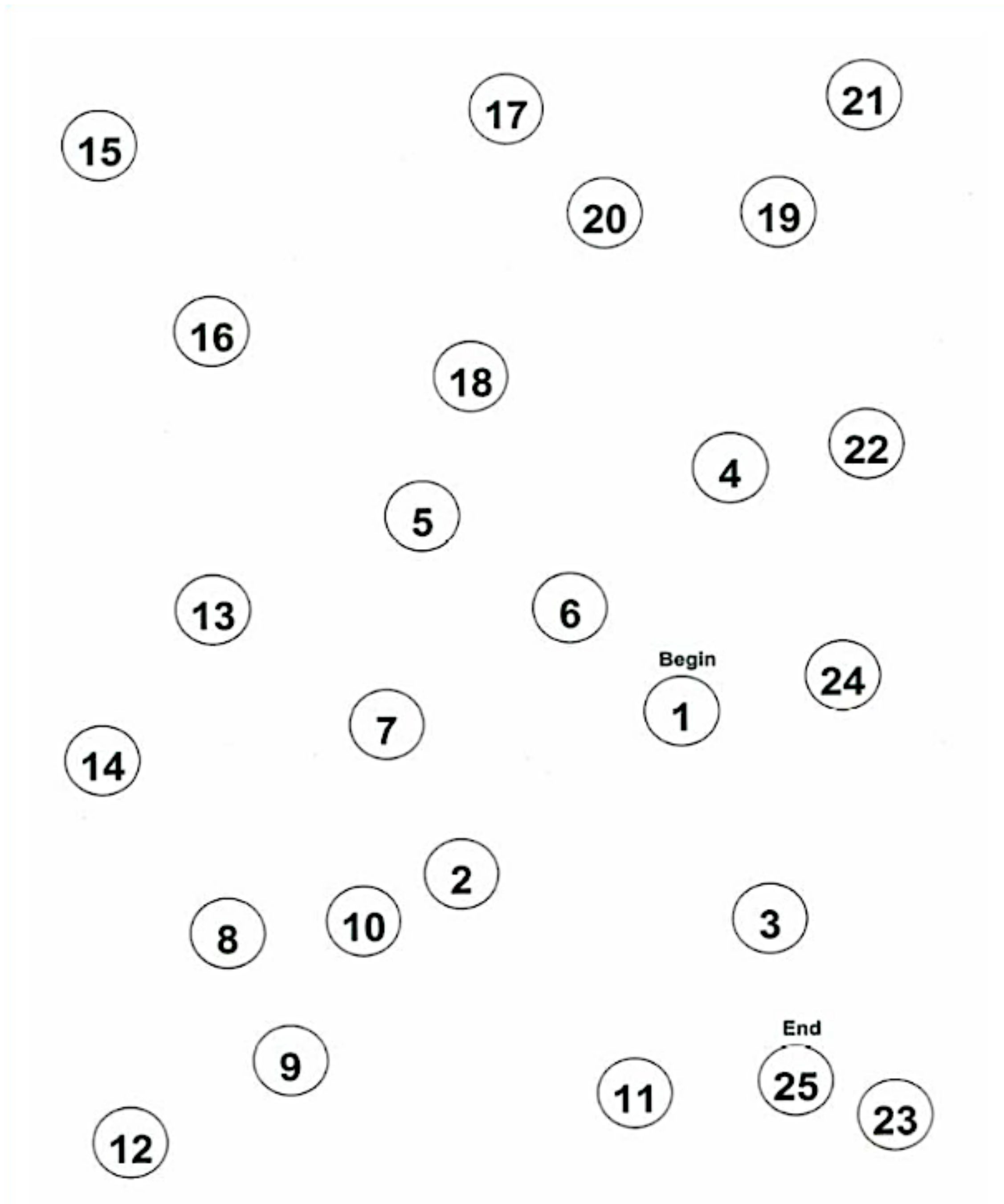

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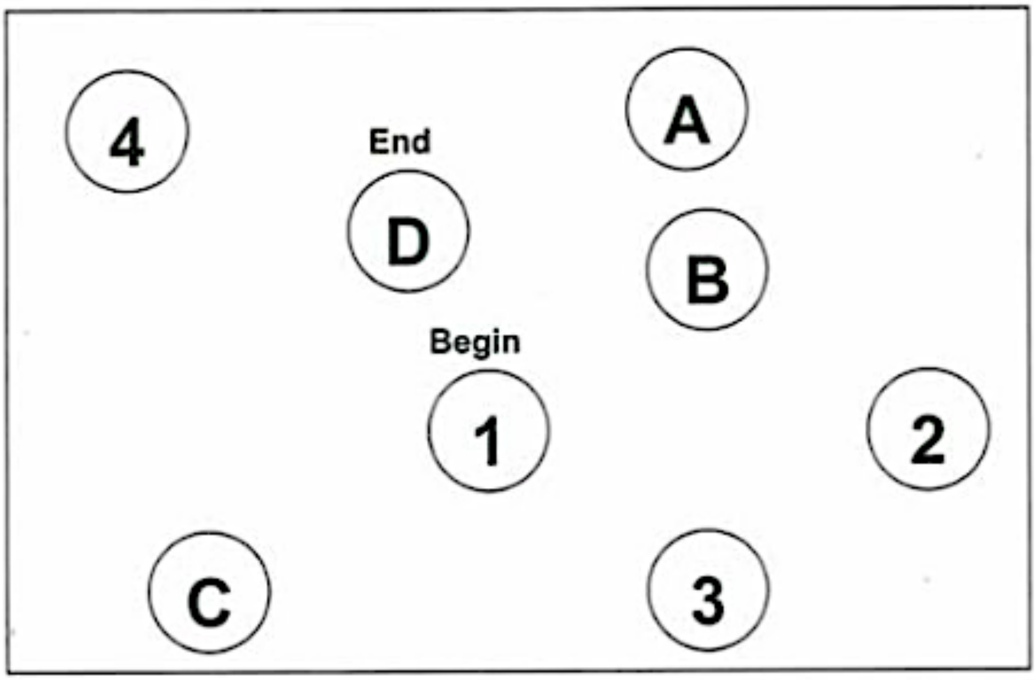
Sample B



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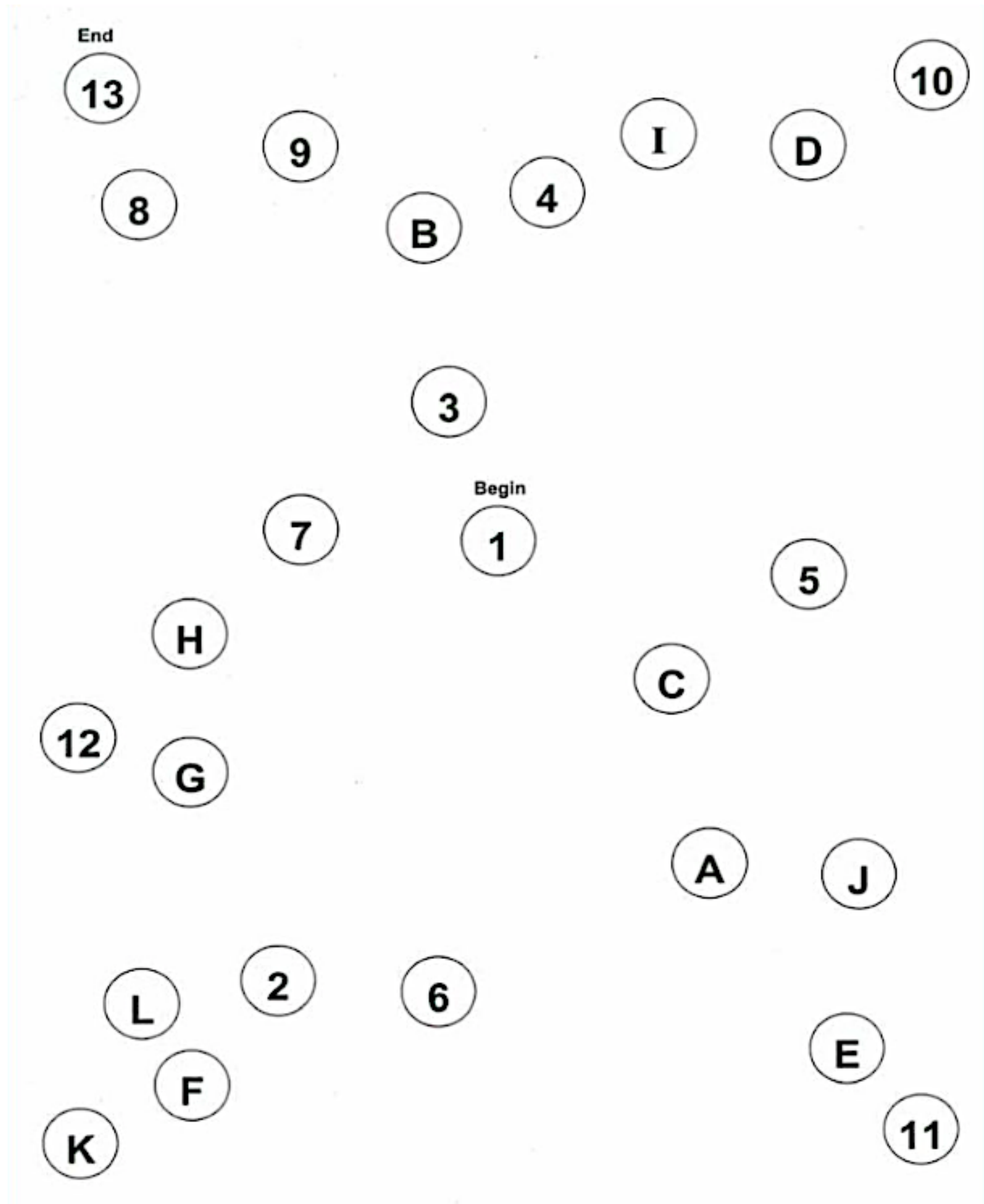
End
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