Prospective Memory abilities in aging and Mild Cognitive Impairment/ Early Alzheimer's Disease

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Abstract

This dissertation describes separate but related studies that explore the prospective memory abilities of older adults and individuals with Mild Cognitive Impairment/Early Alzheimer's disease. Prospective memory (PM) refers to the type of memory utilized to execute planned actions in accordance with a specific event. PM is critical to maintaining functional independence in older adults, as it can refer to such basic acts as remembering to turn off a stove or taking one's medication. Research suggests PM abilities decline within normal aging and to a greater extent in Mild Cognitive Impairment (MCI) and early Alzheimer's Disease (AD). Together, the studies assessed and compared the PM abilities across healthy younger and older adults, individuals with MCI, and individuals with early AD while exploring two major theories that seek to explain PM retrieval. The preparatory attentional and memory process theory of PM (PAM) assumes that PM retrieval requires resource-demanding preparatory attentional processes, whereas the Dynamic Multiprocess theory (DMPT) assumes that retrieval can also occur spontaneously (Scullin, McDaniel, & Shelton, 2013; Smith & Bayen, 2006).

Study 1 used a novel laboratory PM task in which the focality and the frequency of PM cues were manipulated to compare the PM abilities of cognitively healthy younger and older adults. The results revealed significant differences in the patterns of performance between the younger and older adults based on the focality and frequency of cues which indicated different attentional allocation strategies.

Study 2 examined the impact of cognitive impairment on PM abilities by using the same paradigm to compare the performance of cognitively healthy older adults to individuals with MCI and early AD. The results again revealed significant differences in the patterns of performance which indicated that these groups may have used different strategies of attentional

allocation depending on the focality and cue frequency. Taken together, the findings in Studies 1 and 2 were mixed with respect to the predictions of the DMPT and PAM. The MCI group, in particular, demonstrated a unique performance profile that suggests the neuropathophysiological changes associated with this diagnosis may lead to the reliance on different PM retrieval processes compared to healthy older adults.

Finally, Study 3 explored the use of a more naturalistic and ecologically valid PM task to compare the PM performance of individuals with MCI and early AD to healthy older adults without cognitive impairment. The results showed that, after taking the learning and retrospective memory scores into account, the significant differences between groups in PM accuracy on this task can mostly be accounted for by these factors. Nevertheless, the AD group was found to display significantly lower PM accuracy with event-based cues with a weak association between cue and action compared to the older adult and MCI groups after controlling for these factors. These findings provide valuable theoretical, methodological, and clinical contributions which will be discussed.

Contributions of Authors

The studies in this dissertation were conceived by Mike Van Adel, with guidance from Dr. Vanessa Taler. Mike Van Adel selected the stimuli, designed the experiments, programmed the tasks, recruited and tested participants, and processed and analyzed the data under the supervision of Dr. Taler. Members of the Taler Lab also assisted with testing participants. Mike Van Adel and Dr. Taler interpreted the results in collaboration. Manuscripts will be prepared for publication as a result of this thesis with Dr. Taler and Laura Thompson as co-authors.

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Introduction

As the demographics of our population shift to a more aged population, the number of individuals at risk of or suffering from Alzheimer's disease (AD) is increasing. Intense research interest has focused on identifying older adults at risk of developing AD in order to facilitate early intervention, and there now exists considerable evidence that a prodromal phase of AD may occur years before diagnosis. A recently introduced term designed to capture this point on the spectrum of cognitive function between healthy aging and dementia is mild cognitive impairment (MCI). MCI is defined as cognitive decline greater than expected for an individual's age and education level but that does not meet criteria for dementia. Patients who meet the diagnostic criteria for MCI progress to dementia, particularly of the Alzheimer's type (AD), at a significantly greater rate than the general elderly population (6-15% vs. 1-2% per year) (Petersen & Morris, 2005). MCI should therefore be a significant focus of cognitive rehabilitation and, as such, it is critical to understand the nature of the cognitive deficits observed in MCI. The current study focuses on one specific and important cognitive deficit in this population, prospective memory.

Prospective memory (PM) is crucial to the maintenance of functional independence and is more closely associated with deficits in activities of daily living, instrumental activities of daily living, and caregiver burden than retrospective memory failure (Smith, Della Sala, Logie, & Maylor, 2000). It is, therefore, of considerable concern that PM is often disrupted in the context of normal adult aging (Henry, MacLeod, Phillips, & Crawford, 2004) and to an even greater extent in dementia, even in the mild (Martins & Damasceno, 2008) and preclinical (Duchek, Balota, & Cortese, 2006; Jones, Livner, & Backman, 2006) stages. Before providing the literature on PM, including theoretical frameworks that attempt to delineate the functioning

of this ability, an examination of the populations of interest is important.

Background

Alzheimer's Disease

Alzheimer's disease is a progressive disease that impacts substantial areas of the brain and associated cognitive functions. It is also the most common cause of dementia, accounting for 60-80% of cases (Barnes & Yaffe, 2011). Extensive research has focused on identifying older adults who will develop AD in order to facilitate early intervention, and there now exists considerable evidence that a prodromal phase of AD may occur years before diagnosis. Evidence for a prodromal phase has documented deficits both in neuropathology and in cognition prior to clinically diagnosed AD. The observed neuropathological changes include neuronal loss in the limbic system and the formation of neurofibrillary tangles and senile plaques (hallmarks of AD) in very mild or questionable AD (Gómez-Isla & Hyman, 2003; Iqbal et al., 2005). In addition, hippocampal atrophy has been observed prior to the onset of dementia (Fox, Warrington, Stevens, & Rossor, 1996; Jak et al., 2009; Visser et al., 1999); and this atrophy has been found to progress prior to an ensuing clinical diagnosis of dementia (Fox et al., 1996). In terms of changes, individuals in the prodromal phase of AD exhibit deficits in executive function (Albert, Moss, Tanzi, & Jones, 2001; Chen et al., 2001; Daly et al., 2000), episodic memory (Bäckman, Small, & Fratiglioni, 2001; Chen, et al., 2001; Elias et al., 2000; Small, Fratiglioni, Viitanen, Winblad, & Backman, 2000; Tierney et al., 1996), information processing speed (Fox, Warrington, Seiffer, Agnew, & Rossor, 1998), visuospatial functions (Albert, et al., 2001; Chen, et al., 2001; Fowler, Saling, Conway, Semple, & Louis, 2002; Howieson et al., 1997), attention (Nielsen, Lolk, Andersen, Andersen, & Kragh-Sorensen, 1999; Rubin et al., 1998; Tierney, et al., 1996), and language (Taler & Phillips, 2008). Taken together, these findings represent evidence

of a continuum of changes that are too subtle to be detected at the outset, followed by an intermediate or prodromal stage and then clinically detectable symptoms that meet criteria for dementia, typically of the Alzheimer's type (Benke, 2011; Gómez-Isla & Hyman, 2003).

Mild Cognitive Impairment

The first term used to describe individuals who display cognitive dysfunction in the absence of any diagnostic impairment was "benign senescent forgetfulness" (Kral, 1962). More detailed concepts have since emerged including age-associated memory impairment (AAMI; Crook et al., 1986), age-associated cognitive decline (AACD; Levy, 1994), and age related cognitive decline (ARCD; F. I. M. Craik & Salthouse, 1992). Initially, these concepts were thought to typify more benign forms of cognitive decline representing the extremes of normal aging, rather than prodromal stages of any form of dementia. Yet, studies began to show that individuals suffering the cognitive decline described by these concepts were at a distinctly increased risk of developing dementia (Celsis et al., 1997; Ritchie, Artero, & Touchon, 2001). However, others have found similar rates of progression to dementia in these individuals and in healthy older adults (Hanninen et al., 1995), suggesting that a more refined concept is necessary to describe those with cognitive impairments that are most predictive of progression to a diagnosis of dementia.

A term now commonly used, mild cognitive impairment (MCI), may represent this refined concept as it is specifically intended to capture the point on the continuum of cognitive function between normal aging and dementia (Petersen et al., 1999). While the term was first used to describe individuals with a Global Deterioration Scale rating of 3 (Reisberg, Ferris, de Leon, & Crook, 1982), the current, more detailed, criteria for a diagnosis of MCI were introduced much later (Winblad et al., 2004). These criteria include: (i) the person is neither

normal nor demented; (ii) there is evidence of cognitive deterioration shown by either objectively measured decline over time and/or subjective report of decline by self and/or informant in conjunction with objective cognitive deficits; and (iii) activities of daily living are preserved and complex instrumental functions are either intact or minimally impaired. More recently, the National Institute on Aging and the Alzheimer's Association had a workgroup develop criteria for the symptomatic predementia phase of AD, a phase which they referred to as MCI due to AD (Albert et al, 2011). Two sets of criteria were developed: core clinical criteria to be used by healthcare providers and research criteria to be used in research settings which incorporates the use of biomarkers based on imaging and cerebrospinal fluid measures. The core criteria are similar to those introduced by Winblad et al (2004) in that they include: (i) concern regarding a change in cognition; (ii) impairment in one or more cognitive domains; (iii) preservation of independence; and (iv) the individual is not demented. Notably, Albert et al. (2011) report that deterioration in episodic memory is the most common cognitive impairment seen in patients with MCI and who eventually receive a diagnosis of Alzheimer's disease.

Originally, cognitive deterioration in patients with MCI was thought to be restricted to the memory domain, with other cognitive domains remaining relatively spared (Petersen, et al., 1999). Based on an MCI diagnosis with an isolated memory impairment, patients were shown to progress to dementia, particularly of the Alzheimer's type (AD), at a significantly greater rate than the general elderly population (6-15% vs. 1-2% per year) (Geslani, Tierney, Herrmann, & Szalai, 2005; Morris et al., 2001; Petersen et al., 2001; Petersen, et al., 1999). However, evidence now exists that the risk of dementia, including AD, is significantly increased in individuals with MCI when impairments in multiple cognitive domains, beyond memory, are identified (Alexopoulos, Grimmer, Perneczky, Domes, & Kurz, 2006; Sacuiu, Sjogren, Johansson,

Gustafson, & Skoog, 2005). These deficits may involve domains such as executive functioning (e.g., Albert, et al., 2001), attention (e.g., Linn et al., 1995), language (e.g., Jacobs et al., 1995), and processing speed (e.g., Fabrigoule et al., 1998).

To better reflect the heterogeneity of individuals with MCI who may possess deficits in these various domains either in isolation or in combination, the diagnostic criteria were expanded to encompass four subtypes. These subtypes include: amnestic (isolated memory impairment); amnestic with multiple domains impaired, but at level insufficient to constitute dementia; non-amnestic multiple domains impaired; and non-amnestic single domain impaired (Petersen, 2004).

The heterogeneity in the number and variety of cognitive domains affected in individuals with MCI is also thought to be reflected in the etiology of the disorder (Petersen et al., 2009). As such, the different subtypes of MCI are suggested to have different etiologies that represent different prodromal dementia disorders. In this model, amnestic MCI is likely to progress to AD, amnestic multiple domain MCI to AD or vascular dementia, non-amnestic multiple domain MCI to dementia with Lewy bodies, and non-amnestic single domain to frontotemporal dementia or dementia with Lewy bodies (Petersen, 2004). However, these subtypes were not rigorously field tested (Petersen, 2004; Petersen, et al., 1999) and there has since been further controversy about the optimal definition and utility of MCI (Artero, Petersen, Touchon, & Ritchie, 2006; Palmer, Fratiglioni, & Winblad, 2003; Ritchie & Touchon, 2000; Whitehouse, 2007). Indeed, many, and perhaps most, people with MCI do not deteroriate to dementia within five years of diagnosis, with a significant proportion improving (Mitchell & Shiri-Feshki, 2009). Yet, regardless of the definition used, individuals with MCI progress to dementia in higher proportions than do cognitively healthy people. Therefore, this diagnosis remains a useful concept for early indentification and intervention (Jak et al., 2009; Matthews, Stephan, McKeith, Bond, & Brayne,

2008; Palmer, Backman, Winblad, & Fratiglioni, 2008; Saxton et al., 2009).

In MCI, the heterogeneity in the affected cognitive domains is also reflected in the variable, complex pattern of brain atrophy that evolves significantly over time. Notably, it has been found that approximately two-thirds of MCI patients are more anatomically similar to patients with AD than to cognitively normal individuals (Fan, Batmanghelich, Clark, & Davatzikos, 2008). In predicting time to progression from MCI to AD, atrophy of the hippocampus and other medial temporal lobe structures is associated with a higher risk of progression from MCI to AD (Adak et al., 2004; Geroldi et al., 2006). By the time individuals with MCI reach diagnosis of dementia, the cerebral atrophy has become more widespread in the temporal and parietal lobes and includes, for the first time, substantial involvement of the frontal lobes (Whitwell et al., 2007). Dysfunction in the frontal systems and the executive cognitive functions associated with these systems can result in deficits in planning, organization, self-control, and awareness of problems (Malloy & Richardson, 1994). Executive dysfunction, as measured by neuropsychological tests, has been suggested as the best predictor of functional decline (Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000). Thus, there is consistent evidence that the neuropathological presentation of MCI has parallels with its neuropsychological expression. In addition, these studies provide strong support for evaluating cognitive domains beyond memory in individuals with MCI.

Given the heterogeneity in presentation and progression of individuals with MCI, it is essential that any neuropsychological assessment delineate the performance of these individuals across a variety of cognitive domains. However, the neuropathological deterioration seen in individuals with MCI begins prior to the onset of observable or measurable effects on behaviour (Morris, et al., 2001). This suggests that current behavioural measures may not be sensitive

enough to detect the underlying brain atrophy (Brooks, Iverson, Holdnack, & Feldman, 2008). Therefore, there is a need to develop new measures capable of identifying early cognitive changes. Consequently, knowledge of the underlying neuropathology of MCI should inform the assessment and diagnostic process, including in the development of more sensitive measures.

Memory in MCI

In terms of the neuropsychological expression of MCI, memory has received the most attention. This is unsurprising given the evidence that the brain structures critical for memory, particularly episodic memory, (e.g., the hippocampus) are affected prior to a diagnosis of AD (Braak & Braak, 1995). This research has led to the finding that episodic memory impairment is a cardinal feature of MCI and an impending dementing disease (Bäckman, et al., 2001). However, there are subtleties to these impairments that can aid in the process of predicting cognitive decline. It has consistently been found that the ability to learn and recall verbal information over several consecutive trials is one of the best, and possibly earliest neuropsychological, indicators of impending AD (Jacobs, et al., 1995; Tian, Bucks, Haworth, & Wilcock, 2003). This is supported by findings that show verbal episodic memory impairments in MCI patients similar to those found in mild AD, while measures assessing other cognitive domains are at the level of healthy older controls (Petersen, et al., 1999). Furthermore, these deficits in verbal memory occur prior to impairments in visual memory, which in turn occur prior to global cognitive decline (Fox, et al., 1998). More specifically, impairments in delayed memory are likely to be greater than for immediate memory, which is consistent with the view that individuals with MCI may fail to transfer information from temporary storage into a more permanent memory representation (Bäckman, et al., 2001). Neuropsychological batteries examining these functions have been recommended in identifying patients with dementia,

particularly in populations at increased risk of cognitive impairment, such as those with MCI (Petersen, et al., 2001). Despite the extensive evidence of disruptions in memory in this population, until recently, prospective memory has received very little attention.

Prospective Memory

Prospective memory (PM) is the term used to describe the ability to remember to perform future actions or 'remembering to remember'. More specifically, prospective memory, also referred to as 'intentionality', involves the execution of delayed intentions (Brandimonte, Einstein, & McDaniel, 1996; Kliegel, McDaniel, & Einstein, 2008). It allows us to direct our cognitive resources in the pursuit of future actions we need to perform at a later time such as paying a bill, taking medication or calling someone. PM is therefore crucial to the maintenance of functional independence and is more closely associated with deficits in activities of daily living, instrumental activities of daily living, and caregiver burden than retrospective memory failure (G. Smith, et al., 2000). Memory failure of this type is also common in everyday life, and it has been found that nearly half of all memory failures involve the forgetting of intentions versus forgetting information learned (Crovitz & Daniel, 1984; Terry, 1988). In later life, prospective memory is needed to keep business appointments, pay the bills on time, or send a birthday card to a friend (McDaniel, Einstein, & Rendell, 2008).

More important than the social and professional consequences of prospective memory failures, the decrease of prospective memory performance can be life threatening, especially in adulthood and late adulthood, because of the high demands on prospective functioning when following medical regimes and in health behaviour (e.g. remembering to take the correct pills at the appropriate time of day, or to adhere to the administered diet; Wilson & Park, 2008). Indeed, impaired prospective memory abilities may be associated with non-adherence to a medication

regime independent of well-established risk factors including standard neuropsychological assessments, psychiatric comorbities, and demographics (Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012). It is, therefore, of considerable concern that PM is often disrupted in the context of normal adult aging (Henry, et al., 2004) and to an even greater extent in dementia, even in the mild and preclinical stages (Martins & Damasceno, 2008; Duchek, et al., 2006; Jones, et al., 2006). More specifically, impairment of PM has been observed early in the course of AD (Huppert & Beardsall, 1993; Maylor, Smith, Della Sala, & Logie, 2002). Moreover, failure on a PM task has been found to be more accurate than traditional tests of retrospective memory in discriminating between persons in the very early stage of dementia and healthy subjects (Huppert & Beardsall, 1993). Based on these documented associations between PM and the early stages of dementia, a clearer understanding of this ability, especially in these populations, is needed.

Prospective Memory Processes

Though the term PM appears to represent a unitary process, PM is actually an umbrella term that refers to the complex cognitive processes involved in retrieving and executing a previously formed intention at the appropriate time in the future (Ellis & Freeman, 2008; Kvavilashvili & Ellis, 1996). The integration of these cognitive operations in PM has been subdivided into a number of steps in order to represent the process of prospective remembering (Ellis, 1996). Kliegel, Martin, McDaniel and Einstien (2002) proposed a four phase process model of PM: intention formation, intention retention, intention initiation, and intention execution, although others have combined the last two phases (e.g., Carey, Woods, Rippeth, Heaton, & Grant, 2006).

The initial stage is intention formation (e.g., “I will buy milk on the way home from work”), which requires knowledge of the potential factors that could hinder performance

(Burgess, Veitch, de Lacy Costello, & Shallice, 2000). Embedded in this stage is encoding of the action to be carried out at the appropriate time and generation of a plan of this action. The next stage, intention retention, involves a retention interval during which attentional resources are allocated to another ongoing task, which precludes the continuous rehearsal of the encoded intention. The intention initiation phase then occurs at the appropriate point in which the action should be implemented. The ongoing activity must be interrupted at this stage in order for the realization of the intention to occur. The final stage, intention execution, involves the execution of the action plan (Carey, et al., 2006). This stage is performed without the individual being put in a retrieval mode by an external agent, as in many retrospective memory tests (Einstein et al., 2005).

Importantly, during the intention retention phase, despite the lack of ongoing rehearsal, it is thought that the intention must be kept in active memory in some form, which may or may not require voluntary attentional resources (Guynn, McDaniel, & Einstein, 2001; Smith, 2003). In order to assess whether the circumstances are appropriate for the performance of the intended action, various processes may be used for monitoring depending on the nature of the association between the cue and the action to be performed (McDaniel & Einstein, 2000). These processes have been hypothesized to involve strategic monitoring, relying on executive control processes of the frontal lobes, and/or more involuntary automatic associative memory systems, subserved by medial temporal (e.g., hippocampal) structures. This distinction is explored further below (see Monitoring Theories of PM).

The stages of this model can be observed in many daily activities. For example, if one wants to remember to purchase milk at the grocery store on the way home from work (intention formation), the intention must be maintained in memory throughout the course of the day at work

(intention retention). Subsequently, on the way home, one has to remember to take the appropriate turn to the grocery store (intention initiation) and purchase the milk at the store (intention execution).

Overall, prospective remembering is proposed to consist of two distinct components, a prospective and a retrospective component. The prospective component refers to the self-initiated retrieval of the intention to be performed in response to the appropriate cue. The retrospective component refers to retrieval of the content of the task; this includes the action to be performed as well as the appropriate context to execute the action (Einstein, Holland, McDaniel, & Guynn, 1992; Ellis, 1996; R. E. Smith & Bayen, 2006). Studies typically attempt to simplify the retrospective memory requirements on tasks of PM in order to ensure that errors in recall on PM tasks are not due to failures in recalling the content of the task (Ellis & Kvavilashvili, 2000). This is intended to allow for a clearer focus on the variables that influence the prospective component, beyond retrospective memory. However, there are examples in which the distinction between the retrospective and prospective components is blurred and it is necessary to include the study of the retrospective component (Maylor, Darby, Logie, Della Sala, & Smith, 2002).

Regardless, it is clear that prospective memory is not a unitary process, but rather is composed of multiple stages of operation, each relying on various cognitive abilities, including higher order cognitive processes necessary for planning, inhibiting, switching, and executing the action (Ellis, 1996; Kvavilashvili & Ellis, 1996; Martin, Kliegel, & McDaniel, 2003). More precisely, if the PM task is broken down into several steps, the formation of the intention would also involve the capacity to plan and initiate (Kliegel, McDaniel, & Einstein, 2000), while the steps involving the maintenance and execution of the intention require cognitive flexibility and

inhibition (Cockburn, 1995).

Prospective Memory Tasks

In order to represent this structure, it is suggested that PM tasks should be composed of at least three characteristics (Ellis & Kvavilashvili, 2000). First, there should be a delay filled with an ongoing activity between encoding an intention and the opportunity to retrieve it (precluding ongoing rehearsal of the intention). Second, there should not be an explicit prompt to signal the execution of the intention, thereby ensuring that the task requires self-initiated retrieval processes. Third, the participant should need to interrupt an ongoing task in order to perform the action.

Current investigations of PM typically use a dual-task situation in the laboratory to implement these attributes. Einstein and McDaniel (1990) were among the first to present such a paradigm consisting of a PM task and an ongoing activity. The ongoing task required participants to remember the words presented on a display and was intended to prevent participants from continuous rehearsal of the intention. The prospective task involved responding when the word "rake" occurred on the display. Consequently, participants had to interrupt performance of the ongoing task in order execute the intended action. Current laboratory-based studies continue to follow this paradigm while utilizing variations on the ongoing task and the prospective action that needs to be executed in response to a specific cue (e.g., Kliegel, Martin, McDaniel, & Einstein, 2004; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Yet, much as the various steps and abilities involved in successful PM performance have come to be better understood, the distinguishing features of PM tasks themselves have also been further elucidated.

Prospective Memory - Subtypes

Firstly, according to Einstein and McDaniel (1990), a broad distinction can be made

between PM tasks depending on the nature of the condition that triggers execution of the action: event-based and time-based. In an event-based task, the cue is an event that signals the activation of the intention. For example: "When the timer sounds (event), I will remove the egg from the boiling water." In this situation, an external event (the timer) can be seen as the external cue that prompts initiation of remembering to perform the action. Moreover, remembering is only considered successful in the context of the external cue (one should not take the egg out before or too long after the timer). In contrast, time-based tasks must be performed after a period of time has elapsed or at a certain point of time (e.g., taking medication at 6:00pm or in 4 hours). As such, there is no explicit external cue to trigger to the intended action (assuming that an external mnemonic, such as an alarm, is not used); rather, the individual must monitor the time and initiate the action themselves. Successful PM performance on time-based tasks is therefore thought to be highly dependent on self-initiated monitoring processes (Harris & Wilkins, 1982).

The degree of reliance on self-initiated processes needed to facilitate retrieval has been suggested to be a key feature in explaining inconsistency in the findings with respect to age-associated changes in PM. Variability in the degree of strategically deployed cognitive resources was first delineated by Craik (1986). A hierarchy of memory tasks was proposed, based on the amount of environmental support and self-initiated activity. In this model, procedural memory involves a highly supportive environmental structure and few self-initiated activities. As the level of contextual support decreases and self-initiation increases, the hierarchy moves from “Relearning” to “Recognition” to “Cued Recall” and to “Free Recall”, culminating with “Remembering to remember” (i.e., prospective memory). In relation to age effects, it is assumed that tasks relying mostly on self- initiated operations may require more processing resources (Hasher & Zacks, 1979). It has been suggested that older adults may have decreased processing

resources (Salthouse, 1991), and that this may account for declines in tasks with high self-initiation in older adults (Craik & Byrd, 1982). As PM is thought to involve a high level of self-initiation and is therefore considered to be very resource-demanding, it may be more sensitive to developmental processes and cognitive impairment. Prior to examining the developmental trajectory of PM in older adults, it is first necessary to examine the cognitive processes that are associated with this ability.

Prospective Memory and Associative Processes

Not surprisingly, given the complex steps involved in successful performance, PM is supported by a number of other cognitive abilities. It is important to gain an understanding of the cognitive mechanisms associated with PM; research has suggested that PM is amenable to targeted intervention efforts if the component processes of PM failures are taken into account (Raskin & Sohlberg, 2009). The role of executive functions in PM is indicated by numerous neuro-imaging studies (see above) that highlight frontal lobe involvement in PM tasks. Indeed, a review of various neuroimaging studies concluded that processes associated with PM including training, maintenance and execution of an intention rely on the pre-frontal cortex (Burgess, Gonen-Yaacovi, & Volle, 2011). Furthermore, this finding was consistently found regardless of several associated variables such as the type of concurrent task, the type of cue or the specific intention. Marsh and Hicks (1998) have also demonstrated that executive functions play a role in PM for event-based tasks. In addition, this study also showed that the involvement of working memory in PM tasks increases along with the amount of processing required for the concurrent task during the retention interval such that more difficult concurrent tasks (i.e., those showing increased allocation of frontal lobe resources) resulted in a decline in PM performance. Overall, age-related differences in PM appear to be partially mediated by cognitive resources such as

processing speed, inhibitory control, and working memory. As a result, cognitive declines in these abilities need to be understood, because they are likely to have an impact on PM.

Effect of Normal Aging on General Cognition

A large number of studies on cognitive aging have consistently demonstrated that several cognitive functions associated with PM such as processing speed, inhibitory control, attention, and working memory (Salthouse, 1991; Marsh & Hicks, 1998; Uttl, 2006; West & Craik, 2001; West, Krompinger, & Bowry, 2005), are affected by normal aging. First it, seems clear that processing speed decreases with aging, as a decline in this domain has been observed in numerous studies (e.g., Rogers, Hertzog, & Fisk, 2000). Thus, in some timed tasks, older adults may fail primarily as a result of reduced processing speed compared to younger adults; age has been shown to have a greater impact on this domain than even executive functioning (Albinet, Boucard, Bouquet, & Audiffren, 2012). Studies investigating the relationship between processing speed and PM have found that the two have an important association (Zeintl, Kliegel, & Hofer, 2007).

Second, studies report a decrease in the efficiency of working memory with age (for a review, see Reuter-Lorenz & Sylvester, 2005). According to the view that monitoring is always required for PM retrieval, associations between working memory capacity and PM should be expected (McDaniel & Einstein, 2007). This suggests that PM abilities can be impacted by decreases in working memory efficiency with age, including a reduction of the working memory span (Verhaeghen, Marcoen, & Goossens, 1993). Indeed, many studies have found a reliable association between working memory and PM (Cherry & LeCompte, 1999; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Kliegel, Mackinlay, & Jager, 2008; Reese & Cherry, 2006; Smith, 2003). However, some studies have not found this relationship (Kidder, Park, Hertzog, &

Morrell, 1997; Park, et al., 1997; West & Craik, 2001), though these disparities may be attributable to differences in the engagement of monitoring processes, which is discussed below (see *Models of Prospective Memory*; McDaniel & Einstein, 2007).

Third, attention is another cognitive process that decreases with age, including both divided and selective attention (Verhaeghen & Cerella, 2002). Moreover, according to Craik and Byrd (1982), cognitive functions are particularly influenced by a deficit of attentional resources when the processing of information requires controlled operations, as in PM tasks (Marsh & Hicks, 1998). The role of attentional processes in PM has repeatedly been demonstrated in studies showing a decrement in performance of the ongoing task whilst maintaining an intention in mind (for a review, see Smith, 2008). In addition, the rostral pre-frontal cortex, an area that may play a role as an attentional gateway in attending to prospective cues by controlling attention towards stimulus-independent thought versus stimulus-oriented attending, is associated with PM performance (Benoit, Gilbert, Frith, & Burgess, 2012).

Last, in discussing the individual cognitive functions associated with aging, memory has undoubtedly been the most thoroughly studied. There is a multitude of research investigating the evolution of different types of memory during aging. Using various types of materials and tasks, studies have found a decline in episodic memory including shallower processing during encoding as well as difficulties with retrieval in older adults (e.g., Nyberg, Lovden, Riklund, Lindenberger, & Bäckman, 2012; Shing et al., 2010). Declines in implicit memory for complex material requiring more attentional resources have also been highlighted (Lemaire & Bherer, 2005). Findings are less consistent with respect to procedural and semantic memory, with some studies finding relatively small changes from early to late adulthood (Bäckman, Jones, Berger, Laukka, & Small, 2005), while other studies find no change with age (Churchill, Stanis, Press, Kushelev,

& Greenough, 2003). Interest in the evolution of PM abilities has begun to expand in the last ten years and some interesting findings have emerged revealing, again, that PM is not a unitary process defined by a uniform decline.

Prospective Memory and Aging

As discussed above, the cognitive functions associated with PM performance are more or less reduced during aging, and it is assumed that these would contribute to an age-related decline in PM. However, initial studies of PM frequently failed to identify the expected declines thought to be associated with aging (e.g., Einstein & McDaniel, 1990; Maylor, 1990) and comprehensive reviews have revealed inconsistencies in studies investigating the hypothesis that PM abilities decline with age (Henry, et al., 2004; Kliegel, Jager, & Phillips, 2008; McDaniel et al., 2008; Phillips, Henry, & Martin, 2008). Einstein, McDaniel, Richardson, Guynn & Cunfer (1995) suggested that the initial lack of age-related differences identified in PM may be attributable to a lack of a thorough understanding of PM rather than a lack of age-related processing deficits in this domain. Indeed, the initial distinction between event and time-based PM was motivated by studies showing no age-related deficits in event-based PM (Einstein & McDaniel, 1990; Einstein et al., 1995) while deleterious effects of age were found in time-based PM tasks (d'Ydewalle, Bouckaert, & Brunfaut, 2001; Einstein, et al., 1995; Jager & Kliegel, 2008). These findings were consistent with the suggestion that detection of age-related declines in PM is associated with engagement of self- initiated retrieval processes (Mantyla & Nilsson, 1997).

Time-based PM tasks would require self- initiated processes whereas event-based tasks rely on more automatic processes, suggesting that there may be a decline associated with self-initiated processes (Einstein, et al., 1995). In examining a seminal study by Einstein & McDaniel (1990), the results were consistent with this view and did not support a unitary decrement in PM

performance with age. In their study, participants (aged 17 - 24 and 60 - 78) performed a traditional dual-task PM paradigm. A short- term memory task was used as the ongoing task, while the PM task was embedded within the ongoing task and required the participant to press a button in response to certain target words appearing on screen. As would be hypothesized on the basis that declines in self-initiated retrieval processes may lead to declines in PM abilities, results revealed no age-related decline in the performance of this event-based PM task; the researchers suggested that these types of tasks may not produce large age-related effects. Given the variability in results of studies examining age-related declines in PM, along with the variety in the structure of PM tasks, researchers began looking for task characteristics that could account for these findings.

Eusop-Roussel and Ergis (2008) distinguish three characteristics that can help to further elucidate the variability in results of PM studies, all of which can be influenced by self-initiated and automatic processes: the salience of the cue (salient cue: automatic retrieval, non-salient cue: self-initiated retrieval), the relationship between the retrieval cue and intention (strong association: automatic retrieval; weak association: effortful, self-initiated retrieval) and the type of task (event vs. time-based).

First, regarding the effect of the salience of the retrieval cue, several studies have shown that older adults perform as well as younger adults when a salient cue is used such that the subject relies on automatic retrieval processes (i.e., a strong link between cue and retrieval). Older adults are, however, less efficient than younger subjects when the retrieval cue is less salient (e.g., a highly typical word) (Cherry et al., 2001). Second, the work of McDaniel et al. (2004) studying the PM performance of younger adults also seems to show that the type of retrieval depends on the strength of the relationship between the retrieval cue and intention. With

respect to the third type of effect, as discussed above, several studies have shown a slight differential effect of age (with lower performance in older adults) in PM tasks involving time-based actions (d'Ydewalle, et al., 2001; Einstein, et al., 1995). Again, differences on time- based PM tasks may reflect impairment in self-initiated retrieval processes in this population.

However, studies differ with respect to the effect of age on event-based PM tasks, with some studies finding no age effect (Einstein & McDaniel, 1996), while others showed impaired performance in older adults compared to younger adults (Cherry & LeCompte, 1999; Dobbs & Reeves, 1996; Maylor, 1996; West & Covell, 2001). It is possible that the procedures used in these studies are not homogeneous, that is, that some PM tasks involving event-based actions involve more effortful, controlled monitoring processes than others. In their meta-analysis, Henry et al. (2004) indeed comment on the effect of this factor on older adults' performance. Furthermore, they note that the demands on effortful monitoring or executive processes of the frontal lobe are an important factor in detecting age-related decline.

Consistent with this suggestion, findings have shown an age-related decline on tasks that are more cognitively demanding and require increased attentional resources (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003; Einstein, Smith, McDaniel, & Shaw, 1997; Mantyla, 1994; Maylor, 1996). Studies using tasks that are less cognitively demanding or require fewer resources of the frontal lobe, have not demonstrated differences to the same extent between younger and older adults as those using more demanding tasks (d'Ydewalle et al., 1999; Kliegel, et al., 2000; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999). On the basis of these findings, it has been suggested that initial studies of aging and event-based PM, that did not show age- related declines, may not have been using PM tasks that engaged individuals' self-initiated monitoring processes. This may have resulted in an absence of consistent evidence for a decline

in these processes, as opposed to evidence for an absence of a decline. Taken together, clarification is still needed with regard to the development of prospective memory abilities in adulthood and old age. As a result of these disparate findings and the resultant exploration of factors that can account for them, several useful models of PM have emerged.

Models of Prospective Memory

Current models of PM that have been used to explain the disparate findings, described above, differ primarily in their explanations of the mechanisms of retrieval of an intended action. First, there could be continuous monitoring of the environment for cues or markers associated with the intended action, which would require the allocation of executive resources (Smith, 2003). According to this account, retrieval of the intended action is a voluntary, strategic process in which the environment is monitored for a target cue while being engaged in the ongoing activity (Ellis, 1996). Following this rationale, prospective remembering is dependent on available cognitive resources. In contrast, the intended action could be periodically brought online in order to maintain the activation of the cue-intention association such that when the triggering event occurs, it can be more readily activated. Based on this explanation, an involuntary associative memory system enables relative automatic retrieval of the delayed intention (Guynn, et al., 2001). This relatively automatic retrieval, therefore, does not require strategic monitoring for the cue and requires fewer cognitive resources for successful prospective remembering. These contrasting explanations for the retrieval of delayed intentions will be further elaborated before discussing a model that attempts to align the two approaches.

Monitoring Theory

Despite the potential differences in monitoring processes, a key shared assumption is that executive resources are set aside to be available to monitor the environment for cues.

Specifically, attentional resources are voluntarily allocated to strategically monitor for environmental conditions (the cue/event that triggers the intended action) and/or periodically bring to mind the intended action. Several studies have supported this view by demonstrating that response times on non-target trials of the ongoing task are slowed when participants hold a delayed intention in mind (Einstein, et al., 2005; Smith, 2003). These slowed response times, termed the PM task interference effect, are thought to reflect the re-allocation of limited capacity cognitive resources from ongoing task performance to monitoring for PM targets.

Smith (2003) provided support for the assumption of a re-allocation of resources using a PM task by showing that speed of responding on the ongoing task was significantly slowed, even on trials for which the PM cue did not appear, compared to control trials performed without PM instructions (but see McNerney & West, 2007 for conflicting results). Furthermore, the magnitude of the PM task interference effect is associated with the percentage of PM targets detected, suggesting a functional relationship between the interference effect and detection of PM targets (Smith, 2003). Evidence for this functional relationship is provided by results showing that response times on non-target ongoing trials preceding a PM miss were faster than trials preceding a PM hit (West, et al., 2005). This pattern of results suggests that a disruption in preparatory attentional monitoring, associated with faster ongoing response times, predicted subsequent PM misses. Together, these findings imply that attentional resources are being strategically allocated to monitor the environment for the PM cue, thereby reducing the cognitive resources available to perform the ongoing task.

In contrast with monitoring theories, some authors have suggested that, in certain circumstances, PM cue detection can be triggered relatively automatically, in the absence of deliberate preparatory attentional monitoring (Einstein, et al., 2005; Knight et al., 2011; Scullin,

McDaniel, & Einstein, 2010; Scullin, McDaniel, Shelton, & Lee, 2010). According to these accounts, target monitoring can still play a part in prospective remembering, but it need not be mandatory. This alternative theoretical approach posits that an involuntary associative memory system enables relatively spontaneous, automatic retrieval of the intended action (Guynn, et al., 2001). This system is assumed to bring to mind information (i.e., the intended action) associated with attended environmental stimuli. It engages when a cue triggers the associative memory system to rapidly, automatically deliver to consciousness the information previously associated with the cue during encoding (Moscovitch, 1994).

The key difference suggested with the theoretical approach focusing on spontaneous retrieval is that the automatic processes are thought to require few cognitive resources, especially compared to the strategic monitoring approach. That is, according to this approach, strategic monitoring for the target is not required in event-based PM. In order to understand the validity of these theories of monitoring in PM, studies investigating the developmental trajectory of PM have been undertaken and those investigations with older adults have revealed significant dissociations between types of PM (e.g., event and time-based PM). These studies have led to the formulation of another model of PM that attempts to integrate the monitoring processes proposed to account for retrieval of intended actions as well as account for the discrepant findings in studies of age-related changes in PM.

Dynamic Multiprocess Theory

In introducing their highly influential framework, McDaniel & Einstein (2000) have proposed a number of critical factors related to event-based PM that can be used to attempt to explain the lack of consistent declines found on these tasks in older adults. This framework has a particular focus on the degree of attentional resources that are allocated to monitoring for the PM

cue and executing the action. As described, PM tasks do not involve an external agent making a request for a memory search (as in laboratory tasks of retrospective memory). Instead, the recall of the intended action at the appropriate time is triggered without an external agent signaling retrieval. This framework attempts to explain how this is accomplished by focusing on event-based PM, though certain aspects of the model are clearly relevant to time-based PM tasks as well.

As a way to understand the discrepant results in studies of age-related changes using event- based PM tasks, variability in the reliance on self-initiated retrieval processes is proposed a key feature. In the *multiprocess framework,* McDaniel and Einstein (2000) suggest that aspects of the PM task determine the type of monitoring needed, with strategic monitoring requiring increased reliance on self-initiated retrieval processes compared to automatic retrieval processes. This implies that neither model of PM cue monitoring can wholly account for the relevant findings. Instead, this framework integrates both approaches to PM cue monitoring suggesting that PM intention retrieval can be either strategic or automatic. Though the original framework posited that individuals relied on either of these retrieval strategies for prospective remembering, it is now suggested that reliance on spontaneous retrieval or monitoring is a dynamic process within individuals (Scullin, McDaniel, & Shelton, 2013). More specifically, the Dynamic Multiprocess Theory (DMPT) proposes that these retrieval processes may be interconnected and operate in a dynamic manner to support PM and that engagement of these distinct processes depends on factors that relate to the ongoing task and to the cue that triggers the action.

With respect to the ongoing task, the relationship between the cue and the intention (i.e., the focality) as well as the complexity of the ongoing task and the associated amount of cognitive resources required for the task are proposed as factors that determine the amount of automatic

versus controlled processes recruited when performing a PM task. With regard to the cue-related factors, the degree of association between the cue and intended action as well as the distinctiveness of the cue are proposed to impact PM performance. In addition to these aspects, planning of the prospective task, motivation, and individual differences are also thought to affect retrieval processes. The current study will focus on an evaluation of two of the factors: (1) the association between cue and intention, and (2) the association between cue and action.

Given the variable degree of controlled processing that is required, greater age differences are expected in cases where strategic retrieval is necessary, because cognitive resources are recruited to monitor for the appropriate situation to perform the prospective task. In these situations, people with fewer cognitive resources (e.g., older adults, Brown & Park, 2002) would be expected to be less successful on PM tasks. In contrast, age differences should be attenuated in PM tasks that facilitate automatic retrieval, because the retrieval processes recruited for these tasks do not make as many demands on the person's cognitive resources.

With regard to ongoing task-related characteristics, cue focality relates to the level of integration of the prospective cue within the processing of the ongoing task. In the case of focal cues, the cue is thought to be part of the information that is extracted in the course of performing the ongoing task. For example, if the ongoing task requires participants to identify whether a word is part of a higher order category, a focal cue may be a particular word since the ongoing activity requires processing of the words (McDaniel & Einstein, 2011). As an everyday example, one has to remember to buy milk while engaged in shopping in a grocery store. When the ongoing task involves selecting grocery items, the recall of a specific grocery item can be considered focal to the ongoing task as it is consistent with the information being processed during the ongoing task.

The multiprocess framework suggests that in focal PM tasks, processing the cue as part of the ongoing task is sufficient to allow spontaneous, automatic non-resource-demanding retrieval of the intended action. Conversely, in the case of non-focal cues, the cue is presented within the ongoing task but does not overlap with the information that is extracted in order to successfully perform this task. For example, if the ongoing task again required participants to identify whether a word was part of a higher order category, a non-focal cue may be a specific syllable since syllabic processing is not essential to the ongoing task. As an everyday example, one may have to remember to buy milk while engaged in a conversation with a friend on the drive home. These non-focal tasks are assumed to require resource-demanding strategic processes in order to perform the additional monitoring for the cue (Kliegel et al., 2008; McDaniel, et al., 2008). As a result, age effects are expected for PM tasks with non-focal cues due to the more effortful, strategic monitoring processes. In contrast, age effects are assumed to be attenuated or non-existent in the case of focal tasks requiring primarily automatic processes.

The predictions of the multiprocess theory related to cue focality were examined in a study by Einstein et al. (2005) (see also Scullin, McDaniel, Shelton, & Lee, 2010). Results of this study showed that participants were significantly slower to perform the ongoing task when non-focal PM cues were embedded, whereas no significant costs were observed (i.e., no significant increase in reaction time) when focal cues were used (relative to the control condition that involved only the ongoing task). The response costs in the ongoing task in the non-focal condition were found to be directly associated with detection of PM cues and to decline over time during the task. Consistent with the multi-process framework, the ongoing task costs found in the non-focal condition, as well as their decline over time, were interpreted as evidence for effortful, strategic monitoring processes. Similarly, the lack of costs to ongoing task performance

in the focal condition, along with high PM performance, suggested automatic, spontaneous retrieval processes without the need for resource demanding monitoring processes.

McDaniel and Einstein (2007) also conducted a review of event-based PM studies and classified each according to the use of "focal", "non-focal", and "indeterminate" PM cues. The findings suggested that age-related declines were larger for non-focal than focal cues. Others have argued this review did not provide evidence that age-related declines are actually absent with focal cues as the authors suggest, as a result of methodological factors related to the tasks and samples used. However, additional analyses taking into account methodological limitations such as ceiling effects and age confounds (e.g., intelligence, ongoing task difficulty) continued to reveal differences in the magnitude of age-related declines according to the focality of the cues, which supports the continued evaluation of these differences (Uttl, 2011). Furthermore, other researchers have supported have supported McDaniel's and Einstein's framework.

Using a lexical decision task in which the cues were either highly related to response words or had no relation, Loft & Yeo (2007), found support for the multiprocess view. Specifically, in the low association (i.e., non-focal) condition , PM was more dependent on the allocation of resources immediately prior to cue presentation compared to the high association (i.e., focal) condition. Similarly, the high association (i.e., non-focal) condition was found to be more resource-demanding, because it engaged more processes on cue trials compared to the low association (i.e., focal) condition.

The results of these studies also support the assertion of the multiprocess theory that separate brain networks are engaged in PM performance depending on the relative focal or non-focal nature of the task (McDaniel & Einstein, 2011; McDaniel & Einstein, 2007). Recent work directly examining the structural correlates in performing focal and non-focal tasks has also

supported the relationship between PM behaviour and underlying brain structures proposed by the multi-process theory (Gordon, Shelton, Bugg, McDaniel, & Head, 2011). In particular, a strong relationship between the medial temporal lobes and performance on a focal PM task, independent of age and cognitive status, was found, while such a relationship was not apparent for non-focal PM performance. Notably, Significant associations between non-focal PM performance and ventrolateral/dorsolateral prefrontal cortices were not observed in this study. However, this finding was thought to reflect the poor behavioural performance on this task overall in addition to the low number of PM target trials. A low number of target trials may have prevented a reliable estimate of reaction time for use as a dependent measure (a common issue in PM tasks that will be discussed below; Uttl, 2011).

A more recent study examining the behavioural and event-related potential (ERP) correlates of the processes involved in focal and non-focal PM tasks also showed results supporting the multiprocess view for both focal and non-focal tasks (Cona, Bisiacchi, & Moscovitch, 2013). Strategic monitoring, associated with slowed reaction time on ongoing task trials and with frontal and parietal ERP modulations, was greater for the non-focal than the focal task. There was also evidence that detection of the PM cue may occur automatically in focal PM tasks, as suggested by an increase for the FN400 in focal trials. The FN400 has been proposed to be associated with familiarity and automatic retrieval (Curran, 2000; Jennings & Jacoby, 1993), though it has also been argued to reflect conceptual implicit priming (Voss, Lucas & Paller, 2012). In contrast, non-focal trials were associated with a slower return to baseline of the prospective positivity (this positivity occurs at approximately 600-700 ms and is associated with post-retrieval monitoring (West, McNerney, & Travers, 2007)) and frontal slow wave. These findings suggest that non-focal tasks are supported by more controlled, effortful retrieval

resources.

Similar results were found in a meta-analysis of neuroimaging studies examining the effects of cue focality on the neural mechanisms associated with PM (Cona, Bisiacchi, Sartori, & Scarpazza, 2016). The meta-analysis revealed several differences in brain activity as a function of focality of the PM cue. The focality-related pattern of activations was interpreted as suggesting that PM in non-focal tasks is mediated mainly by top-down and stimulus-independent proceses, whereas in focal tasks, more automatic, bottom-up processes are relied on. Taken together, the differences identified in ERP and neuroimaging studies support the assertion that different retrieval processes underlie the recognition of the PM cue in focal and non-focal PM tasks.

Further to the cue-related aspects, the association between the cue and the intended action can have an important impact by similarly facilitating either more resource-demanding, strategic processes or automatic associative memory based processes (McDaniel & Einstein, 2000). A weak association between cue and action is suggested to facilitate the former and a strong association the latter. For example, remembering to buy milk on the way home from work is expected to require less effort if passing a grocery store rather than a post office. As an example of a laboratory task, participants can be asked to write down the word “sauce” whenever the word “spaghetti” is presented (high association condition) or write the word “needle” when “spaghetti” is presented (low association condition). Results of a study using such a task have found that PM performance was significantly better when there was a high degree of association between the cue and intended action (McDaniel, Guynn, Einstein, & Breneiser, 2004). Similar to the focality of the cue, a high degree of association is assumed to attenuate age differences due to increased reliance on automatic retrieval processes.

Overall, the multiprocess approach of McDaniel and Einstein (2000) provides a useful framework to further explore the evolution of prospective memory mechanisms in older age and in people with cognitive impairment. The factors discussed above may offer explanations for the age effects observed in PM tasks. As such, tasks that facilitate spontaneous, automatic retrieval of intentions should attenuate age effects, while tasks that induce strategic resource-demanding monitoring processes should result in increased age effects due to the changes in available cognitive resources in older adults (Salthouse, 1991). However, these hypotheses become more complicated when considering people with MCI who, in addition to having the cognitive changes associated with aging, have also been shown to have specific changes in the brain in the areas associated with the retrieval processes discussed above.

Mild Cognitive Impairment and Prospective Memory

Previous studies comparing patients with MCI with control groups of older adults without cognitive impairment have demonstrated that PM is disrupted in patients with MCI (e.g., Blanco-Campal, Coen, Lawlor, Walsh, & Burke, 2009; see Costa, Caltagirone, & Carlesimo, 2011 for review; Thompson, Henry, Rendell, Withall, & Brodaty, 2010). As indicated above, individuals with MCI are typically characterized by memory deficits including deficits of declarative memory. Studies examining this aspect in relation to PM have found that failures in retrospective remembering can significantly impact the PM performance of these individuals (Costa et al., 2011; Costa et al., 2010; Karantzoulis, Troyer, & Rich, 2009; Thompson, et al., 2010), by interfering with either the recognition of the target cue or retrieval of the intended action.

However, there is also evidence demonstrating that deficits in PM performance in these participants cannot solely be attributed to retrospective memory impairments. Blanco-Campal and colleagues (2009) had people with MCI and healthy older adults perform two traditional

retrospective memory tests (Word List and Short Paragraph recalls) as well as an event-based PM task. The PM task involved having the participants say the word "animal" aloud when they encountered either a specific animal (e.g. "lion"; specific condition) or any type of animal (non-specific condition) in the course of performing a lexical decision task (i.e., the ongoing task). The salience of the cue was also varied in both conditions (i.e., target words written in italics in the salient condition and target words in the same font as the lexical decision task in the non-salient condition). Results revealed that the PM task had greater sensitivity and specificity (84% and 95%, respectively) in identifying individuals with MCI than all other traditional declarative memory tests administered, including both immediate and delayed recall conditions.

A similar study directly compared the retrospective and prospective components of a PM task (Costa, et al., 2010). In this task participants were asked to execute three unrelated actions (e.g., tell the examiner to turn off the computer; write their name on a sheet of paper; replace the telephone receiver) in response to either a time-based or event-based cue. They examined the impact of retrospective memory failure on PM performance by assessing participants' recall of the actions they were instructed to perform in situations in which they failed to autonomously retrieve the intention. Again, the findings showed that people with either amnestic or non-amnestic MCI were more severely impaired on the prospective than on the retrospective component of the PM task. Moreover, the number of MCI participants obtaining a score $\geq$1.5 SD below the mean of the group of healthy controls was significantly higher on the prospective component than the retrospective component (85% and 35%, respectively).

There is further evidence that in people with MCI the rate of failure to execute the intention in a PM task is beyond the memory impairment for the content of the intention itself. In one such study (Schmitter-Edgecombe, Woo, & Greeley, 2009), the ongoing activity for the PM

task was the completion of a variety of cognitive tests in various domains and, as the PM task, at the completion of each one they were required to rate it according to how much they enjoyed the task. Results showed that people with MCI often failed to execute the intention despite being able to recall the PM instructions. Similarly, Thompson and colleagues (2010) found that even after statistically controlling for the retrospective component of a PM task, people with MCI were still significantly impaired at spontaneously retrieving the intention. This same pattern of results has been found when the retrospective memory requirements are reduced by having a single target word as the PM cue (Costa et al., 2011). In this study, healthy older adults executed the intended action over 70% of the time when the target appeared, while those in the MCI group responded appropriately to 50% of targets.

Finally, research has also examined the impact of the executive demands of the PM tasks on the performance of individuals with MCI. Two such studies found more severe impairment on time-based compared to event-based PM tasks. Costa and colleagues (2010), in the study described above, found that individuals with MCI were 80% less accurate than healthy older adults in the time-based condition compared to 40% in the event-based condition. Troyer and Murphy (2007) had participants report the time to the examiner every 30 minutes (time-based) or use a specifically coloured pen when engaging in written tasks (event-based). It was found that, in the context of globally impaired PM abilities, individuals with MCI had more profound deficits in the time-based condition.

The greater impairment on time-based rather than event- based PM tasks may result from the increased degree of self-initiated retrieval posed by this experimental condition (Brandimonte & Passolunghi, 1994; Einstein, et al., 1995; Groot, Wilson, Evans, & Watson, 2002; Maylor et al., 2002; Park, et al., 1997). In contrast, event-based cues serve as environmental supports that

therefore require the allocation of fewer attentional resources (Brandimonte & Passolunghi, 1994; Kvavilashvili, 1987; Marsh & Hicks, 1998; Otani et al., 1997). Furthermore, Blanco-Campal and colleagues (2009) also demonstrated that individuals with MCI perform particularly poorly when the executive demands of the PM task are high. More specifically, the use of a non-specific, non-salient PM cue, which is intended to increase reliance on strategic, executive monitoring processes, showed the largest differences in PM recall between older adults and individuals with MCI. However, notably absent from the list of cue characteristics that encourage strategic monitoring processes is the focality of the cue; this area has only begun to be explored in people with MCI.

Taken together, the results of studies exploring the PM abilities of people with MCI suggest that they may experience a disproportionately severe deficit on these tasks relative to tasks assessing declarative memory. Studies have shown failures to spontaneously activate the prospective intention despite intact retrospective recall of the intention itself in this population. Moreover, these individuals have been found to be particularly impaired on PM tasks that provide minimal contextual support for intention retrieval, thereby involving more executive control processes. However, this last point has not been fully explored, and there is less support for the suggestion that executive impairment underlies the PM deficits observed in individuals with MCI. For instance, in studies by Costa and colleagues (2011) as well as Karantzoulis et al. (2009), no evidence of a significant association between intention retrieval in the PM task and performance on tasks thought to tap executive functioning were found. Furthermore, manipulating the attentional/executive demands of the ongoing task, by having participants reproduce a four-word string either forward or backward, did not impact PM performance of individuals with MCI in the study by Costa and colleagues (2011).

Indeed, these results indicate that, while executive dysfunction may play a role in poor PM performance in this population, this factor alone cannot account for the pattern of observed findings. Instead, the reflexive-associative mechanisms proposed to be involved in response to certain types of cues (e.g., focal cues and strong associations between cue and action) by McDaniel and colleagues (2004; discussed above) may also be contributing to the PM deficits seen in these individuals. In these situations, retrieval is supported by the interaction between the cue event and the memory traces that represent the intended action, with stronger associations facilitating retrieval. These strong associations are established during the encoding of the intention, with poor encoding of the association reducing the cue's effectiveness in triggering the intention. Furthermore, spontaneous prospective memory retrieval (reflected at least in part in focal PM but not non-focal PM tasks) may primarily involve the reflexive associative system that is proposed to be subserved by medial temporal (e.g., hippocampal) structures (Moscovitch, 1994). These brain structures are significantly disrupted in individuals with MCI (Pennanen et al., 2004; Wolf et al., 2004). Specifically, autopsy studies in patients with MCI have suggested increased numbers of neurofibrillary tangles in medial temporal lobe structures (Guillozet, Weintraub, Mash, & Mesulam, 2003) and signs of AD pathology (Bennett et al., 2005) as well as additional tauopathy in cholinergic nucleus basalis neurons (Mesulam, Shaw, Mash, & Weintraub, 2004).

Given the evidence of a weaker declarative memory system in individuals with MCI and alternations in the neural networks supporting these systems (Poettrich et al., 2009), less efficient encoding of the associative link between the cue and intended action may be expected. Similarly, changes to the neurological structures underpinning retrieval may lead to difficulties with two types of PM tasks proposed by the multiprocess framework (McDaniel & Einstein, 2000): those

that support spontaneous, automatic retrieval and those that support effortful, attention-demanding retrieval.

As described above, researchers have attempted to manipulate participants' reliance on the various retrieval processes by altering characteristics of the ongoing task and the cues. However, to date very few studies have directly explored the use of focal and non-focal cues, nor examined differences in the strength of association between actions and cues in individuals with MCI. While previous studies have found no age-related declines with focal cues, in contrast to the identification of significant declines with non-focal cues (McDaniel, et al., 2008; see McDaniel & Einstein, 2007 for review), it may be that disruptions in the brain areas associated with spontaneous retrieval as well as deficits in retrospective memory systems may not lead to the same pattern of performance on these tasks for this population. Indeed, a recent study found different profiles of performance on focal and non-focal PM tasks between individuals with amnestic and non-amnestic MCI (Chi et al., 2014). Specifically, both groups were impaired in focal PM accuracy compared to a cognitively healthy control group, while those with non-amnestic MCI were also impaired in non-focal PM accuracy. These results suggest PM failures in amnestic MCI may be primarily related to impairment of spontaneous retrieval processes associated with the medial temporal lobe system. In contrast, PM failures in non-amnestic MCI may also indicate additional deficits in executive control processes associated with pre-frontal lobe systems. However, the complexity of the processes involved in PM and the tasks assessing this ability necessitate the consideration of some factors that can impact the interpretation of research conducted in this area with individuals with MCI.

Methodological Considerations

Prospective Memory in Naturalistic Situations

An interesting concept has recently emerged suggesting that older adults may be more efficient than younger adults in natural situations. The meta-analysis by Henry et al. (2004) emphasizes that increasing a task's ecological validity improves older adults' performance. Several authors have tried to find explanations for this phenomenon and have examined several factors such as lifestyle or the use of external cues (e.g., Maylor, 1990; Rendell & Craik, 2000). Phillips, Henry and Martin (2008) propose two factors to account older adults' improved PM performance in some situations: motivation to perform the task and the use of cues (external reminders). Indeed, it seems that older adults are more motivated than younger adults to succeed at PM tasks and use more strategies, such as noting the actions to be performed.

Recently, Aberle et al. (2010) used a naturalistic task that required participants to send a message to the experimenter at specific times for five days. In this experiment, they attempted to manipulate motivation by telling participants that they could have one or more entries in a lottery to win money depending on the accuracy of the time they sent the message. The results showed that when the motivation is greater among younger adults, they have a performance similar to the older adults. On the other hand, the older adults exhibit the same results whether or not they are in the motivation condition. This indicates that older adults may have a higher intrinsic motivation, regardless of the situation, which may play a part in their performance. The lack of motivation observed in younger adults may be in part due to frequently having their participation be based on receiving credit toward their degree, while older adults are generally volunteers (Henrich, Heine, & Norenzayan, 2010; see also Maylor, 1996 for discussion of non-cognitive variables that can explain older vs. younger adults' performance on PM tasks in natural settings).

Another important consideration relates to the frequency of PM cues. In typical PM paradigms, PM responses are relatively rare (i.e., a PM response is required at the occurrence of

less than 20% of total stimuli presented) but nonetheless exist on a continuum in terms of the frequency of required responses. To capture the differences in these rates of response, Graf and Uttl (2001) introduced distinctions between subdomains of PM: prospective memory proper, vigilance/monitoring, and habitual PM. They suggest that PM proper involves retrieval processes bringing previously formed intentions back to awareness at the appropriate time and place in order to execute the intention. For example, it is PM proper that brings back to consciousness the plan to buy groceries when approaching the supermarket. In contrast, in the case of vigilance/ monitoring the plan remains in consciousness (Brandimonte, Ferrante, Feresin, & Delbello, 2001; Graf & Uttl, 2001). As an example an air-traffic controller must maintain plans in consciousness, that being to issue instructions to maintain the separation of airplanes, while attending to cues signaling the implementation of the plan. Habitual PM is proposed to be similar to PM proper in that a plan is formed, leaves consciousness and is then retrieved in response to the appropriate cue, but it differs in that the plan needs to be repeatedly brought back to consciousness each time the cue is encountered. For instance, taking medication with breakfast each day is a situation that necessitates habitual PM.

It can be hypothesized that these subdomains may also involve different retrieval processes when considering the multiprocess framework. While studies directly examining this suggestion have not been conducted, Cohen, Jaudas and Gollwitzer (2008) found that there were significant response costs on the ongoing task with three or more PM targets, whereas no response costs were identified with fewer than three PM targets (approximately every 20th trial involved a prospective memory target regardless of the number of targets). It should also be pointed out that this study did not identify significant task interference effects with one or two focal PM targets, thereby providing further support for the multiprocess view.

Furthermore, a recent meta-analysis lends support to the distinctions between PM subdomains (Uttl, 2011). These analyses showed that age-related declines show large differences between PM subdomains and, for focal cues, age-related declines were much larger for PM proper than for vigilance/monitoring. Age-related declines were also identified with non-focal cues in vigilance/monitoring tasks. However, few studies examining PM proper age contrasts using non-focal cues were identified by the review, preventing comparison between these PM subdomains with non-focal cues. In applying the multi-process framework to these subdomains of PM, it can be suggested that as the frequency of responding to PM cues increases, so too may the reliance on spontaneous, automatic retrieval processes rather than effortful, attention demanding processes. The meta-analytic results showing greater age-related decline in PM proper than in vigilance/monitoring are consistent with this assertion. However, a previous study that found a relationship between participants' executive abilities and their non-focal PM performance also showed stronger associations between these abilities and performance on blocks that require more vigilance compared to prospective memory proper (Reynolds, West, & Braver, 2009).

The multi-process view also predicts an interaction between cue frequency and the cue-intention association, such that PM performance in non-focal tasks should be impacted more by manipulations in cue frequency than performance in focal tasks. Specifically, when relying on spontaneous retrieval processes, cue frequency is expected to have a minimal impact. Again, a previous study found that decreasing the frequency of cues had a comparable effect on PM performance in conditions with a high and low association between the cue and intention (Loft & Yeo, 2007). These divergent findings suggest that a study directly examining the impact of these task characteristics in a population with neurological deficits in the areas associated with these

abilities, namely individuals with MCI, would further our understanding of PM processes and the multi-process framework as well as cognitive changes in the MCI population.

Objectives

1) To assess and compare the prospective memory performance of individuals with MCI, early AD, and older and younger adults without cognitive impairment.
2) To determine the extent to which the relation between the ongoing task and the prospective memory cue (Focal vs. Non-Focal) impacts the prospective memory performance of the studied populations.
3) To determine the extent to which performance on Focal & Non-Focal PM tasks is impacted by manipulations in the frequency of PM cues in the studied populations.
4) To determine the impact on PM performance of utilizing an ecologically valid task of PM, which includes high/low associations conditions between the cue and intended action, on the performance of the studied populations.

Hypotheses/Anticipated Results

1) Cognitively healthy younger adults will perform significantly better (i.e., increased PM accuracy and/or reduced interference costs) in non-focal prospective memory task blocks than cognitively healthy older adults who, in turn, will perform better than individuals with mild cognitive impairment and early AD.
2) All groups will perform better on measures of focal prospective memory compared to measures of non-focal prospective memory.
3) Manipulations of the frequency of PM cues will result changes in performance in the non-focal, but not focal, PM blocks (i.e., increased PM performance and reduced

interference costs with more frequent PM cues).

4) Performance on the ongoing trials of the non-focal PM task, as measured by reaction time (response costs), will increase as a function of the number of PM cues, while reaction time in the focal PM task will not be impacted by cue frequency.
5) All groups will perform better on trials of a more ecologically valid PM task when there is a high association between the cue and intended action in the prospective memory task compared those with a low association between the cue and intended action.
6) Cognitively healthy older adults will demonstrate superior PM performance compared to individuals with MCI and early AD in the more ecologically valid PM task.

Contributions of the Studies

Clinical Contributions

The current studies provide substantial contributions to a number of domains. In terms of knowledge gained regarding MCI, the findings of these studies have practical implications in terms of identifying individuals who are in the very early stages of MCI and may progress to Alzheimer's Disease. A recent study found that focal PM performance alone provided sensitive detection of individuals in the very early stages of Alzheimer's Disease (McDaniel & Einstein, 2011). Given the increased rate at which individuals with MCI progress to Alzheimer's Disease (Petersen & Morris, 2005), early identification of these individuals and subsequent early intervention is essential, and can be aided significantly if this measure proves sensitive to MCI.

In addition, examining the performance of individuals with MCI on both focal and non-focal tasks in comparison to older and younger control participants, allowed for an enhanced

understanding of the PM retrieval processes used by people with MCI. Previous studies have predicted no age-related declines with focal cues, though there are significant declines with non-focal cues (McDaniel, et al., 2008; McDaniel & Einstein, 2007). When a PM cue is focally processed, participants may rely on spontaneous retrieval processes to achieve high levels of prospective remembering. The practical implication is therefore that cues should be set up that are likely to be focally processed near the time in which the intention should be executed (e.g., take the pill with dinner). However, studies have not examined these declines using focal and non-focal PM tasks while varying cue frequency with individuals with MCI, a population that may show disproportionate declines on tasks using focal cues because of the neuropathophysiology associated with this condition. By examining both focal and non-focal PM while manipulating the frequency of cues, these studies shed light on the potentially unique declines in PM in individuals with MCI and provide suggestions for studies examining effective strategies for enhancing their PM performance in real life. For instance, these findings can be used to develop strategies to increase medication adherence in a vulnerable population (Schmitter-Edgecombe, et al., 2009).

Theoretical contributions

The studies also explored two major theories that seek to explain PM retrieval. The preparatory attentional and memory process theory of PM assumes that PM retrieval requires resource-demanding preparatory attentional processes, whereas the multiprocess theory assumes that retrieval can also occur spontaneously (McDaniel & Einstein, 2007; Smith & Bayen, 2006). By examining response costs on the ongoing task and comparing younger and older adults without MCI (i.e., longer reaction times implies preparatory attentional processes) the current studies provide further insight into whether preparatory attentional processes are necessary for

PM retrieval. Moreover, the studies investigated whether the same processes occur in individuals with MCI and early AD. These examinations are based on a novel measure of focal and non-focal prospective memory, a task that reduces language processing requirements and, therefore, may be more appropriate for this population.

Finally, the impact of the strength of the association between the cue and the action was explored using a more naturalistic and ecologically valid task, a type of task that may attenuate age-related declines. To this end, we employed a methodology previously used to show differences between individuals with AD and healthy older adults (Maylor et al., 2002): namely, a twenty-minute film simulating a path in a mall through a first person perspective. Participants are asked to remember to perform actions at various locations throughout the mall in response to specific cues (a basic activity of daily living which is thought to require prospective memory). This method includes two types of PM cues, event-based and time-based in a virtual environment. For event-based cues multiple, conditions were tested in which the link between the cue and the target is varied (strong vs. weak link between cue and actions, which simulates focal vs. non-focal cues). Altogether, the findings of this research provide important information to facilitate research into PM as well as studies exploring early diagnosis of and intervention in individuals with MCI and early AD.

Study 1

Participants

A total of 131 individuals participated in this study. Eighty-seven young adults between the ages of 18-31 (M = 20.23, SD = 3.50; 59 females) were recruited through the University of Ottawa Social Sciences and Humanities Integrated System of Participation in Research. Participants were compensated for participation with school credit. Forty-four cognitively healthy older adults, aged 65 and older (M = 70.79, SD = 4.48; 25 females), were recruited from community centres, exercise classes, and advertisements placed in local newspapers, supermarkets, and nursing homes. Withdrawal from the study was permitted at any point with no effect on compensation received. Exclusion criteria included any neurological disorder or medication likely to affect cognitive function, severe ADD or ADHD, major depression and/or low self-reported English language ability. A breakdown of age, education, and the neuropsychological measures is presented in Table 1.

Table 1.
Participants' demographic and neuropsychological characteristics. Scores are given as Mean (Standard deviation).

	Younger adults	Older adults
N (Male:Female)	87 (27:59)	44 (14:25)
Age**	20.23 (3.50)	70.79 (4.48)
Education**	14.00 (1.83)	15.55 (2.80)
MoCA	-	27.60 (1.63)
Digit Span (forward + backward)	-	17.57 (3.75)
Boston Naming Test	-	53.91 (4.98)

Category Fluency	-	20.88 (4.13)
Phonemic Fluency	-	13.86 (4.37)
Stroop Color-Word Interference**	53.43 (12.80)	61.14 (16.14)
Wisconsin Card Sorting Test	3.40 (1.36)	3.88 (1.08)
CVLT total	-	58.00 (9.87)
Logical memory (immediate)	-	26.71 (7.74)
Logical memory (delayed)	-	24.63 (8.35)

* significant at the 0.05 level (2-tailed).
** significant at the 0.01 level (2-tailed).

***The Stroop Color-Word Interference score was calculated by subtracting the time on the word-reading condition from the color-word condition.

Materials

PM Task

This task was created for this study using E-prime software (Psychology Software Tools, Inc., www.pstnet.com). The PM task included two PM conditions (Focal and Non-Focal) each with four different cue frequencies (1, 5, 10, and 20 cues) in addition to the 100 ongoing decision trials as well as a control block of 100 decision trials without any PM cues. For the PM conditions, we embedded a PM task in a numerical decision task. Participants were instructed to remember to press the SPACEBAR key (and type response words) when presented with cues during the numerical decision task.

The control block consists of six initial practice trials plus six additional practice trials with feedback to encourage speed and accuracy (the accuracy and speed of the response were reported on the screen) followed by 100 trials of the ongoing decision task. Each PM block

contained 100 trials of the decision task in addition to the PM trials. The stimuli for each trial were presented on the computer screen for three seconds. Of the 100 trials for each block of testing, 50 yield correct responses to be made with the right hand and 50 yield correct responses to be made with the left hand. Prior to beginning the control block, participants were given the following instructions on the computer, which were also restated verbally:

Equally important in this task are your speed and accuracy in responding to each trial. We are looking at your response time for each pair. Therefore, it is very important that you respond to each trial as quickly and as accurately as you can.

Decision Task: For each trial, two strings of numbers (each with lengths between two and five digits, counter-balanced across trials) were presented on the left and right hand side of the computer screen. Participants were instructed to press the key corresponding to the side of the screen displaying the higher number. Red tape was placed over the "L" and "A" keys on the keyboard to easily identify the keys representing the right and left sides of the computer screen.

Focal PM Task: The PM cue for the focal PM task was when the two numbers differ in their number of digits (e.g., "21" and "142"; 2 digits on the left and 3 on the right). In response to this cue, the participant was to press the spacebar after responding to the decision task. This task is considered focal as the decision task itself requires determining which number is larger (Kliegel, Jager, and Phillips, 2008).

Non-Focal PM Task: The PM cue for the non-focal PM task was when the number "3" appeared in either number. In response to this cue, the participant was to press the spacebar after responding to the decision task. This task is considered non-focal as the decision task requires participants to determine the number as a whole, whereas identifying individual numbers within

the string (i.e., “3”) is not integral to processing the decision task (Kliegel, Jager, and Phillips, 2008).

Dependent variables included reaction time on the decision task trials (i.e., interference costs), the number of correct responses on the decision task trials, the number of PM cues correctly identified, and the reaction time on the three trials following a correct response to a PM cue (hereafter referred to as ‘monitoring’ trials). This last variable was intended to capture the degree of monitoring (i.e., slowed reaction time) which may occur following the identification of a PM cue (Smith, 2003). Following Einstein et al.'s (2005) trimming method, we examined mean reaction times (RTs) on correct decision task trials that were no greater than two standard deviations from each individual's mean (all blocks were trimmed separately). The reaction time for each experimental condition was then based on the difference between the participants’ average reaction time on the control block and their average reaction time on the experimental block for the same stimulus type (hereafter referred to as reaction time). Consistent with previous work in these laboratory PM paradigms (Scullin, McDaniel, & Einstein, 2010), late responses occurring within two trials of the PM target were coded as correct.

After all blocks of the PM task were completed, participants were asked two questions: (a) “what were the cues you were looking for?”; and (b) “what key were you supposed to press when you saw them?” Incorrect responses to any of these questions led to the exclusion of that person’s data due to retrospective memory failures (in total there were no cognitively healthy older adults excluded while there were five younger adults excluded on this basis).

Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005).

The MoCA is a brief (approximately 12-minute) battery assessing general cognitive function. It is made up of a series of brief neuropsychological tasks, namely trail-making

(joining letters and numbers in ascending order using a pencil); copying (copying a cube); clock drawing; naming (naming pictures of 3 animals); delayed recall (hearing 5 words and recalling them after a 5-minute delay); digit span (repeating a list of 5 digits in forward order and 3 digits in backward order); attention (hearing a list of letters and tapping the table each time the letter A is heard); serial subtraction (counting backwards from 100 in increments of 7); language (repeating sentences; naming as many words starting with F as possible in 1 minute); similarities (stating how two words are similar; for example, orange and banana are both fruit); and orientation (stating the date and where the participant is). This assessment was scored out of 30 and any participant with fewer than 12 years of education was given one extra point on their score.

Wisconsin Card Sorting Test (WCST) (Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993)

The 64-card version of the WCST was used as a measure of prefrontal lobe function of deductive reasoning and the ability to shift cognitive strategies in response to changing environmental demands (Eslinger & Grattan, 1993). In a latent variable analysis on separability of basic executive functions, the WCST was found to be most strongly related to mental set shifting and related to a lesser degree to other executive functions such as information updating and monitoring and inhibition of pre-potent responses (Miyake et al., 2000). The psychometric properties of this task have been found satisfactory, and it has shown to be sensitive to frontal lobe dysfunction (Strauss, Sherman, & Spreen, 2006).

The test requires the subject to match cards, one at a time from a deck of 64 response cards, that contain sets of geometric designs varying in colour, form, and number with four key cards. The participant must sort the cards according to four stimulus cards laid out in front of the

participant. The participant was given feedback if they are correct or incorrect following the placement of each card. From this feedback, they must learn the correct sorting criterion. The criterion for correct matching begins with colour and after ten consecutive correct matches are made (a completed category) the sorting criterion is changed. Testing terminated following the completion of six categories of correct matches (i.e., colour, form, number, colour, form, and number) or after placement of all 64 cards. The dependent variable from this task was the number of categories completed.

Stroop Task (Stroop, 1935)

The Stroop task is a generally accepted and widely used measure of prepotent response inhibition (e.g., Bull & Scerif, 2001; Dimoska-Di Marco, McDonald, Kelly, Tate, & Johnstone, 2011; Goldstein, Volkow, Wang, Fowler, & Rajaram, 2001; Moritz et al., 2002). The version used in the current study was comprised of three timed conditions of 45 seconds each. For each condition a typed sheet of paper was given with columns of stimuli. The participant was asked to read aloud moving down the columns as quickly and as accurately as possible. The first condition contained the names of colours in black font (i.e. blue, yellow, green, red). In the second condition participants were asked to name the colours of sets of six uppercase "X"s in coloured ink. The third condition contained names of colours written in ink of a different colour (e.g., the word "BLUE" written in "RED" ink). Participants were asked to read the colour of the ink, not the word itself, thereby suppressing their prepotent response to respond the word that is written. The dependent variable was an interference score calculated by subtracting the number of correct items of the colour-word condition from the number of correct items in the word reading condition.

California Verbal Learning Test – II (CVLT-II, Delis, Kaplan, & Ober, 2000)

This test assesses verbal learning and immediate and delayed memory. Participants listen to 16 words from 4 categories (i.e. tools, fruits, insects and clothing - 4 items per category). The test begins with an immediate free recall phase and after a short delay (10 minutes) free and cued recall trials occur. Following a longer delay (20 minutes) free and cued recall trials are again completed. Finally, participants complete recognition memory trials in which they are asked if a word was on the original list from a list of 44 items including distractors. The dependent variable used in the current study was the T-score, which takes the participant's sex, age, and education level into account, generated from the initial 5 learning trials.

Wechsler Memory Scale-III (WMS-III, Weschler, 1997)

The WMS-III includes a battery of subtests but for the purposes of this study only the Digit Span and Logical Memory subtests were used. In the Logical Memory subtest participants were read two stories and then instructed to restate as much of the stories as they could (immediate recall). Following a twenty-minute delay participants again recalled the stories (delayed recall). The Digit Span subtest asked participants to recall increasing lists of numbers, which were used to assess short term and working memory. Participants were tested up to their maximum working memory span, or the maximum number of stimuli that they can successfully recall. This task was in two parts, one assessing forward span (i.e., the maximum number of items they can recall in the same order that they were heard in) and one assessing backward span (i.e., the maximum number of items they can recall in the reverse order).

Boston Naming Test (BNT, Kaplan, Goodglass, & Weintraub, 1983)

Participants were shown and asked to name 60 images that are ordered in increasing difficulty. Images were presented via slide show on a laptop computer. For some of the images more than one response was accepted. Participants receivde one point for each image correctly

identified, for a maximum possible overall score of 60.

Procedure

Ethical approval was obtained from the Research Ethics Board of the University of Ottawa and participants were treated according to the principles outlined by this board throughout the study. At the start of the testing session participants were provided with a consent form that outlined the purpose, procedures, risks/benefits, and voluntary nature of the study. Participants were required to sign the consent form before continuing with the study. Testing sessions were individually conducted and took place in a quiet room with a research assistant or the primary investigator administering the tasks. Sessions lasted approximately 90 minutes and computer-based tasks were administered using 15-inch Dell laptop. In addition to the PM task, participants also completed a small battery of neuropsychological tests. As this study was part of a broader ongoing study, participants also completed additional measures not included in the current study. The neuropsychological battery included the Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005), the CVLT-II (Delis, Kaplan, & Ober, 2000), the Stroop Color-Word Test (Stroop, 1935), the Forward and Backward Digit Span and Logical Memory subtests of the Wechsler Memory Scale-III (WMS-III, Weschler, 1997), the Boston Naming Test (BNT, Kaplan, Goodglass, & Weintraub, 1983), the Wisconsin Card Sorting Test (WCST, Grant & Berg, 1948), and a semantic verbal fluency task.

With respect to the PM task, participants first completed the control block, consisting of only the numerical decision task without any PM cues. Each participant then completed the assigned PM blocks such that the number of cues increased in order to maintain the fidelity of the PM proper blocks (i.e., one PM cue). Furthermore, due to time constraints, participants did not complete all of the PM task. Instead, each participant completed the control block as well as

two each of the focal and non-focal blocks such that they performed a block with each number of PM cues and an equal number of focal and non-focal blocks (i.e., one participant completed the control, Focal 1 PM cue, Focal 10 PM cue, Non-Focal 5 PM cue, and Non-Focal 20 PM cue conditions). This structure was quasi-randomly assigned and counter-balanced across participants.

Statistical Analyses

Prior to the main analyses, all data were cleaned which included removing incorrect responses to decision task trials and reaction times $\geq$2.0 standard deviations than the individual's mean reaction time. The proportion of correctly identified PM cues was then calculated (i.e., the frequency participants remembered to press the *Spacebar* key on presentation of the focal and the non-focal PM targets). False alarms to non-target items were infrequent, with only 100 commission errors (i.e., <0.2% of trials) in total made across all conditions. The data were evaluated to insure that the assumptions of ANCOVA and ANOVA were met. If the distribution of scores was largely skewed, the appropriate transformations were applied. To identify variables to include as potential covariates, all analyses were examined separately for sex, handedness and primary language to determine if these demographic variables impacted the results. Data were pooled where no significant differences existed. The alpha level was set at .05 for all analyses. All statistical analyses were conducted using PASW Statistics 23.0 (SPSS Inc., Chicago, USA).

The dependent variables from the PM task - the proportion of correct PM cues, reaction time on the decision task trials, the reaction time on 'monitoring' trials, and the number of correct decision task trials - were entered into separate 2 (Group: younger adults and older adults) x 2 (Focality: focal and nonfocal) X 4 (PM Cue: 1, 5, 10, and 20) mixed analysis of variance (ANOVA), with Group as between-subjects variable and both Focality and Number of

PM cues as within-subjects variables. In all cases the fit of the model was evaluated by rerunning the analyses with different repeated covariance types and the smallest Akaike's Information Criterion was found using a compound symmetry: heterogeneous approach. As expected, no prospective memory responses were observed in the control block of the numeric decision task. Tukey's HSD was used for all *post-hoc* analyses. Correlational designs were used to examine the relationship between each of the neuropsychological measures and the proportion of correctly identified PM cues (including focal/non-focal and each level of cue frequency).

Results

Interference Costs

A series of paired samples t-tests comparing reaction time in the control block to reaction time in the PM blocks were performed to assess for the presence of interference costs for each group in each focality. Healthy younger adults were found to exhibit significant interference costs compared to the control block (M= 898.99, SD= 300.23) in both the focal (M= 1092.43, SD= 222.05; $t(74)= -6.34$, $p <0.0001$) and the non-focal conditions (M= 1117.94, SD= 198.43; $t(76)= -7.45$, $p <0.0001$). Cognitively healthy older adults were also found to exhibit significant interference costs compared to the control block (M= 1101.71, SD= 163.84) in both the focal (M= 1269.33, SD= 177.79; $t(61)= -12.14$, $p <0.0001$) and the non-focal conditions (M= 1357.54, SD= 221.72; $t(80)= -13.20$, $p <0.0001$).

Further analyses comparing these interference costs between the groups in the context of manipulating the focality and frequency of the PM cues will now be explored. In order to facilitate interpretation of speed/accuracy tradeoffs PM accuracy and RT data will be presented together.

PM Accuracy and Interference Costs

To the assess the groups' performance in terms of accurate responses to PM cues, interference costs, ongoing decision task accuracy, and post-PM cue monitoring within each block, two 2 X 2 X 4 mixed model ANOVAs were conducted with Group (younger adults and older adults) as a between-subjects variable and both Focality (focal and non-focal) and Cue frequency (1, 5, 10, 20) as repeated measures variables. First, a summary of these results is presented in Table 2. Each of these ANOVAs is then explored in detail. The results of PM accuracy and interference cost analyses are presented in Tables 3 and 4, respectively.

Table 2
Summary of ANOVA analyses comparing the PM performance of younger and older adults

	PM Accuracy	Interference Costs	Decision Task Accuracy	Post-PM Cue Monitoring
Focality	**ME:** ns	**ME:** Non-focal > focal	**ME:** ns	**ME:** Non-focal > Focal
Cues	**ME:** 20 > 1 = 5 = 10	**ME:** 5 > 10	**ME:** ns	ns
Group	**ME:** ns	**ME:** OA > YA	**ME:** ns	**ME:** OA > YA
Focality X Cues	**Focal:** ns **Non-Focal:** 1 = 5 = 20 > 10 **10 Cues:** Focal > Non-Focal	**Focal:** ns **Non-Focal:** 1 = 5 = 20 > 10 **1, 5, 20 Cues:** Non-Focal > Focal **10 Cues:** Focal > Non-Focal	ns	ns
Group X Focality	ns	**Focal:** OA > YA **Non-Focal:** OA > YA **OA:** Non-Focal > Focal **YA:** ns	ns	**Focal:** ns **Non-Focal:** OA > YA
Group X Cues	**5 Cues:** OA > YA; **OA:** 5, 20 > 10; **YA:** 20 > 1 = 5; 20 > 10 (*p*=.07)	**1, 10 Cues:** OA > YA **OA:** 1 = 5 > 20 **YA:** 20 > 1 = 10	ns	**10 cues:** OA > YA
Group X Focality X Cues	**Focal**: group = OA > YA(*p*=.08) cues = ns group X cues = ns **Non-Focal:** group: ns cues: 1 = 20 >10 group X cues = 5 cues: OA > YA; OA: 1 = 5 = 20 > 10 YA: 20 > 5	**Focal**: group: OA > YA cues: ns group X cues = 1, 10 cues: OA > YA **Non-Focal:** group = OA > YA cues: ns group X cues = 1 cue: OA > YA OA: 1 = 5 > 10	ns	ns

Table 3

Mixed Model Analysis of Variance of PM trials correct by Group, Focality, and Cue

Source	*Numerator df*	*Denominator df*	*F*	*p*
Intercept	1	505.90	1981.45	<0.001
Focality	1	203.21	1.21	.273
Cues	3	286.11	5.34	.001
Group	1	505.90	2.91	.089
Focality X Cues	3	615.60	6.33	<0.001
Group X Focality	1	203.21	.15	.695
Group X Cues	3	286.11	3.14	.026
Group X Focality X Cues	3	615.60	3.42	.017

Table 4

Mixed Model Analysis of Variance of Reaction Time on Decision Trials by Group, Focality, and Cue

Source	*Numerator df*	*Denominator df*	*F*	*p*
Intercept	1	617.51	94.21	<0.001
Focality	1	470.13	9.45	.002
Cues	3	176.89	2.81	.041
Group	1	617.51	7.17	.008
Focality X Cues	3	194.18	3.58	.015
Group X Focality	1	470.13	3.37	.067
Group X Cues	3	176.89	5.67	.001
Group X Focality X Cues	3	194.18	1.100	.350

Focality

First, when collapsing across groups and cue frequencies, no significant differences between focal and non-focal PM blocks were found in terms of PM accuracy (Focal: M= 87.23, SD= 24.39); Non-Focal: M=80.91, SD= 30.24; see Figures 1 and 2). In contrast, reaction times to decision trials (after controlling for reaction time in the control block; i.e., interference costs) were significantly faster in the focal (M= 145.83, SD= 98.12) than in the non-focal blocks (M= 232.97, SD= 367.36) $F(1, 470)$: 9.45, $p = 0.002$. As stated above, interference costs were seen for both the focal and non-focal blocks such that including a prospective memory load in any way caused numerical decision reaction times to be slower than without the load.

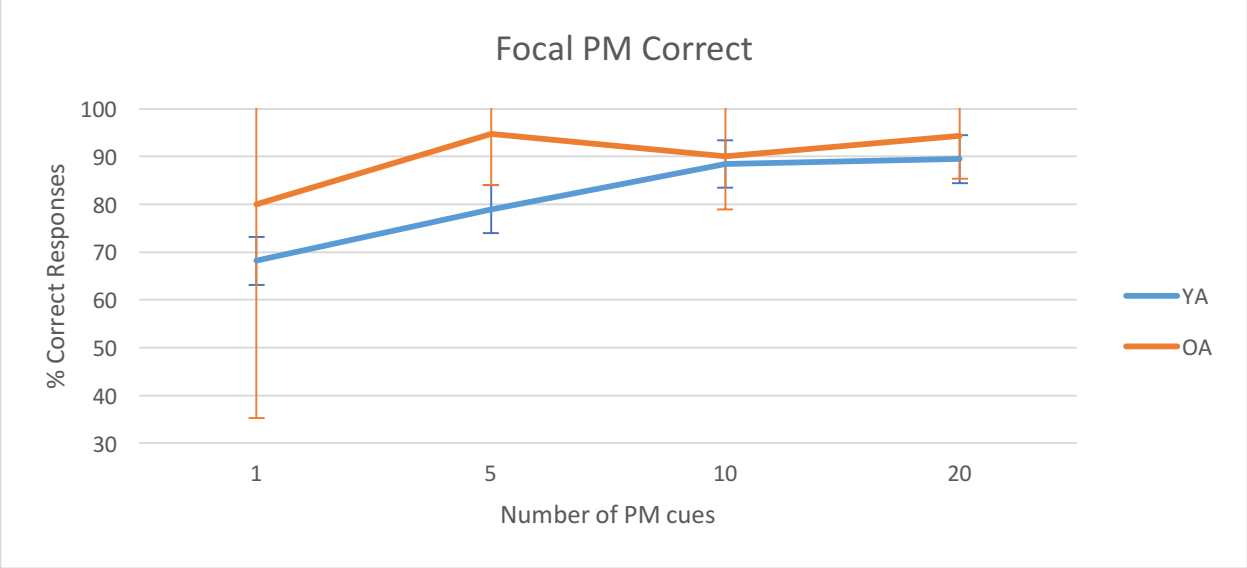

Figure 1: Proportion of correctly identified PM cues in the Focal condition with error bars representing standard deviation.

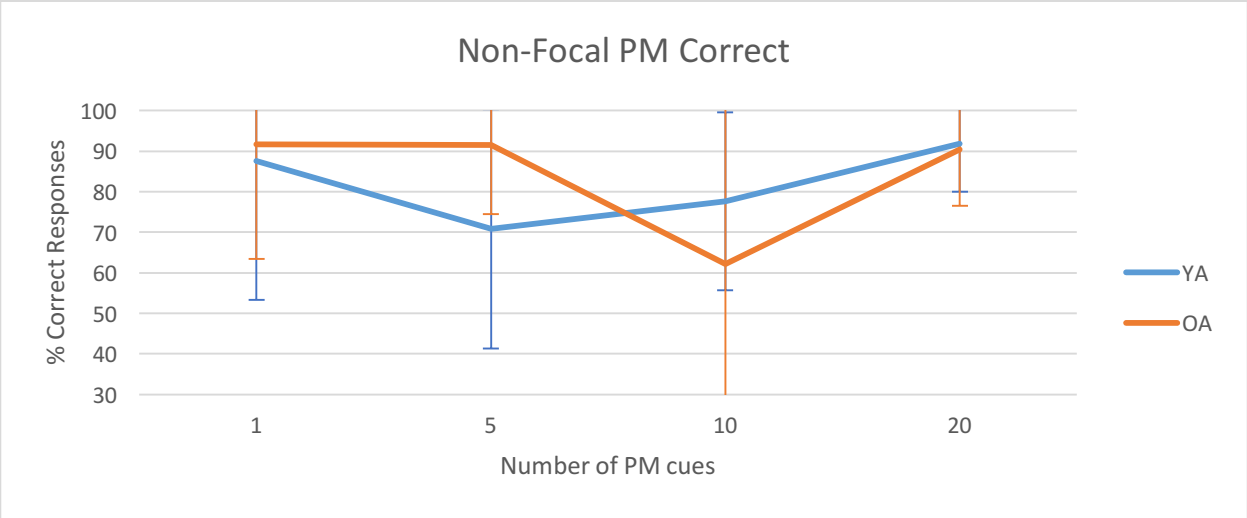

Figure 2: Proportion of correctly identified PM cues in the Non-Focal condition with error bars representing standard deviation.

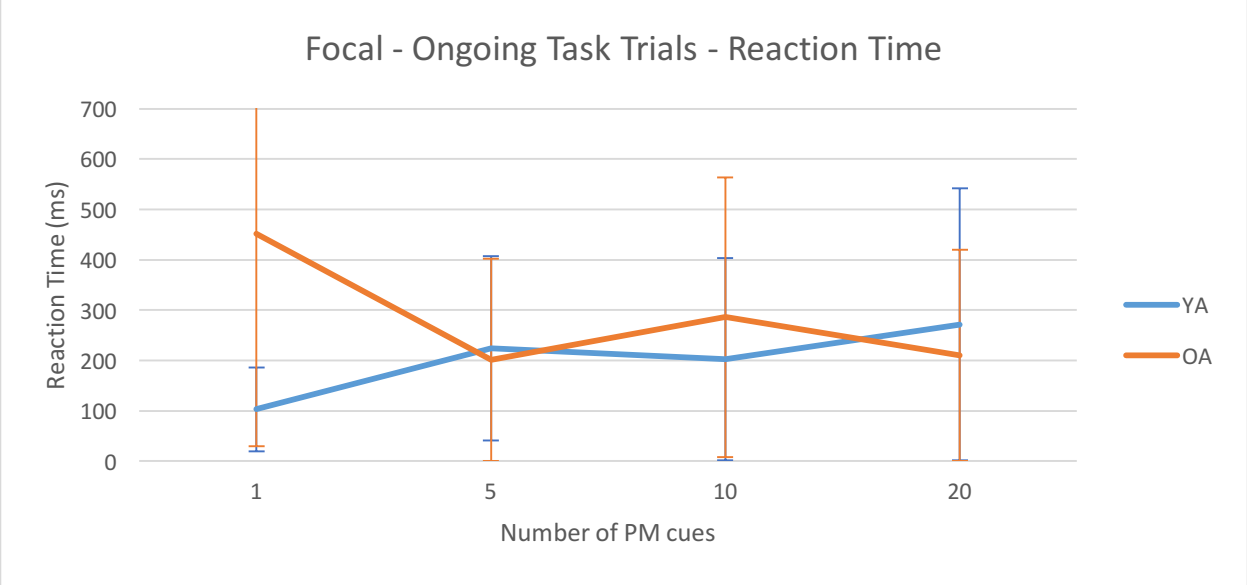

Figure 3: Reaction time (ms) to decision trials in the Focal condition after controlling for reaction time in the Control block with error bars representing standard deviation.

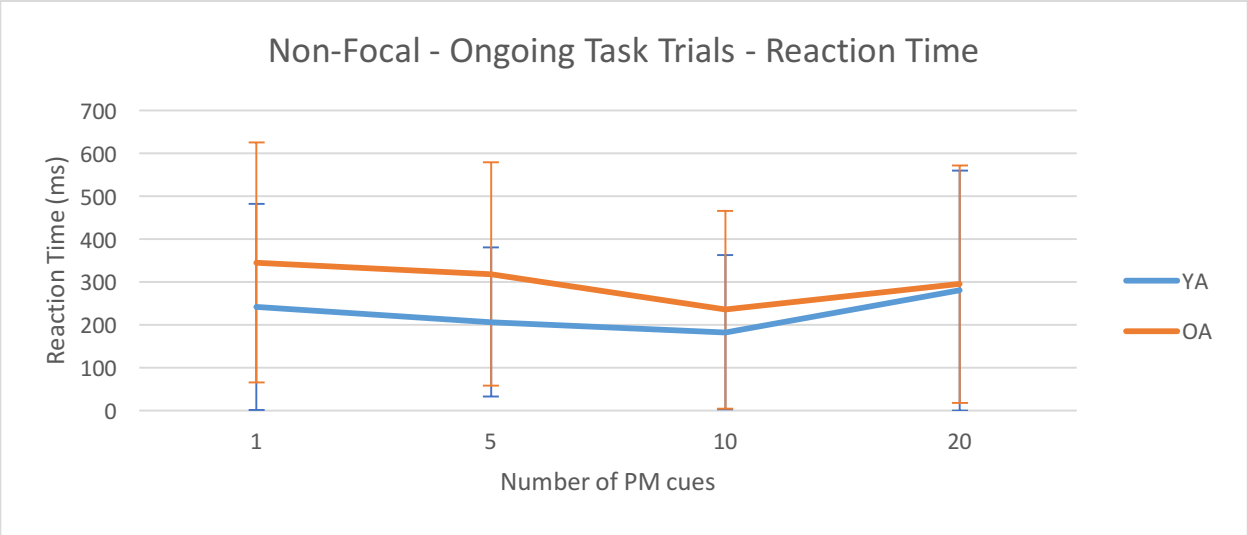

Figure 4: Reaction time (ms) to decision trials in the Non-Focal condition after controlling for reaction time in the Control block with error bars representing standard deviation.

Cues

There are significant differences between cue frequencies when collapsing across groups and focalities in terms of PM accuracy (see Figures 1 and 2). Participants were significantly more accurate in the 20 PM cue blocks (M= 92.51, SD= 2.14) compared to the 1 PM cue blocks (M= 84.00, SD= 4.20, p = .047), the 5 PM cue blocks (M= 86.09, SD= 2.68, p = .037, and the 10 PM cue blocks (M= 80.98, SD= 2.79, p <0.001). With respect to reaction time, interference costs were significantly higher in the 5 PM cue blocks (M= 235.90, SD= 497.34) compared to the 10 PM cue blocks (M= 160.88, SD= 135.37, p = 0.032).

Group

There were no significant differences in PM accuracy between groups when collapsing across focalities and cue frequencies. The Multiprocess view predicts age-related differences with non-focal PM cues but not focal PM cues, which is further explored when examining the group by focality interaction results (see below). The results do reveal significant differences in interference costs between groups, with older adults (M= 239.90, SD= 374.32) demonstrating higher costs when combining focalities and cues compared to younger adults (M= 144.35, SD= 108.05, p = 0.008).

Focality X Cues Interaction

There were significant focality by cue interaction effects identified both in terms of PM accuracy and interference costs.

First, in terms of PM accuracy, within the focal PM blocks there were no significant differences between cue frequencies. In contrast, within the non-focal PM blocks there were significant differences between cue frequencies $F(3, 557) = 7.58$, $p < 0.0001$. Specifically, within the non-focal blocks PM accuracy was lowest in the 10 PM cue block (M= 68.08, SD= 36.36)

compared to all other cue frequency blocks (1 PM cue: M= 92.31, SD= 27.00, p = 0.001; 5 PM cues: M= 78.38, SD= 27.64, p = 0.003; 20 PM cues: M= 91.13, SD= 12.63, p < 0.0001). There is also a significant difference within the 10 PM cue frequency between focalities $F(1, 873) = 19.62$, $p < 0.0001$. Specifically, participants were significantly less accurate in the non-focal 10 PM cue block (M= 68.08, SD= 36.36) than in the focal 10 PM cue block (M= 89.09, SD= 12.34, p < 0.0001).

Second, in terms of interference costs, results were similar to the accuracy data presented above. There were no significant differences in interference costs between cue frequencies within the focal PM blocks. In contrast, within the non-focal PM blocks there were significant differences between cue frequencies $F(3, 119) = 4.21$, $p = 0.007$. Specifically, within the non-focal blocks the 10 PM cue frequency, which had shown the lowest accuracy compared to all other cue frequencies, exhibited the lowest interference costs (M= 169.74, SD= 157.17) compared to all other cue frequency blocks (1 PM cue: M= 247.11, SD= 197.74, p = 0.012; 5 PM cues: M= 320.86, SD= 695.64, p = 0.029; 20 PM cues: M= 215.94, SD= 112.58, p = 0.016). There were also significant differences within cue frequencies between focalities. Specifically, interference costs were higher in the non-focal compared to the focal block for all cue frequencies other than 10 PM cues (1 PM cue: Focal M= 125.78, SD= 105.23; Non-Focal: M= 247.11, SD= 197.74, p = 0.036; 5 PM cues: Focal M= 153.24, SD= 99.88; Non-Focal: M= 320.86, SD= 695.64, p = 0.029; 20 PM cues: Focal M= 151.30, SD= 99.80; Non-Focal: M= 215.94, SD= 112.58, p = 0.004).

Taken together, the interference costs found with 1, 5, and 20 PM cue frequencies are consistent with the main effect described above showing greater interference costs in the non-focal condition. Again, only the 10 PM cue frequency does not demonstrate a significant

difference in interference costs between the focal and non-focal blocks. Furthermore, the interference cost results parallel the accuracy results in that the 10 PM cue frequency had the lowest accuracy compared to all other cue frequencies within the non-focal blocks. In addition, the 10 PM cue blocks were the only ones to demonstrate a significant difference in accuracy between focal and non-focal blocks.

Group X Focality

There were no significant group by focality interaction effects identified either in terms of PM accuracy or interference costs. There was a trend toward a significant interaction for interference costs. Because specific hypotheses were made with respect to this interaction, specifically that older adults' PM performance would be affected by varying the focality while the performance of younger adults would not be affected, this trend was further explored. Specifically, separate 2 x 4 mixed model ANOVAs were conducted for each focality with group (younger adults and older adults) as a between-subjects variable and cue frequency (1, 5, 10, 20) as repeated measures variables to evaluate both PM accuracy and interference costs. First, in terms of accuracy there were no significant differences either between groups within each focality or between focalities within each group when collapsing across cue frequencies. However, there were significant differences in terms of interference costs. Consistent with the main effect noted above, older adults' response times revealed significantly greater interference costs in both the focal (M= 167.62, SD= 108.73, p = 0.010) and non-focal (M= 295.22, SD= 482.23, p = 0.019) conditions compared to the younger adults (focal: M= 125.96, SD= 83.26; non-focal: M= 161.96, SD= 125.45). More notably, results revealed that older adults, but not younger adults, demonstrated significantly greater interference costs in the non-focal compared to the focal blocks $F(1,477)= 9.85$, $p = 0.002$).

Group X Cues

There were significant group by cue interaction effects identified both in terms of PM accuracy and interference costs. First, in terms of PM accuracy, there were significant differences found between groups within the 5 PM cue frequency $F(1, 11119) = 10.56$, $p = 0.001$. Specifically, older adults (M= 93.51, SD= 13.39) were significantly more accurate than younger adults (M= 75.50, SD= 29.52) with 5 PM cues. This is an unexpected finding given that no differences between groups are expected with focal PM cues and the older adults are predicted to have reduced PM performance with non-focal PM cues. Within the older adult group, participants were found to have lower PM accuracy in the 10 PM cue blocks (M= 70.65, SD= 37.74) compared to the 5 PM cue blocks ($p = 0.001$) and the 20 PM cue blocks (M= 92.78, SD= 11.11, $p < 0.0001$). Within the younger adult group, participants were significantly more accurate in the 20 PM cue blocks (M= 91.14, SD= 9.32) compared to the 1 PM cue blocks (M= 78.38, SD= 41.73, $p = 0.046$) and the 5 PM cue blocks (M= 75.50, SD= 29.52, $p = 0.004$) with a trend toward lower accuracy in the 10 PM cue blocks (M= 82.82, SD= 19.19, $p = 0.073$) relative to the 20 PM cue blocks as well.

Second, in terms of interference costs, there were significantly different interference costs between groups within the 1 PM cue blocks $F(1, 78) = 14.87$, $p < 0.0001$ and the 10 PM cue blocks $F(1, 92) = 17.37$, $p < 0.0001$. Specifically, older adults (M= 303.53, SD= 188.26; demonstrated significantly greater interference costs compared to younger adults (M= 113.09, SD= 107.91) in the 1 PM cue blocks as well as the 10 PM cue blocks (older adults: M= 202.27, SD= 148.77; younger adults: M= 109.17, SD= 95.44). Within the older adult group, participants had significantly lower interference costs in the 20 PM cue blocks (M=177.00, SD= 108.61) compared to the 1 PM cue blocks (M= 303.53, SD= 188.26, $p = 0.007$) and the 5 PM cue blocks

(M= 300.36, SD= 700.15, p = 0.035). Within the younger adult group, participants demonstrated significantly greater interference costs in the 20 PM cue blocks (M= 183.78, SD= 112.65) compared to the 1 PM cue blocks (M=113.09, SD= 107.91, p = 0.048) and the 10 PM cue blocks (M=109.17, SD= 95.44, p = 0.001).

In sum, older adults were found to be more accurate than younger adults in the 5 PM cue blocks and demonstrated greater costs in the 1 and 10 PM cue conditions with no difference in accuracy at these cue frequencies. This suggests older adults may have employed a speed-accuracy tradeoff at the 1 and 10 PM cue frequencies which emphasized accuracy. In addition, with 20 PM cues, older adults demonstrated reduced interference costs without any difference in PM accuracy with 20 PM cues while younger adults demonstrated a speed/accuracy tradeoff with 20 PM cues, with increased accuracy but greater interference costs.

Group X Focality X Cues

There were significant 3-way interaction effects identified in the omnibus ANOVA in terms of PM accuracy but not interference costs. However, on the basis of planned comparisons both of these 3-way interaction effects will be explored.

First, in terms of PM accuracy within the focal blocks, there were no significant differences between cue frequencies or any group by cue interaction effects. There was a trend toward a significant difference between groups $F(3, 34)= 3.38$, $p = 0.08$), with older adults (M= 92.42, SD= 15.38) being more accurate than younger adults (M= 82.80, SD= 29.39) in the focal blocks.

Second, in terms of interference costs within the focal blocks, there was a main effect of group $F(1, 113)= 8.45$, $p = 0.004$ but not cue frequency. Furthermore, there was a group by cue frequency interaction $F(3, 76)= 4.11$, $p = 0.009$. Older adults (M=167.62, SD= 108.73) displayed

significantly greater interference costs compared to the younger adults (M= 125.96, SD= 83.26, p = 0.004). The interaction effects reveal significant differences between groups with 1 PM cue $F(1, 36)= 12.70$, $p = 0.001$ and 10 PM cues $F(1, 39)= 16.29$, $p < 0.0001$. Specifically, older adults (1 PM cue: M= 226.07, SD= 129.68; 10 PM cues: M= 205.42, SD= 82.48) display significantly greater interference costs compared to younger adults (1 PM cue: M= 100.70, SD= 84.49; 10 PM cues: M= 98.18, SD= 65.43).

In sum, within the focal blocks older adults were found to display significantly greater accuracy in the context of significantly increased interference costs relative to young adults. Specifically, older adult group are displaying increased interference costs within the 1 PM cue and 10 PM cue focal blocks in conjunction with increased accuracy in the focal blocks overall compared to younger adults.

Second, in terms of accuracy within the non-focal blocks, there was a main effect of cue frequency $F(3, 87)= 5.80$, $p = 0.001$ but not group: accuracy was lower in the 10 PM cue blocks (M= 68.08, SD= 36.36) compared to the 1 PM cue (M= 92.31, SD= 27.00, p = 0.002) and the 20 PM cue blocks (M= 91.97, SD= 10.23, p < 0.0001). Furthermore, there was a group by cue frequency interaction $F(3, 87)= 2.92$, $p = 0.04$. The interaction effects reveal significant differences between groups with 5 PM cues $F(1, 31)= 6.11$, $p = 0.02$: older adults (M= 93.51, SD= 13.38) are significantly more accurate at this cue frequency within the non-focal condition compared to younger adults (M= 75.50, SD= 29.52). In addition, older adults were significantly less accurate in the non-focal 10 PM cue block (M= 62.19, SD= 42.10) compared to all other cue frequencies (1 PM cue: M= 95.65, SD= 20.85, p < 0.0001; 5 PM cues: M= 91.43, SD= 17.03, p = 0.002; 20 PM cues, M= 90.36, SD= 13.93, p < 0.0001). Within the younger adult group participants were significantly less accurate in the 5 PM cue block (M= 70.43, SD= 30.07)

compared to the 20 PM cue block (M= 91.76, SD= 11.85, p = 0.001).

In terms of interference costs (i.e., reaction time compared to the control block) within the non-focal blocks, there was a main effect of group $F(1, 216)= 6.36$, $p = 0.012$ but not cue frequency. Furthermore, there was a group by cue frequency interaction $F(3, 88)= 2.74$, $p = 0.04$. Older adults (M= 295.22, SD= 482.23) again displayed significantly greater interference costs compared to the younger adults (M= 161.96, SD= 125.45, p = 0.012) in the non-focal blocks. The interaction effects reveal significant differences between groups with 1 PM cue $F(1, 36)= 10.29$, $p = 0.003$. Specifically, older adults (M= 321.14, SD= 197.29) display significantly greater interference costs compared to younger adults (M= 130.79, SD= 136.21) in the non-focal 1 PM cue block. Older adults also displayed significantly different interference costs between cue frequencies within the non-focal blocks $F(3, 64)= 4.05$, $p = 0.011$. In particular, greater inference costs were found in the 1 PM cue (M= 321.14, SD= 197.29, p = 0.009) and 5 PM cue blocks (M= 544.07, SD= 1092.33, p = 0.043) compared to the 10 PM cue block (M= 200.84, SD= 171.78).

In sum, within the non-focal blocks, older adults displayed greater overall interference costs and this effect was particularly apparent with 1 PM cue. Notably, the only significant group difference in accuracy within the non-focal blocks favoured the older adult group at 5 PM cues. Interestingly, within the non-focal condition older adults displayed the lowest accuracy with 10 PM cues compared to all other cue frequencies, while also displaying fewer interference costs compared to 1 and 5 PM cues.

Supplementary Analyses

Interference costs before and after the PM cue

Given that previous research suggests that task interference may emerge after, but not before, the first target cue (Scullin, 2009), interference costs before and after the PM cue in the 1

PM cue condition were explored for participants who accurately responded to the PM cue. It is important to note that participants are unaware of the frequency of PM cues at the outset of each block. With respect to older adults, a paired-samples t-test revealed that older adults displayed significantly greater interference costs in the focal block before the PM cue (M= 279.50, SD= 101.85) compared to after the PM cue (M= 201.75, SD= 116.78; $t(3)= 3.32$, $p = 0.045$). It may be that older adults increased their speed of responding in the focal block after finding that they were able to spontaneously retrieve the PM response, or allocate fewer cognitive resources, in the focal blocks as suggested by the multiprocess theory. There were no significant differences before or after the response to the PM cue in the non-focal block for the older adults. The younger adults did not display a significant difference in interference costs before or after the PM cue in either the focal or non-focal blocks. Notably, the change in interference costs for older adults before and after the PM cue suggests that this group may be strategically allocating cognitive resources in response to the perceived demands of the task while younger adults are found to respond consistently throughout task blocks.

Decision Task Accuracy

A 2 X 2 X 4 mixed model ANOVA was conducted with Group (younger adults and older adults) as a between-subjects variable and both Focality (focal and non-focal) and Cue frequency (1, 5, 10, 20) as repeated measures variable to assess differences in response accuracy to the ongoing task. Results revealed that there were no significant main effects or interactions. Overall, participants maintained a high degree of accuracy (i.e., $\geq$ 94%) in all PM blocks.

Post-PM Cue Monitoring

A 2 X 2 X 4 mixed model ANOVA was conducted with Group (younger adults and older adults) as a between-subjects variable and both Focality (focal and non-focal) and Cue frequency

(1, 5, 10, 20) as repeated measures variables to assess differences in monitoring (i.e., interference costs in the 3 trials following accurate PM responses; see Table 5).

Table 5

Mixed Model Analysis of Variance of post-PM cue monitoring by Group, Focality, and Cue

Source	*Numerator df*	*Denominator df*	*F*	*p*
Intercept	1	141.64	206.60	.000
Focality	1	197.63	7.84	.006
Cues	3	153.11	2.13	.099
Group	1	141.64	6.95	.009
Focality X Cues	3	175.79	2.42	.068
Group X Focality	1	197.63	12.82	.000
Group X Cues	3	153.11	2.70	.048
Group X Focality X Cues	3	175.79	.817	.486

The results reveal that monitoring was significantly higher in the non-focal (M= 276.43, SD= 265.00) compared to the focal condition (M= 190.73, SD= 144.64) when collapsing by group and cues. Similar to the interference costs results, older adults (M= 286.54, SD= 246.64) were found to display significantly greater monitoring than younger adults (M= 185.61, SD= 179.82). This is consistent with the findings regarding interference costs before and after the 1 PM cue: the change in interference costs for older adults before and after PM cues suggests that this group may be strategically allocating cognitive resources in response to the perceived demands of the task while younger adults are found to respond consistently throughout task blocks.

There was also a significant group by focality interaction showing increased monitoring for the older adults relative to younger adults in the non-focal (older adults: M= 366.79, SD= 290.48, younger adults: M= 183.45, SD= 198.47) but not focal (older adults: M= 193.14, SD= 133.74, younger adults: M= 188.19, SD= 156.42) blocks.

Lastly, the group by cue interaction reveals that older adults (M= 293.38, SD= 175.13) displayed significantly more monitoring compared to younger adults (M= 131.28, SD= 211.51) in the 10 PM cue condition $F(1, 255)= 9.66$, $p = 0.002$. This significant difference is primarily the result of the significantly increased monitoring by the older adults in the non-focal 10 PM cue block (M=344.77, SD= 200.21) compared to the focal 10 PM cue block (M= 212.63, SD= 79.58) $F(1, 68)= 5.78$, $p = 0.019$ (younger adults did not display a significant difference between these blocks). Interestingly, older adults displayed significantly greater monitoring costs in the non-focal 10 PM cue block compared to the overall interference costs (M= 241.77, SD= 179.67) in the same block $t(21)= -6.77$, $p <0.0001$). Though older adults were less accurate in the non-focal 10 PM cue block compared to their performance in all other non-focal cue frequencies, the

increased monitoring following the PM cue indicates that they may have identified the cue but failed to accurately respond. Furthermore, older adults displayed significantly decreased monitoring in the 5 PM cue blocks (M= 199.97, SD= 166.58) compared to 1 PM cue (1 PM cue: M= 423.04, SD= 337.10, p = 0.010) and 20 PM cues (M= 271.06, SD= 268.51, p = 0.037).

Overall, the monitoring results are consistent with the multiprocess theory predictions that: (i) non-focal blocks would require increased resources/monitoring compared to the focal blocks; and (ii) that older adults would display significantly increased monitoring costs compared to younger adults in the non-focal but focal blocks (i.e., the group by focality interaction).

Discussion

In Study 1, we first assessed the presence of interference costs (i.e., the difference in reaction time in the presence of a PM load compared to the control block) in both the focal and non-focal blocks. Spontaneous retrieval is not hypothesized to require preparatory attention processes and thus should not lead to significant interference (divided attention) costs. In contrast to this hypothesis, results showed that task interference was found when PM cues were embedded in the numerical decision task: numerical decision reaction times were longer with a prospective memory load, regardless of focality, compared to the control block with no prospective memory load. The presence of interference costs in all PM conditions and groups suggests that PM always interferes with the ongoing task (Smith & Bayen, 2005), and that some degree of cognitive resources has to be allocated to PM cue detection. Moreover, while reflexive-automatic processes might underlie spontaneous retrieval (McDaniel et al., 2004), the presence of interference costs in the focal blocks is consistent with the assertion that spontaneous

processes should not be equated with automatized prospective memory responding (Loft & Yeo, 2007; McDaniel & Scullin, 2010).

The DMPT and the PAM theory only differ in their predictions when tasks are focal and have no costs (Einstein and McDaniel, 2010). Since costs are present in all conditions, these results concur with both the PAM and DMPT. Specifically, the PAM model of PM proposes that a PM intention is capacity-consuming because it is maintained in working memory until performed (Smith & Bayen, 2006, Guynn, 2003; Marsh et al., 2003; Smith, 2003; Smith & Bayen, 2004; West et al., 2005). The original multiprocess theory emphasized the automaticity (i.e., resource-free demands) of spontaneous retrieval processes (Einstein et al., 2004). In contrast, the more recently advanced Dynamic Multiprocess Framework allows for the variable presence of interference costs during focal PM cues, and is therefore also consistent with the above results.

Notably, the presence of preparatory attentional processes (i.e., interference costs) does not exclude the possibility of the use of spontaneous retrieval processes. It may be, however, that these processes are not fully automatic and may require attentional resources when the cue occurs (note that the DMPT does not propose preparatory attentional processes in these situations; see Einstein & McDaniel, 2008). Specifically, the Dynamic Multiprocess Framework suggests that monitoring is dynamically engaged throughout activities according to whether a PM cue is expected, such that spontaneous retrieval can be relied on in the absence of monitoring when cues are focal and salient.

Harrison and Einstein (2010) examined this proposition by varying the emphasis on the PM or the ongoing task and assessing task interference across quarters of the ongoing task. The results showed high PM performance in the absence of monitoring (i.e., preparatory attentional

processes) in the trials preceeding the PM cue. Notably, this study used the participants' own name as the PM cue, which occurred on only one occasion during the test block. It may be that spontaneous retrieval processes can only be relied on with such a salient target. Furthermore, altering the frequency of the cue could also impact the allocation of monitoring processes. Gao and colleagues (2013) also found that successful PM retrieval can occur in the absence of monitoring when the retrospective memory load of the task is low, the ongoing task is simple, and the PM task is non-verbal. However, the PM cues occurred on over 21% of trials in this study and therefore this may be considered a vigilance rather than PM task. Additional research manipulating these task characteristics can further our understanding of when relatively resource-free processes can be relied on for successful PM.

As was hypothesized, in the present studies interference costs were higher in the non-focal compared to the focal blocks across groups and cue frequencies. This finding is consistent with the increased cognitive demands associated with non-focal PM tasks (Scullin et al., 2013). However, this increased reaction time in the non-focal compared to focal blocks failed to produce a difference in PM accuracy between the focalities (i.e., an absence of a speed/accuracy tradeoff). Rather, it appears that while non-focal PM cues produced increased attentional demands, higher task interference did not lead to an increased likelihood of accurately identifying PM cues. It is worth noting that performance in the present prospective memory task in the focal blocks (87% for younger and older adults) was comparable to performance found in previous research, while the non-focal blocks (81% for younger and older adults) in the current study are higher than in previous studies (e.g., Einstein et al., 2005; mean focal PM accuracy = 90%, mean non-focal PM accuracy = 67%). Ceiling effects, particularly in the focal blocks (M= 87.23, SD= 24.38), may play a role in these results as it has in previous studies of PM (Uttl,

2011).

With respect to target frequency manipulations, the current results showed that participants were more accurate in the 20 PM cue blocks compared to all other cue frequencies. There were also differences in reaction time, with increased interference costs observed in the 5 PM cue blocks compared to the 10 PM cue blocks. The accuracy results are consistent with prospective studies showing increased cue frequency leading to increased PM recall (Loft and Yeo, 2007; Ellis et al., 1999; Czernochowski et al., 2012) as well as meta-analytic findings demonstrating that performance tends to improve as the task increasingly becomes one of vigilance (Uttl et al, 2011).

However, while the accuracy results are consistent with previous research, the interference cost analyses reveal some differences. Loft and Yeo (2007) found that low target frequency reduced prospective memory accuracy as well as interference costs, suggesting a speed/accuracy tradeoff. However, their study used cues with high and low associations with the response as focal and non-focal loads respectively. Furthermore, eight different cue-response pairs were used as targets. This manipulation is highly likely to increase the working memory demands compared to the current task, which required participants to remember one rule (e.g., press the SPACEBAR when the number 3 appears). Czernochowski and colleagues (2012) also found increased interference costs for frequent compared to rare targets, but this study used only non-focal PM cues.

The use of multiple, non-focal PM cues in the studies described above suggests that these tasks are likely to be more demanding than the PM task used in the current study. Interactions between the cognitive demands of a task and cue frequency have previously been identified. Tasks that are characterized by increased cognitive demands have shown greater vigilance

decrements compared to less cognitively demanding tasks, but only with high event rates (Warm, Parasuraman & Matthews, 2008). Furthermore, a meta-analysis of PM studies found interesting interaction effects when examining vigilance and the focality of cues such that age-related declines in vigilance were smaller with focal compared to non-focal cues (Uttl, 2011). The current study also produced significant interaction effects between focalities and cues.

The interaction between focality and cue frequency was significant for both PM accuracy and interference costs. First, there were no significant differences in accuracy or interference costs between cue frequencies within the focal blocks. In contrast, findings examining the non-focal blocks highlight the 10 PM cue block as qualitatively different from other cue frequencies. Specifically, participants displayed both significantly lower PM accuracy and interference costs in the non-focal 10 PM cue block compared to all other cue frequencies within the non-focal blocks. Participants were also less accurate in the non-focal compared to the focal 10 PM cue block, in contrast to the other cue frequency conditions. Furthermore, interference costs were higher in the non-focal relative to focal blocks for all cue frequencies other than 10. These findings suggest a speed/accuracy tradeoff in the 10 PM cue condition in which participants decreased response time on the ongoing task at the cost of reducing the accuracy of responses within the non-focal but not focal condition. Stated another way, participants may have failed to strategically slow their response times in order to increase the overall accuracy level in the non-focal 10 PM cue block.

In order to evaluate the predictions of the DMPT (i.e, age-related declines in non-focal but not focal PM tasks), the group by focality interaction must be explored. Overall, younger and older adults were equally accurate in responding to PM cues and there was no significant difference in accuracy between focal and non-focal conditions for either group. In contrast, the

overall interference costs when combining focalities and cue frequencies were significantly higher for the older adults compared to the younger adults. Furthermore, older adults, but not younger adults, demonstrated significantly greater interference costs in the non-focal compared to the focal blocks. These findings showed that the interference costs for the older adults were consistent with PAM theory, which predicts the presence of interference costs across all conditions, as well as the DMPT, which predicts greater interference costs under non-focal compared to focal conditions. Previous studies have found a similar pattern of results for young and older adults as well as individuals with MCI, in which interference costs are more sensitive than accuracy data to manipulations in characteristics of PM tasks, such as the association between the cue and PM response (Loft & Yeo, 2007; Chi et al, 2014).

Additional interaction effects were identified between groups when varying the cue frequencies. Contrary to expectations based on the DMPT that performance would be equivalent between groups, or at least better for the younger adults when combining focalities (i.e., the DMPT predicts differences only between focal and non-focal performance), older adults were found to be more accurate than younger adults in the 5 PM cue blocks (see below for results indicating the non-focal condition is specifically contributing to this result). In contrast, results were more consistent with predictions in terms of interference costs: older adults demonstrated greater costs in the 1 and 10 PM cue conditions, although there was no difference in accuracy at these cue frequencies. This suggests a speed-accuracy tradeoff such that the slowed response times of older adults at these cue frequencies resulted in similar PM accuracy to that observed in younger adults.

In contrast to a speed/accuracy tradeoff for these cue frequencies, when cues are more frequent and the task can be considered to be increasingly one of vigilance, fewer attention-

demanding resources appear to be required to maintain accuracy for the older adults. This group demonstrated reduced interference costs without any difference in PM accuracy with 20 PM cues. Conversely, younger adults demonstrated a speed/accuracy tradeoff with 20 PM cues, with increased accuracy but greater interference costs. Taken together, these results suggest that the two groups are allocating resources to the various PM cue frequencies in different manners. Furthermore, the differences between cue frequencies in both accuracy and interference costs as well as the different pattern of results within each group suggests that even the smallest change in cue frequency used in the current study (i.e., from 1% to 5%) can have a significant impact on performance.

Finally, there are significant three-way group by focality by cue frequency interaction effects which are inconsistent in terms of the predictions of the DMPT.

First, within the focal blocks, older adults were found to display a trend toward greater accuracy in the context of significantly increased interference costs relative to young adults. Again, according to the DMPT, age-related declines are not expected for focal PM cues, and retrieval of the response with this type of cue is considered relatively automatic, reflexive, and obligatory compared to non-focal cues (Scullin et al., 2013). Instead, the current results reveal that the older adult group are displaying increased interference costs within the 1 PM cue and 10 PM cue focal blocks compared to younger adults. The presence of differences in interference costs in the absence of any differences in accuracy again suggests the groups are allocating resources to the various PM cue frequencies in different ways, with older adults implementing a speed-accuracy tradeoff. Notably, the lack of significant differences in performance between cue frequencies within either group is consistent with the DMPT: changes in cue frequency are not expected to impact the relatively automatic processes thought to be relied on with focal PM cues.

Second, within the non-focal blocks, greater overall interference costs were found for older adults, consistent with the predictions of the DMPT. Notably, the only significant group difference in accuracy within the non-focal blocks favoured the older adult group at 5 PM cues. Again, this not only contradicts the predictions of the DMPT, but the superior accuracy of the older adult group in this block suggests that factors other than PM may be playing a role in the results (to be discussed below).

Third, the significant differences in both accuracy and interference costs identified across all cue frequencies as well as the within and between group differences suggest that even the smallest change in cue frequency in PM tasks (i.e., from 1% to 5%) can have a significant impact on PM performance. Furthermore, significant cue frequency differences support the suggestion that there are different classifications of PM tasks with some measuring "PM proper" and others being vigilance/monitoring tasks (Uttl, 2008, 2011). PM proper is represented by the 1 PM cue conditions and with this cue frequency it was found that older adults display greater interference costs compared to younger adults in both the focal and non-focal blocks.

However, the point at which a task switches from measuring PM to vigilance is still debated (Brandimonte et al., 2001; Czernochowski et al., 2012; Uttl, 2011). Interestingly, within the non-focal condition older adults displayed the lowest accuracy with 10 PM cues compared to all other cue frequencies, while also displaying fewer interference costs compared to 1 and 5 PM cues. This suggests that older adults may experience difficulty in allocating resources to maintain PM accuracy in the 10 PM block, which may represent a point on the continuum between a traditional PM task and one of vigilance/monitoring. Alternatively, older adults may have been emphasizing the ongoing task over the PM task.

Fourth, there is other evidence of conditions in which older and younger adults appear to

display differences in the allocation of attentional resources. While older adults demonstrated significantly different interference costs between cue frequencies in the non-focal blocks, younger adults did not display such differences. This suggests that older adults may be strategically allocating resources to maintain PM accuracy, while younger adults are displaying consistent interference costs across cue frequencies despite significant differences in accuracy. The use of strategic allocation of cognitive resources in the older adult group is further supported by the finding that they displayed significantly different interference costs between ongoing task trials occurring either before or after the PM cue in the focal 1 PM cue block. However, in addition to differences in strategies, it is also important to consider differences in motivation and effort between younger and older adults. Cognitively healthy older adults are typically found to be more motivated than younger adults and may adopt a more cautious strategy to maintain accuracy at the cost of slower response (Seya & Mori, 2007).

Finally, the post-PM cue monitoring were the most consistent with the predictions of the DMPT. Increased monitoring was observed in the non-focal compared to focal blocks. Furthrmore, older adults displayed increased monitoring compared to younger adults in the non-focal but not focal groups. Specifically, this group by focality interaction is uniquely consistent with the DMPT and appears to provide an additional valuable variable to explore in assessing the attention allocation strategies used in PM tasks.

Given the importance and differences identified in the performance of PM tasks based on the manipulation of focality and cue frequency as well as the relevance of PM in day-to-day functioning (Schmitter-Edgecombe et al., 2009; Smith, Della Sala, Logie & Maylor, 2000; Zogg et al., 2012) it is clearly necessary to explore the effects of cognitive impairment in relation to PM performance and the effects of focality and cue frequency. Study 2 examines the

performance of people with MCI and AD on the tasks utilized in Study 1.

Study 2

Participants

A total of 77 individuals participated in this study. Forty-four cognitively healthy older adults, aged 65 and older, were recruited from community centres, exercise classes, and advertisements placed in local newspapers, supermarkets, and nursing homes (these participants were the same as those reported in Study 1). Twenty-three individuals with MCI were recruited from the Bruyère Memory Disorders Clinic, a clinic staffed by neurologists, psychologists, and nurses. MCI participants were diagnosed on the basis of criteria similar to that of Petersen and colleagues (1999). The age range for the 23 participants retained in the sample was 65–90 (M = 76.07, SD = 5.72; 9 females). Subjects with MCI were required to have a reported decline (by either the patient or family) in memory function, which is gradual, of at least six months' duration, and documented by impaired performance (i.e., $\geq$1.5 SD) on objective neuropsychological tests with appropriate norms for age and education. None had significant impairment in activities of daily living and none met the criteria for dementia. Typically, such subjects have CDR scores of 0.5, indicating mild forgetfulness, minimal word finding difficulties, and/or slight impairment in mental efficiency (Hughes, Berg, Danziger, Coben, & Martin, 1982). Ten individuals diagnosed with early AD were also recruited from the Bruyère Memory Disorders Clinic. All of these participants, were originally screened for depression, hypertension, reversible dementias, and other disorders that could potentially produce cognitive impairment. Participants in this group met criteria for probable AD consistent with the National Institute of Neurological and Communications Disorders and Stroke—Alzheimer's Disease and Related Disorders Association criteria (McKhann et al., 1984). A breakdown of age, education, and the neuropsychological measures is presented in Table 6.

Table 6:
Participants' demographic and neuropsychological characteristics. Scores are given as Mean (Standard deviation).

	Older adults	MCI	Early AD	Groups differences
N (Male:Female)	44 (15:26)	23 (9:14)	10 (9:1)**	AD >OA=MCI
Age**	70.79 (4.48)	77.00 (5.77)	74.50 (5.58)	MCI=AD >OA
Education	15.55 (2.80)	15.39 (2.52)	15.90 (3.60)	
MoCA**	27.60 (1.63)	22.61 (3.20)	20.80 (4.71)**	OA >MCI=AD
Digit Span (forward + backward)	17.57 (3.75)	16.09 (4.13)	14.80 (3.68)	
Boston Naming Test**	53.91 (4.98)	47.70 (6.34)	45.00 (9.96)**	OA >MCI=AD
Category Fluency**	20.88 (4.13)	13.70 (5.08)	14.00 (3.74)**	OA >MCI=AD
Phonemic Fluency	13.86 (4.37)	12.74 (4.76)	12.20 (5.05)	
Stroop Color-Word Interference	61.14 (16.14)	59.95 (13.96)	55.11 (21.96)	
Wisconsin Card Sorting Test**	3.88 (1.08)	2.22 (1.38)	2.56 (1.01)**	OA >MCI=AD
CVLT total**	58.00 (9.87)	45.38 (11.77)	34.50 (13.19)**	OA >MCI >AD
Logical memory (immediate)**	26.71 (7.74)	19.48 (8.32)	13.22 (8.66)**	OA >MCI=AD
Logical memory (delayed)**	24.63 (8.35)	10.64 (9.07)	7.00 (8.82)**	OA >MCI=AD

* significant at the 0.05 level (2-tailed).
** significant at the 0.01 level (2-tailed).

Materials and Procedure

The materials and procedure were identical to those used in Study 1. The results presented in Study 2 compare cognitively healthy older adults with individuals with MCI or early AD in order to facilitate the interpretation of complex interaction effects.

Statistical Analyses

Prior to the main analyses, all data were cleaned, which included removing incorrect responses to decision task trials and reaction times $\geq$2.0 standard deviations larger than the individual's mean reaction time. The proportion of correctly identified PM cues was then calculated (i.e., the frequency with which participants remembered to press the *Spacebar* key on presentation of the focal and the non-focal PM targets). False alarms to non-target items were infrequent, with only 100 commission errors (i.e., <0.2% of trials) in total made across all conditions. The data were evaluated to ensure that the assumptions of ANCOVA and ANOVA were met. If the distribution of scores was largely skewed, the appropriate transformations were applied. To identify variables to include as potential covariates, all analyses were examined separately for sex, handedness and primary language to determine if these demographic variables impacted the results. Data were pooled where no significant differences existed. The alpha level was set at .05 for all analyses. All statistical analyses were conducted using PASW Statistics 23.0 (SPSS Inc., Chicago, USA).

The dependent variables from the PM task - the proportion of correct PM cues, reaction time on the decision task trials, the reaction time on 'monitoring' trials, and the number of correct decision task trials - were entered into separate 3 (Group: older adults, individuals with MCI, and individuals with early AD) x 2 (Focality: focal and nonfocal) X 4 (PM Cue: 1, 5, 10, and 20) mixed analysis of variance (ANOVA), with Group as between-subjects variable and both

Focality and Number of PM cues as within-subjects variables. In all cases the fit of the model was evaluated by rerunning the analyses with different repeated covariance types and the smallest Akaike's Information Criterion was found using a compound symmetry: heterogeneous approach. As expected, no prospective memory responses were observed in the control block of the numeric decision task. Tukey's HSD will be used for all *post-hoc* analyses.

Results

There were no significant differences identified between groups in terms of handedness or primary language. However, the early AD group was found to have a significantly greater proportion of male participants compared to the other groups; entering sex as a covariate did not significantly alter any of the results and therefore this covariate is not included in the analyses.

Interference Costs

A series of paired samples t-tests comparing reaction time in the control block to reaction time in the PM blocks were performed to assess for the presence of interference costs for each group in each focality condition. As described in the previous section, cognitively healthy older adults were found to exhibit significant interference costs compared to the control block (M= 1101.71, SD= 163.84) in both the focal (M= 1269.33, SD= 177.79; $t(61)= -12.14$, $p <0.0001$) and the non-focal conditions (M= 1357.54, SD= 221.72; $t(80)= -13.20$, $p <0.0001$). Similarly, individuals with MCI also exhibited significant interference costs compared to the control block (M= 1302.21, SD= 236.93) in both the focal (M= 1516.28, SD= 212.59; $t(30)= -6.73$, $p <0.0001$) and the non-focal conditions (M= 1509.09, SD= 188.88; $t(38)= -6.76$, $p <0.0001$). In contrast, the AD group did not show this same pattern of results: no significant RT difference was observed between the control (M= 1259.00, SD= 56.17) and focal blocks (M= 1308.40, SD= 212.59). However, there were significant interference costs observed for the AD in the non-focal

blocks (M= 1561.87, SD= 307.87; t(12)= -4.57, p = 0.001).

In summary, task interference was found when prospective memory cues were embedded in the numerical decision task in all cases except for the AD group in the focal blocks.

Further analyses comparing these interference costs between the groups in the context of manipulating the focality and frequency of the PM cues will now be explored. In order to facilitate interpretation of speed/accuracy tradeoffs PM accuracy and RT data will be presented together.

PM Accuracy and Interference Costs

PM accuracy and interference costs were examined using two 3 X 2 X 4 mixed model ANOVAs, with Group (older adults, MCI, and AD) as a between-subjects variable and both Focality (focal and non-focal) and Cue frequency (1, 5, 10, 20) as within-subjects variables. First, a summary of these results is presented in Table 7. Each of these ANOVAs is then explored in detail. The results of PM accuracy and interference cost analyses are presented in Tables 8 and 9, respectively.

Table 7
Summary of ANOVA analyses comparing the PM performance of older adults and individuals with MCI and AD

	PM Accuracy	Interference Costs	Decision Task Accuracy	Post-PM Cue Monitoring
Focality	**ME:** ns	**ME:** Non-focal > focal (*p*=.09)	**ME:** ns	**ME:** Non-focal > Focal
Cues	**ME:** 5 = 20 > 10	**ME:** 1 > 10	**ME:** 5 = 10 = 20 > 1	ns
Group	**ME:** OA > AD	**ME:** ns	**ME:** OA > MCI	ns
Focality X Cues	**Focal:** ns **Non-Focal:** 5 = 20 > 1 = 10	ns	**Focal:** 5 = 20 > 10 > 1 **Non-Focal:** 10 > 1 = 5 = 20	ns
Group X Focality	ns	ns	**Focal:** OA = AD > MCI **Non-Focal:** OA > MCI = AD **MCI & AD:** Non-focal > Focal	**Focal:** OA =MCI > AD **Non-Focal:** ns **OA & AD:** Non-focal > Focal
Group X Cues	ns	ns	ns	ns
Group X Focality X Cues	**Focal**: group = ns cues = ns group X cues = ns **Non-Focal:** group: OA > AD; MCI > AD (*p*=.06) cues: 5 = 20 > 1 = 10 group X cues = ns	**Focal**: group: OA = MCI > AD (*p*=.06) cues: 1= 10 > 5 group X cues = ns **Non-Focal:** group = ns; cues: 1 = 5 = 20 > 10 group X cues = ns	ns	ns

ME = main effect; ns = not significant

Table 8

Mixed Model Analysis of Variance of PM accuracy by Group, Focality, and Cue

Source	*Numerator df*	*Denominator df*	*F*	*p*
Intercept	1	128.20	602.10	<0.001
Focality	1	398.82	2.19	.140
Cues	3	156.33	7.07	<.001
Group	2	88.14	3.46	.036
Focality X Cues	3	176.78	6.56	<.001
Group X Focality	2	226.47	.13	.876
Group X Cues	6	101.51	1.50	.184
Group X Focality X Cues	5	125.19	1.30	.268

Table 9

Mixed Model Analysis of Variance of Interference Costs by Group, Focality, and Cue

Source	*Numerator df*	*Denominator df*	*F*	*p*
Intercept	1	385.71	28.31	<.001
Focality	1	402.42	3.38	.067
Cues	3	140.18	3.26	.023
Group	2	364.44	.201	.818
Focality X Cues	3	128.05	2.21	.090
Group X Focality	2	337.83	1.48	.229
Group X Cues	6	71.33	1.22	.306
Group X Focality X Cues	5	77.42	.90	.483

Focality

First, no significant differences in accuracy were found between focal and non-focal PM blocks when collapsing across groups and cue frequencies (see Figures 5 and 6). Despite the lack of significant differences, it is worth noting that the results were in the expected direction with increased PM accuracy in the focal (M= 86.90, SD= 20.21) compared to non-focal blocks (M= 74.93, SD= 36.76).

Similarly, reaction time to decision trials (after controlling for reaction time in the control block; i.e., interference costs) showed a *trend* toward being significantly reduced in the focal blocks (M= 176.28, SD= 1123.34) compared to the non-focal blocks (M= 255.23, SD= 393.93; see Table 9). These results suggest that interference costs were higher in the non-focal compared to the focal blocks when combining groups and cue frequencies, which is consistent with predictions. However, as described above, this increased reaction time in the non-focal compared to focal blocks failed to produce a difference in PM accuracy between the focalities, though there is a *trend* toward a focality by cue interaction. It should be noted that ceiling effects (e.g., the older adult group frequently performed with greater than 90% PM accuracy) and a lack of statistical power, may play a role in these results.

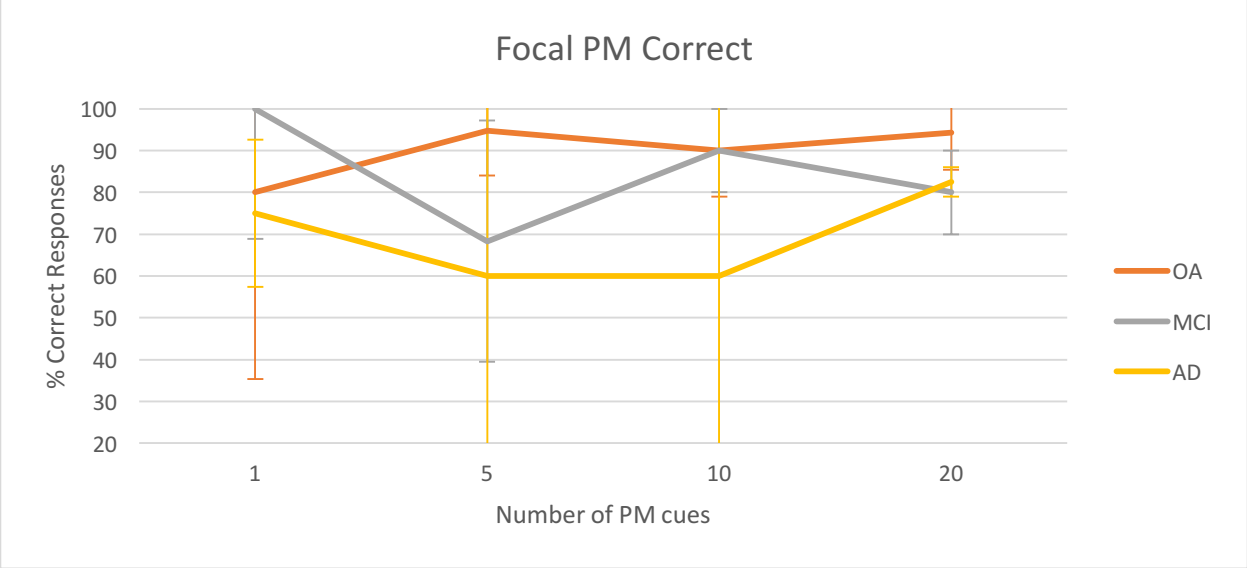

Figure 5: Proportion of correctly identified PM cues in the Focal condition with error bars representing standard deviation.

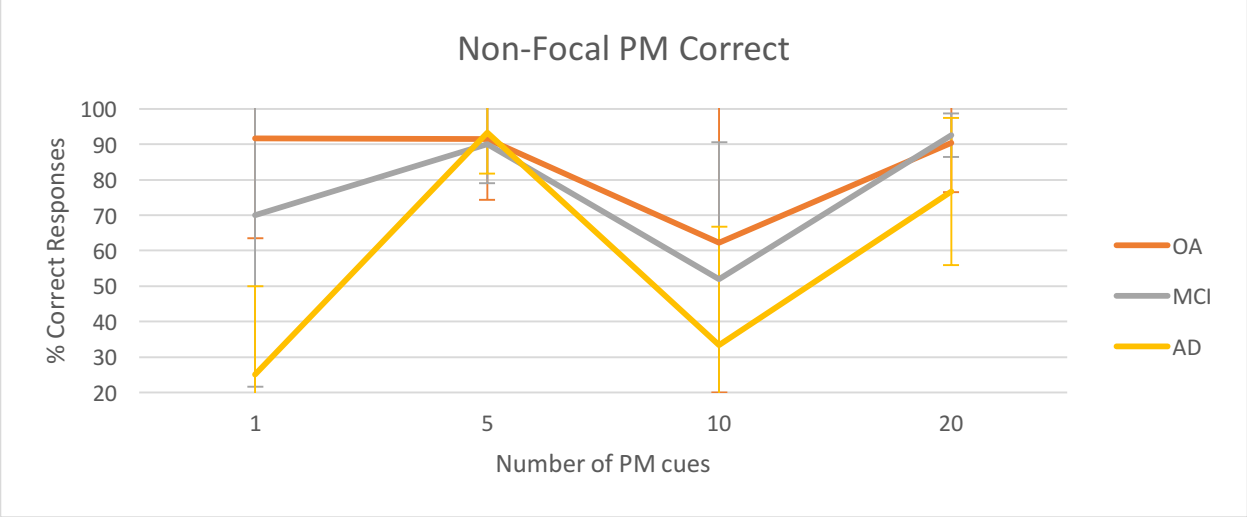

Figure 6: Proportion of correctly identified PM cues in the Non-Focal condition with error bars representing standard deviation.

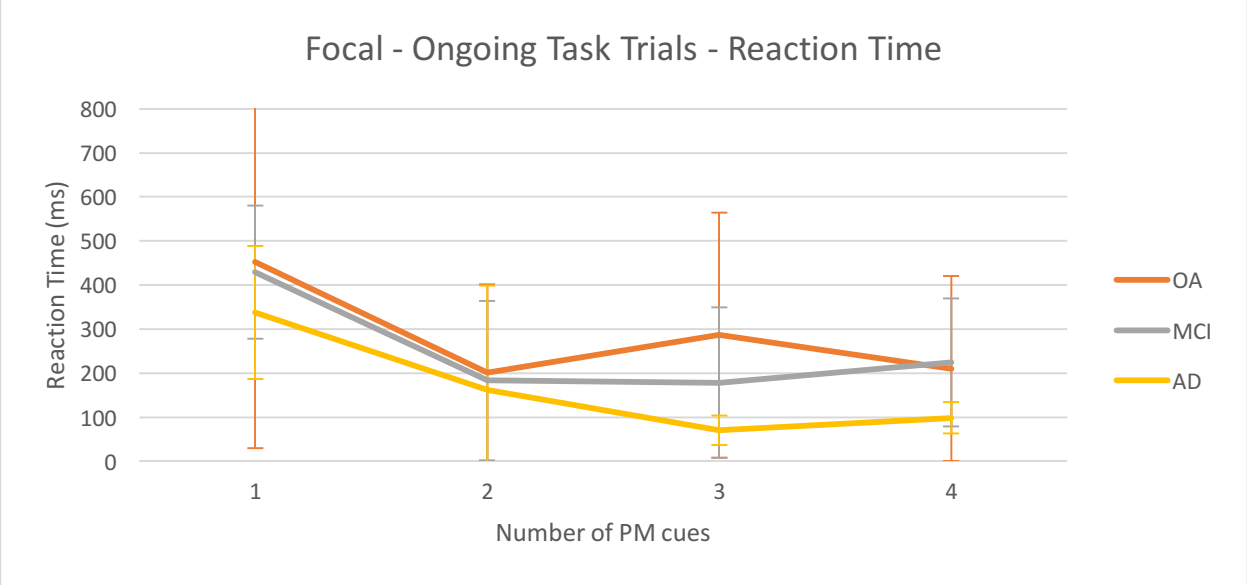

Figure 7: Reaction time (ms) to decision trials in the Focal condition after controlling for reaction time in the Control block with error bars representing standard deviation.

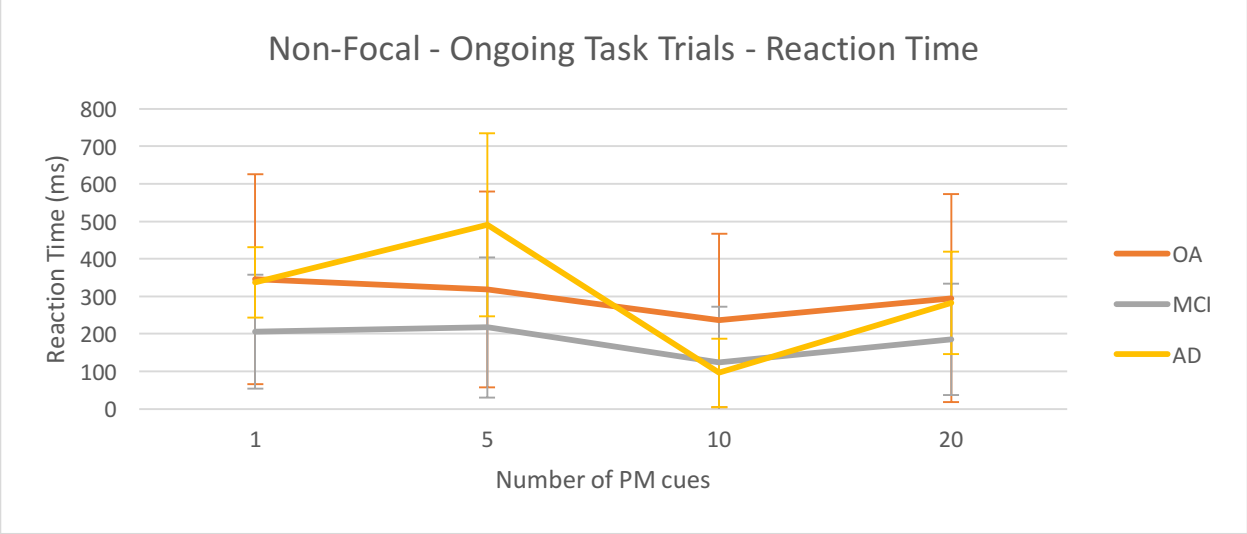

Figure 8: Reaction time (ms) to decision trials in the Non-Focal condition after controlling for reaction time in the Control block with error bars representing standard deviation.

Cues

There are significant differences between cue frequencies when collapsing across groups and focalities in terms of PM accuracy (see Figures 5 and 6). Participants were significantly less accurate in the 10 PM cue blocks (M= 65.07, SD= 39.16) compared to the 5 PM cue blocks (M= 87.80, SD= 19.66, p <0.0001) and the 20 PM cue blocks (M= 89.14, SD= 12.22, p <0.0001). With respect to reaction time, interference costs were significantly higher in the 1 PM cue blocks (M= 284.01, SD= 181.41) compared to the 10 PM cue blocks (M= 170.58, SD= 150.62, p = 0.001). These results are consistent with those from Study 1 showing significant differences between the 5 and 10 PM cue blocks.

Group

There were significant differences in PM accuracy but not interference costs between groups when collapsing across focalities and cue frequencies. Specifically, the older adult group (M= 86.05, SD= 27.36) displayed significantly higher accuracy than the AD group (M= 59.21, SD= 42.70, p = 0.011). Though further significant differences between the groups were not found, the results followed the predicted pattern: older adults displayed the highest accuracy followed by the MCI group, and then the AD group.

Focality X Cues

There were significant focality by cue interaction effects identified in terms of PM accuracy but not interference costs.

In terms of PM accuracy, within the focal PM blocks there were no significant differences between cue frequencies. In contrast, within the non-focal PM blocks there were significant differences between cue frequencies $F(3, 49) = 12.96$, $p < 0.0001$. Specifically, within the non-

focal blocks PM accuracy was lower in the 1 PM cue block (M= 82.86, SD= 38.24) compared to the 5 PM cue block (M= 91.30, SD= 14.56, p = 0.001) and the 20 PM cue blocks (M= 89.13, SD= 13.71, p = 0.003). Accuracy was also lower in the 10 PM cue blocks (M= 56.42, SD= 41.61) compared to the 5 PM cue blocks (p <0.0001) and the 20 PM cue blocks (p<0.0001). The reduced accuracy in the 10 PM cue blocks appears due to the performance in the non-focal 10 PM cue block. In particular, there was a significant difference within the 10 PM cue frequency between focalities $F(1, 82) = 16.61$, $p < 0.0001$ which showed that participants were significantly less accurate in the non-focal 10 PM cue block (M=56.42, SD= 41.61) relative to the focal 10 PM cue block (M= 85.91, SD= 21.75, p < 0.0001).

Overall, the PM accuracy results are mostly consistent with those from Study 1, in which participants demonstrated significantly lower accuracy in the 10 PM cue blocks compared to the 5 and 20 PM cue frequencies. Notably, significantly lower accuracy in the non-focal 10 PM cue condition compared to focal 10 PM cue condition contributed to the significant differences between these cue frequencies in this study.

Group X Focality

There were no significant group by focality interaction effects identified either in terms of PM accuracy or interference costs. As age-related declines are expected with non-focal but not focal PM cues within the DMPT, it was predicted that individuals with cognitive impairment would be further impacted by varying the focality of the PM cue. Although the interaction results were not significant, overall accuracy for the groups did fall in the expected pattern, with the older adult group (M= 86.05, SD= 27.36) being more accurate that the MCI group (M= 72.87, SD= 32.13) who in turn are more accurate than the AD group (M= 59.21, SD= 42.70). Moreover, each group was more accurate in the focal compared to non-focal blocks; though, again, these

differences were not significant.

Group X Focality X Cues

There were no significant 3-way interaction effects identified in the omnibus ANOVA either in terms of PM accuracy or interference costs. However, on the basis of planned comparisons both of these 3-way interactions will be further explored.

First, in terms of PM accuracy within the focal blocks, there were no significant differences between groups or cue frequencies nor any group by cue interaction effects.

In terms of interference costs within the focal blocks, there was a main effect of cue frequency $F(3, 37)= 3.03$, $p = 0.042$. Specifically, there were significantly greater interference costs found in the focal 1 PM cue block (M= 284.22, SD= 157.73) compared to the 5 PM cue block (M= 151.69, SD= 150.07, p = 0.001) and the 10 PM cue block (M= 180.82, SD= 119.45, p = 0.003). Interference costs in the 10 PM cue block were also significantly greater than the 5 PM cue block. There was also a *trend* toward a main effect of group $F(2, 47)= 3.09$, $p = 0.055$: the older adult (M= 167.62, SD= 108.73) and MCI groups (M= 214.07, SD= 177.09) displayed greater interference costs than the AD group (M= 49.40, SD= 84.14).

Second, in terms of accuracy within the non-focal blocks, there was a main effect of cue frequency $F(3, 52)= 11.15$, $p < 0.0001$ and group $F(2, 40)= 4.98$, $p = 0.012$ but no significant group by cue interaction. With respect to cue frequency, accuracy was significantly lower in the 1 PM cue block (M= 82.86, SD= 38.24) compared to the 5 PM cue block (M= 91.30, SD= 14.56, p = 0.003) and the 20 PM cue block (M= 89.13, SD= 13.71, p = 0.012). Furthermore, accuracy was significantly lower in the 10 PM cue block (M= 56.42, SD= 41.61) compared to the 5 PM cue block (p< 0.0001) and the 20 PM cue block (p< 0.0001). With respect to the group differences, the older adult group (M= 81.14, SD= 33.10) performed significantly more

accurately than the AD group (M= 55.71, SD= 44.67, p = 0.005) while the MCI group (M= 68.24, SD=v38.70) also displayed a *trend* toward being more accurate than the AD group (p = 0.06).

In terms of interference costs within the non-focal blocks, there was a main effect of cue frequency $F(3, 62)= 7.70$, $p < 0.0001$ but not group, nor was there any significant group by cue frequency interaction. The groups displayed significantly lower interference costs in the non-focal 10 PM cue block (M= 166.25, SD= 162.89) compared to all other non-focal cue frequency blocks (1 PM cue: M= 283.97, SD= 187.87, p = 0.002; 5 PM cues: M= 451.87, SD= 459.65, p = 0.036; 20 PM cues: M= 216.05, SD= 118.21, p = 0.002).

Supplementary Analyses

Interference costs before and after the PM cue

As described in Study 1, it has been suggested that task interference may emerge after, but not before, the first target cue (Scullin, 2009). Therefore, interference costs before and after the PM cue in the 1 PM cue condition were explored for participants who accurately responded to the PM cue. Again, it is important to note that participants are unaware of the frequency of PM cues at the outset of each block.

With respect to older adults, the results from Study 1 revealed that older adults displayed significantly greater interference costs in the focal block before the PM cue (M= 279.50, SD= 101.85) compared to after the PM cue (M= 201.75, SD= 116.78; t(3)= 3.32, p = 0.045). There were no significant differences before or after the response to the PM cue in the non-focal block for the older adults. For the MCI and AD groups, there were no significant differences in interference costs before or after the PM cue in either the focal or non-focal blocks Notably, the change in interference costs for older adults before and after the PM cue suggests that this group may be strategically allocating cognitive resources in response to the perceived demands of the

task while the MCI and AD groups are found to respond consistently throughout the 1 PM cue task blocks.

Decision Task Accuracy

A 3 X 2 X 4 mixed model ANOVA was conducted with Group (older adults, MCI, and AD) as a between-subjects variable and both Focality (focal and non-focal) and Cue frequency (1, 5, 10, 20) as repeated measures variables (see Table 10 for results).

Table 10

Mixed Model Analysis of Variance of Accuracy on Decision Trials by Group, Focality, and Cue

Source	*Numerator df*	*Denominator df*	*F*	*p*
Intercept	1	69.69	15011.61	<0.001
Focality	1	82.08	1.52	.222
Cues	3	68.28	4.94	.004
Group	2	54.82	14.11	<0.001
Focality X Cues	3	56.59	8.95	<0.001
Group X Focality	2	41.51	9.94	<0.001
Group X Cues	6	57.27	1.61	.160
Group X Focality X Cues	5	77.53	2.14	.069

In exploring the main effect of cues, all groups were less accurate in the 1 PM cue blocks (M= 88.68, SD= 4.39) compared to all other cue frequencies (5 PM cues: M= 92.70, SD= 6.42, p = 0.006; 10 PM cues: M= 92.31, SD= 4.72, p = 0.002; 20 PM cues: M= 92.99, SD= 5.41, p = 0.001). These results are similar to the increased interference costs observed with 1 PM cue compared to 10 PM cues. Overall, the results suggest that 1 PM cue requires increased cognitive resources to be divided between the ongoing and PM tasks for these groups.

In terms of group differences, the older adults (M= 95.52, SD= 3.92) were significantly more accurate in the ongoing task compared to the MCI group (M= 90.47, SD= 6.75, p < 0.0001). There were no significant differences identified relative to the AD group (M= 91.42, SD= 4.93).

The focality by cue frequency interaction revealed significant differences in ongoing task accuracy within both the focal $F(3, 21)= 8.01$, $p = 0.001$ and non-focal blocks $F(3, 60)= 6.86$, $p < 0.0001$. Specifically, within the focal blocks, groups were less accurate in the 1 PM cue block (M= 91.14, SD= 8.45) compared to all other PM cue frequencies (5 PM cues: M= 93.47, SD= 7.26, p < 0.0001; 10 PM cues: M= 92.95, SD= 5.81, p = 0.009; 20 PM cues: M= 93.86, SD= 5.90, p = 0.001). Groups were also less accurate in the 10 PM cue block compared to the 5 PM cue block (p = 0.025) and 20 PM cue block (p = 0.041). The ongoing task accuracy results within the focal blocks are nearly identical to the interference costs documented above, suggesting that the 1 and 10 PM cue blocks are the most resource-demanding. Alternatively, participants may be emphasizing the ongoing task over the PM task in these blocks in contrast to the 5 and 20 PM cue blocks.

Within the non-focal blocks, groups were more accurate in the 10 PM cue block (M= 94.20, SD= 4.19) compared to all other cue frequencies (1 PM cue: M= 91.88, SD= 5.10, p <

0.028; 5 PM cues: M= 90.30, SD= 4.99, p < 0.0001; 20 PM cues: M= 91.68, SD= 4.67, p = 0.021). The increased accuracy on the ongoing task in the 10 PM cue block compared to all other cue frequencies suggests participants may have been emphasizing the ongoing task at the expense of PM accuracy leading to significantly lower PM accuracy in the 10 PM cue block compared to the 5 PM cue frequency.

In examining the group by focality interaction, there are significant differences in accuracy between groups within both the focal $F(2, 45)= 16.07$, $p < 0.0001$ and the non-focal $F(2, 48)= 9.65$, $p < 0.0001$ blocks. Within the focal blocks, the older adult (M= 95.50, SD= 4.43, p < 0.0001) and AD (M= 93.50, SD= 2.66, p = 0.001) groups were more accurate than the MCI group (M= 88.84, SD= 8.28). Within the non-focal blocks, the older adults (M= 95.54, SD= 3.51) were more accurate than both the MCI (M= 91.77, SD= 4.98, p = 0.001) and AD (M= 90.46, SD= 5.50, p = 0.002) groups. In addition, the MCI group was found to be more accurate in the non-focal (M= 91.77, SD= 4.98) compared to the focal blocks (M= 88.84, SD= 8.28, p <0.0001) as was the AD group (focal: M=93.50, SD= 6.52; non-focal: M=90.46, SD= 5.50, p = 0.014). These results are in contrast to expectations in which non-focal PM tasks are expected to be more cognitively demanding and should therefore lead to fewer available resources to allocate to the ongoing decision task. This suggests that these groups may have emphasized the ongoing task above the PM task.

Post-PM Cue Monitoring

A 3 X 2 X 4 mixed model ANOVAs was conducted with Group (older adults, MCI, and AD) as a between-subjects variable and both Focality (focal and non-focal) and Cue frequency (1, 5, 10, 20) as within-subject variables to assess differences in monitoring (i.e., interference costs in the 3 trials following accurate PM response).

The results revealed a main effect of focality $F(1, 12)= 11.31$, $p = 0.005$: significantly greater monitoring was observed in the non-focal (M= 335.80, SD= 289.26) compared to the focal blocks (M= 208.67, SD= 195.68). This result is consistent with the expectation that monitoring for non-focal PM cues is more cognitively demanding than monitoring for focal PM cues.

The results also revealed a significant group by focality interaction $F(2, 7)= 5.73$, $p = 0.032$. Specifically, the AD group (M= 215.57, SD= 337.08) displayed significantly less monitoring compared to both the older adult (M= 286.54, SD= 246.64, p = 0.003) and the MCI groups (M= 274.02, SD= 265.80, p = 0.001) in the focal blocks. There were no significant between group differences within the non-focal blocks. With respect to within group differences, the older adult and AD groups displayed increased monitoring in the non-focal (older adults: M= 366.79, SD= 290.48; AD: M= 318.60, SD= 342.74) compared to the focal blocks (older adults: M= 193.14, SD= 133.74, p = 0.022; AD: M= -42.00, SD= 126.98, p = 0.001).

Discussion

In Study 2, we first examined interference costs (i.e., the difference in reaction time in the presence of a PM load compared to the control block) in both the focal and non-focal blocks. Results revealed the presence of interference costs in all PM conditions for the older adults and MCI participants. This suggests that a PM load always interferes with the ongoing task for these groups, and that some degree of cognitive resources must be allocated to PM cue detection. The findings for these groups are consistent with the PAM theory's proposal that PM tasks are always capacity-consuming (Smith & Bayen, 2005). In contrast, results for the AD group are more accurately reflected by the Dynamic Multiprocess Framework, which proposes that capacity-

consuming resources may not be required to respond to focal PM cues (Scullin et al., 2013), although the accuracy results, which will be discussed below, indicate that the lack of interference costs in this group was associated with increased PM failures compared to the older adults.

Similar to Study 1, higher interference costs were found for non-focal compared to focal PM cues. This is, again, consistent with the predictions of the DMPT, because non-focal cues are proposed to be more cognitively demanding. However, increased reaction time in the non-focal compared to focal blocks failed to produce a difference in PM accuracy between the focalities. Rather, it appears that non-focal PM cues produced an increase on attentional demands. It should be noted that ceiling effects (e.g., the older adult group frequently performed with greater than 90% PM accuracy) may play a role in these results.

In terms of cue frequency effects, results were also similar to those from Study 1 and revealed significant differences in accuracy between the 5 and 10 PM cue blocks. This reinforces the assertion that slight changes in PM cue frequency (e.g., 5-9%) can lead to changes in PM performance. In addition, interference costs were higher in the 1 PM cue condition compared to the 10 PM cue condition, suggesting that performance tends to improve as the task increasingly becomes one of vigilance (Uttl, 2011). However, this possibility also predicts reduced costs with 20 PM cues which were not observed. Instead, it is possible that the 10 PM cue block is qualitatively different than other PM cue frequencies. A qualitative difference with 10 PM cues may occur because the task can be approached as either a PM or vigilance task. This could lead to difficulties efficiently allocating cognitive/monitoring resources at this cue frequency.

Unique results regarding the 10 PM cue frequency are also apparent in the focality by cue interaction effects. Across focalities, significantly lower accuracy was observed in the 10 PM cue

blocks relative to other cue frequency conditions. This reduced accuracy was driven by significantly lower accuracy in the non-focal compared to the focal 10 PM cue blocks. Thus, as in Study 1, the results with respect to 10 PM cue frequency are largely consistent with the predictions of DMPT, while other cue frequencies do not display this pattern. Taken together, these findings suggest that older adults and those with cognitive impairment may experience difficulty in allocating resources to maintain PM accuracy in the 10 PM block, where they did not slow their response speed to maintain accuracy.

There are also cue frequency differences that align with the meta-analytic findings reporting large age-related declines in PM with 1 cue (referred to as "PM proper") and smaller declines in PM tasks that may be considered to measure vigilance (Uttl, 2011). Specifically, lower accuracy in the 1 PM cue blocks compared to the 5 and 20 PM cue blocks is consistent with these findings. But, again, the 10 PM cue frequency remains an outlier. Taken together, 10 PM cues may represent a point on the continuum between a traditional PM task and one of vigilance/monitoring. Moreover, the significant differences between the 5 and 10 PM cue blocks suggest that relatively small manipulations in cue frequency (i.e. PM cues on 5% to 9% of trials) can produce significantly different PM performance.

As in Study 1, the three-way interaction effects between group, focality, and cue frequency are inconsistent in terms of the predictions of the DMPT.

First, within the focal blocks, though there were no differences in PM accuracy, significantly different interference costs were found. Specifically, interference was higher in the 1 and 10 PM cue blocks compared to the 5 PM cue block. Differences between cue frequencies were not predicted in the focal blocks. The increased interference costs observed in the focal 1 PM cue block raises the possibility that participants may have slowed their responses until

encountering the first PM cue. Indeed, older adults, but not individuals with MCI or AD, were found to be slower before compared to after the PM cue in in the focal block. Notably, the change in interference costs for older adults following the PM cue suggests that this group may be strategically allocating cognitive resources in response to the perceived demands of the task. In contrast, the MCI and early AD groups are found to respond consistently throughout the 1 PM cue task blocks.

Second, within the non-focal blocks, the significant differences identified in both accuracy and interference costs between the cue frequencies were predicted by the DMPT. The increased cognitive demands of non-focal, compared to focal, PM tasks are predicted to be susceptible to the influence of manipulations that impact monitoring. In addition, reduced accuracy in the 1 PM cue block compared to the 5 and 20 PM cue blocks is also consistent with previous research showing greater age-related declines in 'PM proper' compared to vigilance tasks (Uttl, 2011). Furthermore, there were again differences between the 5 and 10 PM cue blocks, suggesting that participants were utilizing a speed/accuracy tradeoff strategy, because both accuracy and interference costs were greater in the 5 PM cue block. Similar to Study 1, the contrasting performances between the 5 and 10 PM cue blocks suggest that participants may be implementing different strategies at these cue frequencies.

Third, post-PM cue monitoring was also examined and the results, as in Study 1, are consistent with the DMPT predictions that non-focal blocks would require increased resources/monitoring compared to the focal blocks. Moreover, this effect was observed in both the older adult and early AD groups but not the MCI group. The early AD group also displayed significantly less monitoring overall than the other groups, in combination with reduced PM accuracy. This finding is in line with research indicating individuals with AD may have

difficulties allocating cognitive resources (Baddeley et al, 2001). Attentional, or cognitive, control is a key element in PM and is likely a factor in the performance of this group (Bugg, McDaniel, & Einstein, 2013; Balota & Faust, 2001).

Finally, there were also significant differences in accuracy on the ongoing task for these groups. Specifically, within the focal blocks, the ongoing task accuracy results showing lower performance in the 1 and 10 PM cue blocks are nearly identical to the interference costs documented above, suggesting that these conditions are the most resource-demanding. Alternatively, participants may be emphasizing the ongoing task over the PM task in these blocks in contrast to the 5 and 20 PM cue blocks; however, task instructions were identical, making this possibility less likely.

Within the non-focal blocks, ongoing task accuracy was highest with 10 PM cues, though PM accuracy in this block was lower compared to the 5 PM cue block, suggesting a tradeoff in attentional allocation. There were also between-group differences that showed that individuals with MCI were less accurate in the focal blocks compared to the older adult and AD groups, while older adults were more accurate in the non-focal blocks compared to the MCI and AD groups. In addition, the MCI and AD groups were found to be more accurate in the non-focal compared to focal blocks. Non-focal blocks are expected to be more cognitively demanding and should therefore lead to fewer available resources to allocate to the ongoing decision task. Thus, the increased accuracy in the non-focal blocks is in contrast to predictions based on the DMPT. This finding suggests that these groups may have used different strategies of attentional allocation, variably emphasizing the ongoing task above the PM task, depending on the focality and cue frequency.

The purpose of Study 3 is to further explore the relationship between the PM cue and

intended action by manipulating the strength of the relationship between these two variables. Furthermore, Study 3 assesses the PM performance of cognitively healthy older adults and those with cognitive impairment (i.e., MCI or early AD) on a video shopping task that can be considered more ecologically valid than the task used in Studies 1 and 2.

Study 3

Participants

A total of 71 individuals participated in this study. Forty-one cognitively healthy older adults, aged 65 and older were a subset as those from Studies 1 and 2 who were recruited from community centres, exercise classes, and advertisements placed in local newspapers, supermarkets, and nursing homes. Twenty individuals with MCI and 10 individuals with early AD were recruited, diagnosed, and screened using the same methodology as Study 2. A breakdown of age, education, and the neuropsychological measures is presented in Table 11.

Table 11

Participants' demographic and neuropsychological characteristics. Scores are given as Mean (Standard deviation).

	Older adults	MCI	Early AD	Groups differences
N (Male:Female)	41 (15:26)	20 (9:8)	10 (9:1)**	AD >OA=MCI
Age**	70.47 (4.38)	77.00 (5.77)	74.50 (5.58)*	MCI=AD >OA
Education	15.64 (2.78)	15.39 (2.52)	15.90 (3.60)	
MoCA**	27.54 (1.68)	22.65 (3.28)	20.80 (4.71)**	OA >MCI=AD
Digit Span (forward + backward)	17.58 (3.92)	16.05 (3.66)	14.80 (3.68)*	
Boston Naming Test**	53.87 (5.04)	48.00 (6.58)	45.00 (9.96)**	OA >MCI=AD
Category Fluency**	21.00 (4.19)	13.50 (5.40)	14.00 (3.74)**	OA >MCI=AD
Phonemic Fluency	13.77 (4.52)	12.80 (4.97)	12.20 (5.05)	
Stroop Color-Word Interference	61.00 (16.22)	58.94 (13.95)	55.11 (21.96)	
Wisconsin Card Sorting Test**	3.81 (1.10)	2.30 (1.38)	2.56 (1.01)**	OA >MCI=AD
CVLT total**	58.18 (10.32)	45.72 (12.47)	34.50 (13.19)**	OA >MCI >AD
Logical memory (immediate)**	26.73 (8.01)	19.10 (8.58)	13.22 (8.66)**	OA >MCI=AD
Logical memory (delayed)**	24.76 (8.61)	10.16 (9.16)	7.00 (8.82)**	OA >MCI=AD

* significant at the 0.05 level (2-tailed).
** significant at the 0.01 level (2-tailed).

Materials

Prospective Memory Video Task

The Prospective Memory Video Task consisted of a 23-minute film that simulated a person walking through a mall and passing a variety of stores from a first person perspective. The video was presented to participants on a 15-inch screen laptop screen. Before presenting the video, the participant was told a story describing the purpose of the visit to the mall in order to engage them with the task. Subsequently, a list of PM tasks related to the story was presented to the participant orally. The list contained 10 tasks including eight event-based PM tasks and two time-based PM tasks. With respect to the event-based tasks, four were intended to have a strong link between the cue and intended action (e.g., buying bus tickets at the bus ticket counter) and four were intended to have a weak link between the cue and intended action (e.g., buy a bottle of water at the newsstand; see Appendix for a list of the tasks). The three time-based tasks were to be executed at different times during the video. The first was to be completed ten minutes into the video and the second twenty minutes into the video. A third time-based task was not part of the initial task list. Upon completing one of the PM intentions, the participant was instructed to announce to the examiner that they needed to return to this location after five minutes had passed. This last task was intended to evaluate whether participants could adapt to novel situations in their environment (see Appendix C for a list of tasks).

The PM Video task was divided into two stages: learning the tasks and watching the film. Learning took place using the principles of the Grober and Buschke procedure (Grober & Buschke, 1987). After being told the story about their purpose in the mall, the participant was instructed to try and remember a list of locations (cues) and actions that were read to them. After the presentation of the tasks, the participant was asked to freely recall as many locations and actions as possible, in any order. After two minutes, for any locations or tasks not recalled, cues

were provided as follows: (i) if the participant failed to recall the location and task, the cue was the location (or the time for time-based tasks); ((ii) if the participant failed to recall the location (or time), the cue was the action to be completed; and (iii) if the participant failed to recall the action, the cue was the location (or time) of the task. This process was repeated two additional times for a total of three presentations and recalls of the information.

Prior to beginning the video, the participant was told that, once the video begins, they could stop the video using the SPACEBAR and announce the completion of a task. The participant could also monitor the time of the video by moving the cursor, which briefly displayed the current time. The examiner recorded the time, location and announced actions whenever the video was stopped throughout the task. Immediately following completion of the video, the participant completed a single delayed recall trial of the locations and tasks that followed the same cued recall procedures as in the learning phase.

Scoring

During the learning phase, the participant was awarded two points if they recalled the location and action. If the participant recalled only one of the location or action, one point was awarded. The maximum number of points a participant could obtain for each recall was 20, corresponding to the 10 locations/times and the 10 actions. The total score for the free recall consisted of the sum of the free recall sessions. The same scoring was used for delayed recall.

During the video, scoring of the event-based tasks consisted of awarding one point for each correct component: one point for pausing the video at the appropriate point, one point for announcing the location, and one point for announcing the correct action. This corresponded to 3 points for a completed task with a total of 24 points for the event-based tasks. The same scoring was applied to the time-based task introduced during the course of the task. Scoring the time-

based tasks consisted of awarding one point for stopping the video at the appropriate time and one point for announcing the correct action, for a maximum score of seven. Therefore, the maximum overall score in performing this portion of the task was 31. All scores were converted to the proportion correct for statistical analyses.

Four types of errors were also scored: anticipation, delay, transformation and perseveration. Anticipation errors occurred when the participant paused the video or announced a location or action prior to the appropriate time. Delay errors occurred when the participant stopped the video or announced a location or action after the appropriate time. Transformation errors occurred when a participant announced an action or location that was not introduced. Finally, a perseverative error occurred when the participant announced an action or location that had already been announced.

Procedure

Ethical approval was obtained from the Research Ethics Board of the University of Ottawa and participants were treated according to the principles outlined by this board throughout the study. At the start of the testing session participants were provided with a consent form that outlined the purpose, procedures, risks/benefits, and voluntary nature of the study. Participants were required to sign the consent form before continuing with the study. Testing sessions were individually conducted and took place in a quiet room with a research assistant or the primary investigator administering the tasks. Sessions lasted approximately 90 minutes and computer-based tasks were administered using 15-inch Dell laptop. In addition to the PM task, participants also completed a small battery of neuropsychological tests as part of a broader ongoing study, the results of which, due to the limited power associated with the sample sizes, were not included in the current study. Finally, participants also indicated their familiarity with

the shopping location used in the current task as well as with the use of public transportation.

Statistical Analyses

The data were analyzed using a 3x3 MANOVA to examine the test phase of the PM video task. Group (cognitively healthy older adults, individuals with MCI, and individuals with early AD) served as the between-subjects variable and cue-type (event-based strong, event-based weak, and time-based) as the within-subjects variable. In addition, two one-way ANOVAs were conducted with Group (cognitively healthy older adults, individuals with MCI, and individuals with early AD) serving as the independent variable and the learning and retrospective recall scores as dependent variables. Finally, if differences are found in terms of learning and retrospective recall, these variables were entered as covariates in an additional 3 x 3 MANOVA with Group as the between-subject variable and cue-type from the test phase as the within-subject variable. Tukey's HSD was used for all *post-hoc* analyses. The data were evaluated to insure that the assumptions of ANCOVA and ANOVA are met. To identify variables to include as potential covariates, all analyses were examined separately for sex, handedness and primary language to determine if these demographic variables impacted the results. The alpha level was set at .05 for all analyses and effect sizes were estimated using partial eta squared (η^2). All statistical analyses were conducted using PASW Statistics 23.0 (SPSS Inc., Chicago, USA).

Results

No significant group differences were observed in handedness, primary language, or familiarity with the shopping location or the use of public transportation. However, the early AD group was found to have a significantly greater proportion of male participants compared to the other groups; entering sex as a covariate did not significantly alter any of the results.

Learning Phase

Learning scores were compared using a one-way ANOVA in which Group (cognitively healthy older adults, individuals with MCI, and individuals with early AD) served as the independent variable and proportion of tasks learned served as the dependent variable. There were statistically significant differences with respect to the learning phase of the PM video task, $F(2, 68) = 29.85$, $p < 0.0001$, $\eta^2 = 0.47$. *Post-hoc* analyses reveal that the older adult group (M= 90.85, SD= 9.61) learned significantly more PM tasks than both the MCI (M= 62.25, SD= 28.90, $p < 0.0001$) and AD (M= 45.50, SD= 24.99, $p < 0.0001$) groups. In addition, there was a *trend* indicating the MCI group also learned more PM tasks than the AD group, $p = 0.07$.

Retrospective Recall Phase

Retrospective recall scores were compared using a one-way ANOVA in which Group (cognitively healthy older adults, individuals with MCI, and individuals with early AD) served as the independent variable and proportion of tasks recalled as the dependent variable. There were statistically significant differences with respect to the retrospective recall phase of the PM video task after covarying for learning scores, $F(2, 66) = 12.01$, $p < 0.0001$, $\eta^2 = 0.26$. *Post-hoc* analyses reveal that the older adult group (M= 79.55, SD= 20.04) recalled significantly more PM tasks than both the MCI (M= 54.77, SD= 28.50, $p = 0.001$) and AD (M= 45.45, SD=, $p < 0.0001$) groups. There was no significant difference between the MCI and AD groups.

Due to the significant differences in learning scores, an additional 3 x 1 ANCOVA was performed again with Group as the independent variable and proportion of tasks recalled as the dependent variable while the proportion of tasks learned was entered as a covariate. After controlling for learning, there were no statistically significant differences in retrospective recall between groups. However, it should be noted that the observed power with covariate included was determined to be 0.07 compared to 0.99 without the covariate which suggests that the

ANCOVA results may not be reliable.

Test Phase

Proportions of correct PM responses are presented in Figure 9. The results of a 3 x 3 MANOVA using cue-type (event-based strong, event-based weak, and time-based) as within subjects variables and group as a between subjects variable revealed a main effect of cue-type, $F(2, 136) = 44.60$, $p < 0.0001$, $\eta^2 = 0.40$ and group, $F(2, 68) = 25.84$, $p < 0.0001$, $\eta^2 = 0.43$. In terms of cue-type, participants displayed significantly greater PM accuracy with event-based cues with a strong association between the cue and action (M= 92.37, SD= 18.46) compared to the other cue types (event-based weak: M= 82.04, SD= 24.34, $p < 0.0001$; time-based: M= 67.81, SD= 35.05, $p < 0.0001$). Participants were also significantly more accurate with event-based weak cues compared to time-based cues, consistent with predictions. In terms of group, older adults were significantly more accurate (M= 92.70, SD= 6.60) compared to MCI (M= 69.70, SD= 25.22, $p < 0.0001$) and AD groups (M= 53.77, SD= 27.23, $p < 0.0001$) when combining all cue-types. The MCI group also performed significantly more accurately than the AD group.

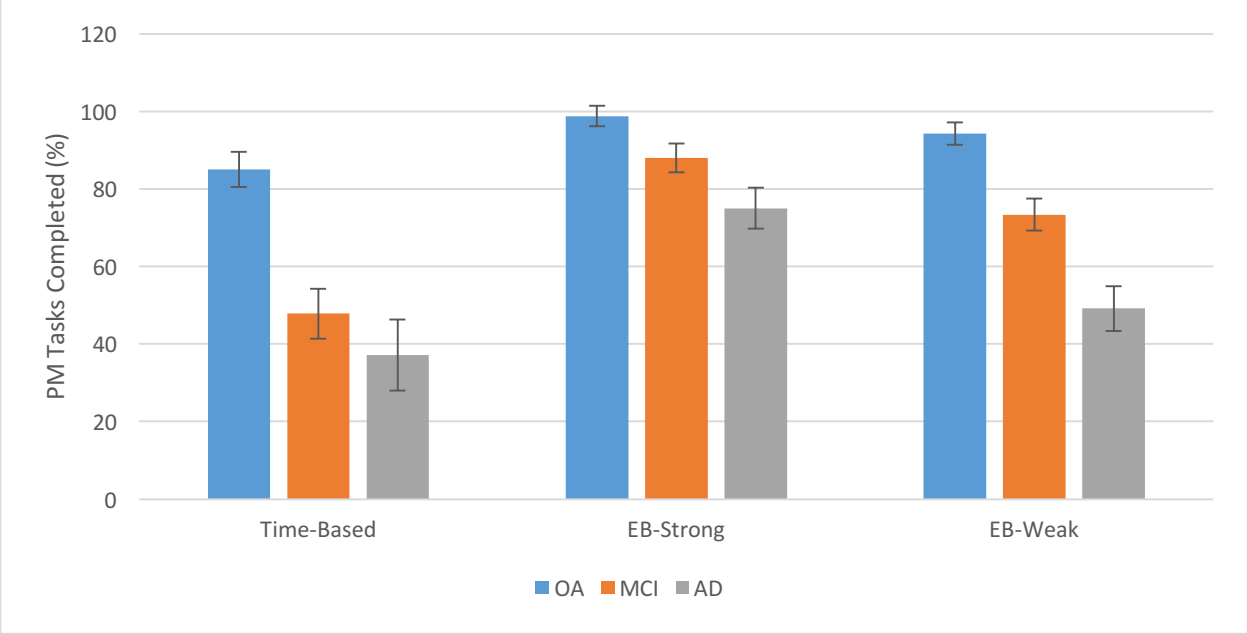

Figure 9: Proportion of correctly identified PM cues for each cue-action association and group with error bars representing standard deviation.

These main effects were qualified by a significant two-way interaction, $F(4, 136) = 6.51$, $p < 0.0001$, $\eta^2 = 0.16$ (see Figure 9). Post-hoc analyses revealed significant differences between cue-types within each group: (i) Older adults: $F(2, 67) = 5.05$, $p = 0.009$, $\eta^2 = 0.13$; (ii) MCI: $F(2, 67) = 21.83$, $p < 0.0001$, $\eta^2 = 0.40$; and (iii) AD: $F(2, 67) = 18.41$, $p < 0.0001$, $\eta^2 = 0.36$. Older adults displayed significantly greater accuracy with event-based strong cues (M= 98.78, SD= 3.98) compared to the other cue types (event-based weak: M= 94.31, SD= 9.58, $p = 0.021$; time-based: M= 85.02, SD= 18.06, $p = 0.003$). Furthermore, older adults performed significantly more accurately with event-based weak cues compared to time-based cues ($p = 0.021$). The MCI group also displayed significantly greater accuracy with event-based strong cues (M= 87.92, SD= 23.02) compared to the other cue types (event-based weak: M= 73.33, SD= 26.16, $p < 0.0001$; time-based: M= 47.85, SD= 41.01, $p < 0.0001$). And, again, the MCI group performed significantly more accurately with event-based weak cues compared to time-based cues ($p < 0.0001$). The AD group showed a similar pattern: significantly greater accuracy with event-based strong cues (M= 75.00, SD= 29.92) compared to the other cue types (event-based weak: M= 49.17, SD= 26.48, $p < 0.0001$; time-based: M= 37.14, SD= 35.76, $p < 0.0001$). However, in contrast to the other groups, the AD group did not display a significantly different performance between event-based weak and time-based cues. The results for the older adult and MCI groups mirror those of the combined groups. Notably, the overall pattern of PM accuracy was the same for the AD group despite the lack of a statistically significant difference between event-based weak and time-based cues. Given that this group had the smallest sample size of the groups, this last finding may be influenced by a lack of power.

Due to the significant differences in learning and retrospective recall between groups, these variables were entered as covariates in a 3 x 3 MANCOVA using cue-type (event-based

strong, event-based weak, and time-based) as a within-subjects variables and group as a between-subjects variable. These comparisons help to inform whether the differences in PM were simply due to expected differences between groups in learning and retrospective memory. Results of the omnibus MANOVA did not reveal a main effect of Group $F(6, 126) = 1.81$, $p = 0.10$, $\eta^2 = 0.08$. However, on the basis of planned comparisons to evaluate the predictions outlined in the introduction, separate one-way ANCOVAs for each cue-type (event-based strong, event-based weak, and time-based) were performed with learning and retrospective recall scores entered as covariates. These results showed no significant differences between groups in terms of event-based strong or time-based cues. However, there were significant differences identified with event-based weak cues $F(2, 65) = 3.85$, $p = .02$, $\eta^2 = 0.11$. In exploring the pairwise comparisons, it was found that the AD group (M= 49.17, SD= 26.48) recalled significantly fewer actions with event-based weak cues compared to the older adult group (M= 94.31, SD= 9.58, p = 0.023) and the MCI group (M= 73.33, SD= 26.16, p = .008).

Additional performance errors

A 3 x 4 MANOVA was performed to compare the number of errors (anticipation, transformation, delay, and perseverative errors) between groups. There were significant group effects in terms of the additional errors recorded $F(8, 124) = 2.63$, $p = 0.011$, $\eta^2 = 0.15$. Specifically, there were significant group differences in terms of anticipation errors $F(2, 64) = 3.35$, $p = 0.041$, $\eta^2 = 0.10$ which revealed that the AD group (M= 1.56, SD= 3.24) committed more of these errors than the older adult group (M= 0.03, SD= 0.16). In addition, there were also significant group differences in terms of transformation errors $F(2, 64) = 9.33$, $p < 0.0001$, $\eta^2 = 0.23$ with the AD (M= 13.78, SD= 13.12, p = 0.001) and MCI (M= 8.84, SD= 12.20, p = 0.013) groups committing more of these errors than the older adult group (M= 2.03, SD= 3.24).

Discussion

The goal of Study 3 was to compare the impact of a more naturalistic and ecologically valid PM task on the PM performance of cognitively healthy older adults and those with cognitive impairment (i.e., MCI or early AD). This novel PM task included both strong and weak associations between the cue and intended action, as well as a combination of event and time-based tasks. The results were largely in keeping with expectations that cognitive impairment and weaker associations between the PM cue and action would lead to reduced PM performance.

First, participants displayed greater accuracy with event-based cues with a strong association between cue and action compared to the other cue types. Furthermore, accuracy with event-based cues with a weak association was greater than with time-based cues. In examining the groups separately, this same pattern of results remains. The association between the cue and the intended action has been argued to have an important impact on the use of either more resource-demanding, strategic processes or automatic associative memory based processes (McDaniel & Einstein, 2000). More specifically, retrieval of the PM intention is enhanced when the cue is highly associated with the action, since the detection of the cue allows a spontaneous retrieval of the action through the automatic associative memory-based system (Moscovitch, 1994). Performance on PM tasks is thus faster and more accurate when the cue and the action are associated (McDaniel & Einstein, 1993, 2007).

Given the varied resource demands of different cue-action associations, PM performance has, unsurprisingly, been shown to be significantly better when there is a high degree of association between the cue and intended action (McDaniel et al., 2004). These findings have been extended to apply to individuals with MCI and Alzheimer's disease as well as non-demented Apolipoprotein E ε4 allele carriers (a known risk factor for developing AD), all of

whom are found to respond to PM cues faster and more accurately when the cue and response are highly associated (Maylor et al., 2002; Pereira, Ellis, & Freeman, 2012; Pereira et al., 2015; Driscoll, McDaniel & Guynn, 2005). The current results examining the group as whole or within-group differences, therefore, fit well within the context of the existing body of research.

The differences between groups, however, provide an interesting contrast to previous research when considering traditional versus more ecologically valid PM tasks. In the current study, cognitively healthy older adults were found to display greater PM accuracy compared to the other groups. Individuals with MCI were also more accurate than the AD group. These findings are highly consistent with previous research showing PM impairments associated with MCI and AD when using traditional measures of PM (e.g., Blanco-Campal et al., 2009; Schmitter-Edgecombe et al., 2009; Costa et al., 2011; Martins & Damasceno, 2008; Duchek et al., 2006; Jones et al., 2006; Karantzoulis et al., 2009; Thompson et al., 2010). The use of a more naturalistic PM task has been found to attenuate or eliminate PM performance declines for individuals with MCI, although there have been conflicting results in this area as well.

Thompson, Henry, Withall, Rendell, and Brodaty (2011) utilized a more naturalistic PM task in which participants were asked to perform a time-based PM task that was embedded into participants' everyday lives and executed over an extended (2-day) time frame. Results showed that individuals with dementia (specific diagnoses were not provided) exhibited significant difficulties with this task, which were correlated with their impairments on laboratory-based assessments. On the other hand, individuals in the MCI group did not appear to show deficits relative to healthy control group on the naturalistic task.

In contrast, Delprado, Kinsella, Ong, and Pike (2013) examined the use of a naturalistic measures of PM to compare the performance of cognitively healthy older adults and individuals

with MCI over two weeks and found significant difficulties in the latter group. In addition to PM recall, another distinguishing feature between the two groups was that healthy older adults used more written strategies, whereas individuals with MCI relied more on a caregiver providing a reminder. These authors attributed the differences in strategy use as an explanation for the discrepancy with the previous naturalistic PM study in these groups. The results of the current study are more closely aligned with those showing deficits in PM associated with cognitive impairment.

However, both of the naturalistic PM studies described above used prolonged tasks which are likely to be more naturalistic than the current PM video task; the degree of ecological validity has also been an important topic in this area. In order to better understand and compare ecological validity across PM tasks, Phillips and colleagues (2008) proposed five levels of ecological validity. The first level is rarely seen in studies of PM, and refers more to everyday PM tasks, in that both the setting and intention are part of daily routine. The second level involves intentions generated by the experimenter that fit into the participant's daily routine. These two levels apply to the two studies described above. In contrast, the current study aligns with the third level: tasks set in a real or complex virtual environment that are not part of the participants' everyday routine. The lack of assimilation with the everyday routine in the current task likely plays a strong role in the findings. Specifically, participants may not have been able to implement their existing strategies to compensate for the demands of the PM tasks. There is also another important difference between the current study and the previously described studies; namely, in contrast to those studies, learning and retrospective memory were systematically evaluated as part of the current PM task.

The importance of accounting for the degree of learning and retrospective recall is clear

given that there are two distinct cognitive components involved in PM: (i) the prospective component, which refers to the ability to track the PM cue or monitor the time to self-initiate intended responses and; (ii) a retrospective memory component, which relies on declarative memory to facilitate the encoding, retention and recall of the content of the intentions and the PM cue (Costa et al., 2011; Ellis & Kvavilashvili, 2000). Participants may, therefore, fail to accurately respond to a PM cue not necessarily because of a PM failure but because of a retrospective memory failure—that is, failure to recall the content of the PM task (cf. Maylor et al., 2002; Zhou et al., 2012). It is well known that retrospective memory is impaired in dementia (McKhann *et al.*, 1984; Spaan, Raaijmakers, & Jonker, 2005) and in MCI (Artero, Petersen, Touchon, & Ritchie, 2006).

Indeed, there were significant differences in learning and retrospective memory between the groups in the present study. With respect to learning, older adults learned significantly more tasks than the other groups. The MCI group also displayed a trend toward increased learning relative to the AD group. These results are unsurprising given the documented learning deficits in MCI and AD (Grober & Kawas, 1997; Germano & Kinsella, 2005; Greene, Baddeley, & Hodges, 1996; Ribeiro, Guerreiro, & De Mendonca, 2007; Bondi, Salmon, Galasko, Thomas, & Thal, 1999). Although initial analyses indicated additional differences in retrospective memory, after controlling for the number of tasks learned there were no significant differences between groups. However, the power to detect these differences was low after including the covariate. Given the well-documented deficits in delayed recall for the cognitively impaired groups, which are part of their defining features (see Albert et al, 2011), it is likely that the low power of these statistical analyses may have resulted in a failure to detect differences between these groups and the older adults.

After taking the learning and retrospective performances into account, results showed that the significant differences between groups in PM accuracy on this task can mostly be accounted for by these factors, especially learning.

Nevertheless, after controlling for these factors, the AD group was found to display significantly lower PM accuracy with event-based cues with a weak association between cue and action compared to the older adult and MCI groups. As discussed above, it is expected that cues with a weaker association to the action would be more resource-demanding and therefore show decreased performance compared to those with a strong association. Indeed, this is consistent with a previous study assessing PM in healthy older adults and individuals with MCI and AD while manipulating the association between cue and action (Drolet, Lecomte, Lajeunesse, and Rouleau, 2014). During performance of a lexical decision task, participants had to identify the cues and perform the action. Results showed that the groups were equivalent in PM performance when the cue and action were related, but the cognitively impaired groups showed PM deficits when cue and action were unrelated.

Based on these findings it would also be expected that older adults would display superior performance compared to the MCI group. However, no differences were identified in PM between these groups. Once again, it may be that differences in the level of ecological validity between these studies can inform the discrepancy in results. The ecological validity of the current PM task (i.e., Level three according to Phillips and colleagues (2008): naturalistic and familiar but not part of the everyday routine) may have been sufficient to allow the MCI group, to benefit from the use of compensatory mechanisms. The task used by Drolet and colleagues is more consistent with the fifth level of ecological validity in which an artificial task (i.e., lexical decision) is performed in a laboratory setting (Phillips et al., 2008). By using a more familiar

task, compensatory strategies may have helped to attenuate the PM difficulties exhibited on laboratory measures of this construct (see Thompson et al., 2011).

Notably, the task used by Drolet and colleagues (2014) has been adapted to improve ecological validity by examining PM performance in a simulated shopping environment (Potvin, Lajeunesse, Labelle, Baba, & Rouleau, 2014). Results using this video PM task showed that all PM phases and components can be impaired with aging, especially when the cue-action association is less concrete. However, to date this task has not been used with individuals with MCI or AD. Therefore, the current study represents an initial evaluation of PM performance using a naturalistic paradigm that accounts for learning and retrospective memory processes. Overall, the results showing specific impairment in PM for individuals with AD but not MCI is consistent with studies showing PM performance benefits when using more realistic and familiar tasks. Although the shopping task is not part of the participants' daily routines, it provides a balance between simulating a real-life scenario and controlling certain variables known to influence PM performance (e.g., cue-action association, presence of distractors, etc.).

The shopping task was chosen because these groups are all likely to have substantial experience with shopping (no significant differences between groups in familiarity with the location used in the current task were identified) and the task lends itself to administration under controlled laboratory conditions. Yet, because the task involved only the recall of a number of distinct intentions (e.g., 'buy sunglasses at Laurier Optical') in the absence of a more traditional ongoing task, some have argued that this type of paradigm does not conform to the standards of a prospective memory task (Farrimond, Knight, & Titov, 2006). Instead, these authors argue that it may considered more akin to a vigilance task in which cues are identified in the face of distraction. However, the current task includes distractor shops for most locations, there are

numerous other distractions which occur in the course of the film, and the occurrence of cues is sufficiently spaced to avoid reliance on vigilance processes (Ellis & Kvavilashvili, 2000).

Nevertheless, this task could be modified to more accurately reflect traditional laboratory paradigms of prospective memory. For instance, an ongoing auditory task such as listening to a radio news report while shopping could be added. Following completion of the task, participants could be required to answers questions regarding the content of the news report. This modification would render this an unequivocal PM task (Einstein & McDaniel, 1996; Kvavilashvili, 1987; McDaniel, Robinson-Riegler, & Einstein, 1998; Potvin, Rouleau, Audy & Giguere, 2011). However, this represents a method for forcing a real-life situation to conform to a laboratory procedure. The current task was instead constructed to represent the realistic features of a shopping trip for older adults. There are also additional factors that need to be taken into account when examining PM in natural situations.

Ihle and colleagues (2012) used matching laboratory and naturalistic PM tasks and found the degree of motivation, stress and usage of memory strategies had an impact on PM performance. This study found that older adults outperformed younger ones on the naturalistic prospective memory task. Further, the better performances of the older adults could be partly explained by the factors noted above, particularly the perceived importance of the task. It is also important to note that PM intentions and cues were participant generated such that this ‘real’ task occurred in the context of everyday life without the interference of an experimenter. Clearly, the manipulation of these factors and the use of participant-generated PM intentions in future studies of PM in cognitively impaired populations will be critical to gaining a more complete understanding of their PM abilities in everyday life.

General Discussion

Prospective memory (PM) can been described as simply as remembering to remember. PM involves performing an intended action at the appropriate point in the future in response to a cue that triggers a memory of the action (Einstein & McDaniel, 1990). Remembering to perform actions at the appropriate time is clearly of great importance in everyday life. Indeed, forgetting to perform delayed actions has been shown to contribute to over half of all everyday memory problems (Crovitz & Daniel, 1984; Terry, 1988). Given this importance, research in this area has been increasing and has begun to explore the changes in PM associated with aging and age-related illnesses affecting memory capabilities (Uttl, 2011; Thompson et al., 2010; Jones et al., 2006; Henry et al., 2004).

As the body of research examining PM has accumulated, so too have the seemingly discrepant findings. There are studies showing age-related declines in PM (Einstein et al., 2003; Einstein et al., 1997; Mantyla, 1994; Maylor, 1996) and those that failed to demonstrate the same differences (d'Ydewalle, Luwel, & Brunfaut, 1999; Kliegel, et al., 2000; McDaniel et al., 1999). There are also studies showing age-related declines in PM in laboratory settings in contrast to age benefits in naturalistic settings (Grundgeiger et al., 2010, Kalpouzos et al., 2010, Kvavilashvili and Fisher, 2007, Rose et al., 2010; Sellen et al., 1997). Taken together, these findings have led to the Dynamic Multiprocess Framework (Scullin, McDaniel & Shelton, 2013) which is built on the proposition that studies failing to detect age-related changes in PM abilities may not have been using PM tasks that engaged individuals' self-initiated monitoring processes.

According to this framework, PM is supported by two distinct cognitive processes, monitoring and spontaneous retrieval, which operate in a dynamic manner; characteristics of PM tasks (e.g., salience of cues, focality of cues, association between cue and action, frequency of

cues, etc.) can be manipulated to encourage the use of one process or the other. In contrast to the Dynamic Multiprocess Framework, the preparatory attentional and memory (PAM) theory (Smith, 2003) assumes resource-demanding monitoring processes are engaged from the formation of the intention until the completion of the PM task. Because the intention to complete the action is actively maintained in working memory, the PM response is not considered automatic. The PAM theory also emphasizes the importance of retrospective memory processes as part of PM events, due to their importance for the recollection of the intended action and differentiating between the task-specific PM cue and other events (Smith and Bayen, 2006).

The retrieval of a PM response is more likely to be relatively spontaneously recalled when intentions are simple, the cue and action are highly associated, cues are salient, and the ongoing tasks encourage the focal processing of PM cues. These conditions are also expected to impose fewer interference costs to ongoing tasks (Guynn et al., 2001; McDaniel et al., 2004; McDaniel et al., 1998). Under other task conditions, successful PM performance is expected to be more dependent on strategic monitoring processes (Smith & Bayen, 2006). In addition, cue frequency effects have also been found to affect the likelihood of the use of monitoring processes (Loft & Yeo, 2007; Czernochowski, Horn, & Bayen, 2012). Higher PM cue frequency has also been found to increase prospective memory performance across the task (Ellis, Kvavilashvili & Milne, 1999).

The current study manipulated these characteristics to explore these two major theories that seek to explain PM retrieval. In the first two studies, a novel laboratory PM task was used in which the focality and the frequency of PM cues was manipulated. PM performance was evaluated by examining the accuracy in identifying PM cues as well as the interference costs to the ongoing task (i.e., the difference in reaction time with a PM load compared to without a PM

load). Moreover, these studies examined the impact of aging as well as that of cognitive impairment by first comparing cognitively healthy younger and older adults and subsequently comparing healthy older adults to individuals with MCI and early AD. Finally, Study 3 explored the use of a more naturalistic and ecologically valid PM task to compare the PM performance of individuals with MCI and early AD to healthy older adults without cognitive impairment. Due to the importance of PM in both general and clinical populations, both laboratory and naturalistic research are essential to further explore this domain. This second PM task also included PM cues with either a strong or weak association between the cue and intended action, as well as a combination of event and time-based tasks.

With respect to Studies 1 and 2, it was hypothesized that there would be group differences in PM performance when using non-focal, but not focal, PM blocks. Similarly, it was expected that all groups would exhibit improved PM performance (i.e., increased accuracy and/or reduced interference costs) in the focal compared to non-focal PM task blocks. Furthermore, it was predicted that, because the non-focal blocks are more cognitively demanding, manipulations of cue frequency would impact performance in these conditions but not focal PM blocks. With respect to Study 3, it was predicted that cognitively healthy older adults would demonstrate superior PM performance compared to individuals with MCI and early AD. Furthermore, it was predicted that PM recall would be better when there is a high association between the cue and intended action in the prospective memory task compared those with a low association between the cue and intended action.

This discussion is structured by first briefly reviewing the findings of each study individually prior to a discussion linking the findings together. Following these sections, the strengths, limitations, and implications of this dissertation for future investigation and clinical

practice are discussed.

Study 1

The results of Study 1 were inconsistent with respect to the predictions of the models of PM. First, the presence of interference costs in all PM conditions and groups suggests that PM always interferes with the ongoing task (Smith & Bayen, 2005), and that some degree of cognitive resources must be allocated to PM cue detection. These findings concur with both the PAM and DMPT. Furthermore, as was hypothesized, interference costs were higher in the non-focal compared to the focal blocks across groups and cue frequencies. However, in contrast to predictions, increased interference costs in the non-focal compared to focal blocks did not lead to differences in PM accuracy. Increased interference costs in the non-focal blocks in combination with the absence of increased PM accuracy suggests these PM cues require greater attentional resources compared to focal PM cues. Thus, the interference cost results are largely consistent with the DMPT framework while the accuracy results reveal inconsistencies with this theory.

In terms of significant interaction effects, the focality by cue and group by cue interaction effects suggest that the 10 PM cue frequency may be qualitatively different from the other cue frequencies studied. Specifically, there was evidence of a speed/accuracy tradeoff in the 10 PM cue condition in which participants decreased response time on the ongoing task at the cost of reducing the accuracy of responses within the non-focal but not the focal condition. Stated another way, participants may have failed to strategically slow their response times in order to increase the overall accuracy level in the non-focal 10 PM cue block. Furthermore, the differences between cue frequencies in both accuracy and interference costs as well as the different pattern of results within each group suggests that even the smallest change in cue

frequency used in the current study (i.e., from 1% to 5%) can have a significant impact on performance.

The significant three-way group by focality by cue frequency interaction effects are also mixed with respect to the predictions of the DMPT. Specifically, the interference cost results are again mostly consistent with the DMPT while the accuracy results provide some contrasts. Within the focal blocks, older adults were found to display a trend toward greater accuracy in the context of significantly increased interference costs relative to young adults. Within the non-focal blocks, greater overall interference costs were found for older adults, consistent with the predictions of the DMPT. Further exploration of these effects revealed PM conditions in which older and younger adults appear to display differences in the allocation of attentional resources. While older adults demonstrated significantly different interference costs between cue frequencies in the non-focal blocks, younger adults did not display such differences. This suggests that older adults may be strategically allocating resources to maintain PM accuracy, while younger adults are displaying consistent interference costs across cue frequencies despite significant differences in accuracy.

Study 2

In Study 2, in contrast to the performance of the cognitively healthy older adult and MCI groups showing the presence of interference costs in all conditions, results for the AD group did not reveal interference costs in the focal blocks. The findings for the AD group are therefore more consistent with the DMPT, which proposes that capacity-consuming resources may not be required to respond to focal PM cues (Scullin et al., 2013). However, when combining the groups, higher interference costs were found for non-focal compared to focal PM cues, as

predicted by the DMPT. However, once again, increased reaction time in the non-focal compared to focal blocks failed to produce a difference in PM accuracy between the focalities.

As in Study 1, the cue frequency and interaction effects suggest that older adults and those with cognitive impairment may experience difficulty in allocating attentional resources to maintain PM accuracy in the 10 PM block. Specifically, it was found that these groups did not slow their response speed to maintain accuracy. In exploring the three-way interaction effects it was found that, within the focal blocks, although there were no differences in PM accuracy, significantly different interference costs were found. In contrast, within the non-focal blocks, significant differences in both accuracy and interference costs were identified between the cue frequencies. Once again, there were also important difference identified between the 5 and 10 PM cue blocks, suggesting that participants may be implementing different strategies at these cue frequencies.

Results with respect to post-PM cue monitoring were also examined and, as in Study 1, found to be consistent with the DMPT predictions that non-focal blocks would require increased resources/monitoring compared to the focal blocks. Furthermore, there were also significant differences in accuracy on the ongoing task for between groups. Specifically, within the focal blocks, the ongoing task accuracy results showed lower performance in the 1 and 10 PM cue blocks. These particular findings parallel the interference costs in these blocks, suggesting that these conditions are the most resource-demanding.

Study 3

The goal of Study 3 was to compare the impact of utilizing a more naturalistic and ecologically valid PM task compared to that used in the previous studies on the PM performance of cognitively healthy older adults and those with cognitive impairment (i.e., MCI or early AD).

Taken together, the findings are highly consistent with previous research showing PM impairments associated with MCI and AD when using traditional measures of PM (e.g., Blanco-Campal et al., 2009; Schmitter-Edgecombe et al., 2009; Costa et al., 2011; Martins & Damasceno, 2008; Duchek et al., 2006; Jones et al., 2006; Karantzoulis et al., 2009; Thompson et al., 2010). However, there were significant differences in learning and retrospective memory between the groups in the present study which provide important context to the PM performance of these groups.

With respect to learning, older adults learned significantly more tasks than the other groups. The MCI group also displayed a trend toward increased learning relative to the AD group. Though initial analyses indicated additional differences in retrospective memory, after controlling for the number of tasks learned there were no significant differences between groups. This indicates that it is essential to account for these factors when exploring PM accuracy results. Indeed, after taking the learning and retrospective performances into account, results showed that the significant differences between groups in PM accuracy on this task can mostly be accounted for by these factors, especially learning. Nevertheless, after controlling for these factors, the AD group was found to display significantly lower PM accuracy with event-based cues with a weak association between cue and action compared to the older adult and MCI groups. While older adults were also predicted to display superior PM performance compared to the MCI group, there were no differences identified in PM accuracy between these groups.

Implications for Prospective Memory Research

As a whole, these studies provide valuable insight into the PM performance and the changes associated with aging and cognitive impairment in both laboratory-based and more

ecologically valid PM tasks. The complexity and inconsistency in certain aspects of the results necessitates caution in terms of making specific and concrete practical recommendations regarding PM interventions. However, there are clear methodological implications for future studies of PM abilities across populations. Furthermore, these studies provided another avenue to explore two of the dominant theories that seek to explain PM retrieval processes. By including populations with cognitive impairment, particularly individuals with MCI who have been shown to have neural changes in the pathways proposed by these theories to be associated with PM retrieval, an expanded understanding of the application of these theories is also possible. The following section will summarize the findings in relation to these theories before providing strengths and limitations of the studies as well as suggest future directions for research based on the results.

First, concerning the effects of aging in Study 1, the findings are mixed with respect to the predictions of the DMPT. The results within the focal blocks are largely consistent with the hypothesis that changes in cue frequency are not expected to impact the relatively "automatic" processes thought to be relied on with focal PM cues (Scullin et al., 2013). Furthermore, the accuracy data, but not the interference costs, for the 10 PM cue blocks are consistent with the prediction that non-focal blocks lead to reduced performance. In contrast, the interference costs, but not the accuracy, results for the 1, 5, and 20 PM cue frequencies are consistent with the expectation that non-focal PM blocks are more cognitively demanding. In addition, results revealed the presence of interference costs in all PM conditions for the younger and older adults as well as individuals with MCI. Interference costs are predicted with non-focal cues but their presence is expected to vary with focal cues in the DMPT (Scullin et al., 2013).

According to the PAM theory, preparatory attention and retrospective memory processes

interact to determine the success of PM. The role of these processes has been well supported by empirical data (e.g., Guynn, 2003; Marsh et al., 2003; Smith, 2003; Smith & Bayen, 2004; West et al., 2005), and are not in dispute here. In fact, the present findings provide further support for the PAM theory. First, the existence of PM interference in all PM conditions and groups suggests that PM always interferes with the ongoing task (Smith & Bayen, 2005), and that some degree of cognitive resources has to be spared for PM cue detection. Consequently, fewer cognitive resources are available for ongoing trials, and interference effects are incurred in ongoing trials (Loft & Yeo, 2007). As such, PM intentions are capacity-consuming while being maintained in working memory (Smith &Bayen, 2005).

However, the requirements of capacity consuming resources to fulfill PM intentions are also consistent with the DMPT. Indeed, the DMPT and PAM theories are compatible on many levels, especially once the Multiprocess theory evolved to further elucidate the more controversial claims that PM responses are not retrieved automatically (i.e., that they are totally resource-free; Einstein et al., 2005; McDaniel et al., 2004). Instead, monitoring processes are thought to be engaged in a dynamic manner such that minimal cognitive resources are utilized and allocated according to aspects of the individuals and tasks (Scullin et al., 2013). This is supported by the results showing that older adults engaged in dynamic allocation of cognitive resources: they displayed significantly different interference costs before compared to after the PM cue in the focal 1 PM cue block.

The focality of the cue is another key aspect that was expected to impact the allocation of resources. The interference cost results were consistent with the predictions of the DMPT, as were the post-PM cue monitoring findings. When performing non-focal PM blocks, participants displayed significantly greater interference costs and post-PM cue monitoring compared to focal

PM blocks. In addition, manipulations of cue frequency affected the PM performance (i.e., interference costs) in non-focal but not focal blocks, consistent with the tenets of the DMPT. PM processes that require fewer cognitive resources, as is suggested to be the case in focal PM tasks, should lead to fewer interference costs and should not have been influenced by changes in the frequency of cue presentation.

In contrast to the consistencies with the DMPT displayed by the interference costs, the accuracy results showed reduced PM retrieval with focal compared to non-focal cues. This may again suggest the implementation of a speed/accuracy tradeoff, because interference costs were higher in the context of increased accuracy. Furthermore, it was predicted that there would be a significant interaction effect between age and focality such that age-related declines would be identified with non-focal but not focal PM cues. Instead, the accuracy results are more consistent with the findings of Uttl (2011). The meta-analysis by Uttl (2011) provided evidence that directly contradicts the claims that PM with focal cues is spared by aging. Rather, confounding factors—including ceiling effects, the low reliability of binary indexes of PM, the use of tasks more consistent with measures of vigilance than PM, and intelligence, particularly verbal intelligence—were suggested to explain the pattern of results that provided the foundation for the DMPT (i.e., many studies finding age-related declines but some finding no age-related declines; Einstein & McDaniel, 2005). Unfortunately, only some of the confounds could be accounted for in the current studies; these will be addressed along with other strengths and limitations below.

In examining the results assessing the cognitively impaired groups, it is again evident that the findings do not entirely align with the predictions of the DMPT. First, in terms of interference costs in the focal blocks, there was a main effect of cue frequency despite the hypothesis that this manipulation should not impact performance in the less demanding (i.e., focal) blocks. Second,

individuals with MCI were found to display greater accuracy on the ongoing task in the non-focal compared to focal blocks in the absence of differences in PM accuracy or interference costs between focalities.

These findings indicate that fewer attentional resources were available for the ongoing focal tasks in contrast to non-focal tasks. This suggestion is consistent with the proposition that MCI disrupts the neural processes that support spontaneous retrieval of intended actions, thereby interfering with PM retrieval during focal PM tasks. This pattern of performance is consistent with previous results showing a preferential deficit in focal PM in individuals with amnestic MCI and very early AD (Chi et al., 2014; McDaniel et al., 2011), albeit in terms of the ongoing task rather PM performance in the current study. Moreover, correlational analyses have also indicated that PM impairment in MCI is associated with compromised medial temporal lobe and hippocampal structures, leading to disruptions in the associated spontaneous retrieval processes. Taken together, these findings indicate that PM deficits with focal cues may represent a signature marker of PM decline in MCI that parallels that seen in early AD (McDaniel, et al, 2011).

There are, however, results in Study 2 that display more consistency with the predictions of the DMPT. Similar to Study 1, within the focal blocks there were no differences in PM accuracy or interference costs between cue frequencies. Overall, interference costs were also greater in the non-focal compared to focal blocks across groups and cue frequencies. In contrast, there were significant accuracy differences between cue frequencies in non-focal blocks. Again, the proposed increase in resource demands for the non-focal compared to focal blocks is in line with these findings. However, based on the meta-analytic results of Uttl (2011), it could be expected that increasing the cue frequency, and thereby enhancing reliance on vigilance over PM retrieval processes, would increase accuracy in focal blocks. In contrast, results showed that

younger and older adults did not differ in their PM accuracy or interference costs when cue frequency increased in the focal blocks. The MCI and early AD groups were both more accurate in the focal 20 PM cue blocks compared to the 5 PM block but not the 1 PM cue block. The absence of a linear pattern of changes in accuracy with increasing cue frequency suggests that for these populations factors beyond alterations in the reliance on vigilance processes may be influencing PM performance as cue frequencies increase.

The change in PM performance associated with variations in cue frequency in the non-focal blocks is an important finding in a prospective study which helps to clarity previous meta-analytic results. In examining cue frequency changes with non-focal blocks, Uttl (2011) suggested that age-related declines with 1 PM cue are reduced compared to focal 1 PM cue blocks, while more frequent cues lead to greater age-related declines in non-focal compared to focal blocks. However, too few studies were included in this meta-analysis to provide a meaningful statistical comparison; previous studies in the area of vigilance have identified changes in performance in which increased cue frequency leads to decrements in performance in tasks requiring high, but not low, mental workloads (Warm et al., 2008).The current results showed that, in non-focal conditions, older adults were more accurate in the 1, 5, and 20 PM cue blocks compared to the 10 PM cue block, while younger adults were more accurate in the 20 compared to 5 PM cue block. In addition, the combined older adult, MCI, and early AD groups were more accurate in the 5 and 20 PM cue blocks compared to the 1 and 10 PM cue blocks. The interference cost results did not display any significant group by cue interaction effects within the non-focal blocks. Once again, changes in accuracy and interference costs do not display a linear pattern of results that align with variations in the frequency of cues.

Although changes in the degree of preparatory attentional, or monitoring, processes have

been found to coincide with changes in cue frequency, the PAM theory has not been extended to make predictions regarding accuracy or interference costs under these conditions. Therefore, an assessment of the fit of the current results with this theory is not possible. Previous research, however, has found that both monitoring and PM accuracy may be reduced with fewer PM cues (Loft & Yeo, 2007). Moreover, decreasing the frequency of cues resulted in comparable performance across both low and high association between the target and response, contrary to the predictions of the DMPT. However, the cue frequencies were low across both conditions in that study (i.e., 1% and 3%) and more ongoing trials were used (i.e., 264). Therefore, even the infrequent condition presented the PM cue on four occasions. In the current study, the PM cue was presented only once in the least frequent condition in order align the classifications of PM as PM proper, vigilance, or habitual (Graf & Uttl, 2001; Uttl, 2010, 2011). Therefore, the results from Loft & Yeo (2007) may relate more closely to the 5 and 10 PM cue blocks in the current study. Yet, in direct contrast to the previous findings, the lower of these two frequencies was associated with increased accuracy in the older adult group and increased monitoring in older, younger, and early AD groups.

The selection of cue frequencies is of paramount importance, particularly given that there is an undefined continuum between PM and vigilance. Other authors (e.g., West, 2008,) have suggested that PM cues be held at between 5% to 10% of total trials. It was proposed that this frequency of cues, combined with an ongoing task which is sufficiently engaging, ensures that the cues are not actively rehearsed. However, there continue to be inconsistencies across studies in PM cue frequencies. Behavioural studies have typically adopted a PM cue frequency of less than 5% (Wilson et al., 2013). However, when you consider that the most typical example of PM from daily life, purchasing a product (e.g., milk or gas) while driving home, occurs on only one

occasion during an ongoing task, it is clear that many previous behavioural studies lack significant ecological validity. Furthermore, a typical ERP-based PM experiment will need a minimum 20 to 30 PM cues and studies examining neural correlates often adopt a relatively higher PM cue frequency (e.g., 11–20%) (Czernochowski et al., 2012). Given the sensitivity of PM performance to changes in cue frequency identified in the current study (i.e., the many differences identified in both accuracy and interference costs between the 5 and 10 PM cue blocks), the results of previous neural correlate studies would only be applicable for the PM monitoring strategy associated with high cue frequencies (Czernochowski et al., 2012; Wilson et al., 2013).

These findings continue to demonstrate the value of assessing varying cue frequencies in PM studies and highlight the importance of examining task interference costs in addition to accuracy (Smith, 2003; Smith & Bayen, 2004; Smith et al., 2007; Marsh et al., 2003; Cohen et al., 2008). The pattern of results for the 10 PM blocks are clearly different compared to other cue frequencies, including the closest frequency, 5 PM cues. It also appears that participants varied their application of speed accuracy tradeoffs emphasizing the ongoing versus PM tasks. This variability in strategy use aligns with the suggestion that starting new tasks serves to reset attentional-allocation policies (Marsh, Hicks, & Cook, 2006). Furthermore, it is also consistent with results showing significantly different interference costs before and after responding to a PM cue.

Though the start of a new task creates an opportunity to reset an attentional plan, an intention to strategically allocate increased cognitive resources to the ongoing rather than PM task may not have been present at the outset of the task. The Dynamic Multiprocess theory suggests that attention allocation policies are dynamic throughout task performance (Scullin et

al., 2013). However, individuals may have a tendency to default to spontaneous retrieval processes, which would reduce interference costs, in order to be more efficient in their daily activities (McDaniel and Einstein, 2007; Bargh & Chartrand, 1999). This suggestion fits with the results found for the non-focal 10 PM cue block but contrasts with that found for 5 PM cue blocks.

The differences between the 5 and 10 PM cue blocks are one of the most notable findings of the current studies. It appears that there are qualitative differences between these cue frequencies that may be related to different attentional allocation strategies. Once the task has begun, the degree of strategic monitoring an individual will utilize is dependent on the demands of the PM and ongoing tasks, and the individual's assessment of task difficulty, cognitive resources, metamemory, and personality (Gao et al, 2013; Kliegel, Martin, McDaniel, & Phillips, 2007; Maujean, Shum, & McQueen, 2003; Einstein & McDaniel, 2008; McDaniel & Einstein, 2007). The individuals' assessment of the task and their cognitive resources were not sufficient to implement an effective strategy to maximize PM accuracy in the 10 PM cue blocks. It may be that individuals have a difficult time allocating attentional resources at a point on the continuum between traditional PM tasks with a 5% cue frequency which enables dynamic monitoring (Scullin et al., 2013) and a 9% cue frequency that may encourage vigilance and therefore continuous monitoring (Brandimonte et al., 2001).

Overall, these studies document that both aging and cognitive impairment are associated with alterations in performance on these novel PM tasks which manipulated the focality and the frequency of cues as well as the strength of association between the cue and action. Taken together, the results suggest different attentional allocation strategies for the studied populations based on these factors. The variability in strategies, in which the ongoing and PM tasks may have

alternately been seen as the most important, likely contributed to the inconsistencies with the predictions of the DMPT. It was also found that, after accounting for differences in learning and retrospective memory, older adults and individuals with MCI do not show differences in PM performance on a more ecologically valid PM task, although deficits in PM remain for individuals with AD when using cues with a weak association to the action. These findings contribute to previous research that has identified an interesting 'paradox' showing declines in PM performance on traditional laboratory measures can be attenuated on more naturalistic or ecologically valid PM tasks (Maylor, 1999; Phillips et al., 2008; Bailey et al., 2010; Rendell & Craik, 2000; Thompson et al., 2010).

Laboratory-based versus Naturalistic PM

The current dissertation also sought to explore the relationship between the laboratory-based measure of PM used in Studies 1 and 2 with the more ecologically valid video PM task used in Study 3. Unfortunately, the small and unequal sample size of the groups produced statistical analyses with insufficient power to detect reliable effects. For the same reasons, relationships with neuropsychological test performance were determined to be unreliable. It is known that PM tasks tax various cognitive abilities, including episodic memory retrieval, complex attention, working memory, and executive functions (Blanco-Campal et al., 2009; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). However, our ability to draw conclusions from the current correlational analyses is greatly limited.

Despite difficulties in comparing the more traditional with the more naturalistic PM task, the results taken as a whole reinforce the important methodological implications of the current findings. Specifically, the focality of the PM cue and the associated variations in cognitive demands, the frequency of the PM cues—even subtle differences can affect the results (e.g., 5%

to 9%)—and the association between the PM and response, as well as the interactions between these elements must be taken into account. Furthermore, these characteristics can lead to varying attentional allocation strategies and differential involvement of prospective and retrospective memory processes depending on the age and degree of cognitive impairment of the individual. While the manipulation of many variables in the current study contributed to its novelty, it also led to difficulties in the interpretation of interaction effects. Previous research had not sufficiently investigated PM proper with non-focal PM cues which would allow comparisons to other cue frequencies, nor to studies using focal PM cues (Uttl, 2011). Additional strengths, limitations, and suggestions for future research will now be explored.

Strengths, Limitations, and Future Directions

This study presented here is the first to provide the opportunity to explore the two major theories that seek to explain PM retrieval while varying the focality and frequency of the cues in these populations. This allowed for exploration of the performance on tasks that may range from measures of PM proper to vigilance. This study also sheds light on the potentially unique declines in PM in individuals with MCI. The findings may, therefore, provide guidance to studies examining effective strategies for enhancing PM performance in real life for these populations. For instance, these findings can be used to study interventions aimed at increasing medication adherence in a vulnerable population (Schmitter-Edgecombe, et al., 2009).

Another novel aspect of the current task was the use of numerical decision task as the ongoing activity along with PM cues that required monitoring for a specific digit or more digits in a number. The intention behind using this task was to reduce the necessity to rely on language processing during performance. Most traditional laboratory-based studies of PM have used lexical or categorical decision tasks (e.g., Cohen et al., 2008; Scullin et al., 2010; Kliegel, et al.,

2004; Brandimonte et al., 2001; Marsh et al., 2003; Brewer, Knight, Marsh, & Unsworth, 2010; Meier & Zimmermann, 2015). While other have used visual ongoing tasks (e.g., colour-matching), the cue has often remained a specific word (Smith & Bayen, 2004; Smith & Hunt, 2014). However, individuals with MCI, those in the prodromal phase of AD, and those diagnosed with early AD all exhibit deficits in language (Jacobs et al., 1995; Taler & Phillips, 2008; Verma & Howard, 2012), suggesting that language-based tasks may not be the most appropriate means for studying PM in these population. Although individuals with MCI and early AD have also shown deficits in numerical processing (Kaufmann et al., 2002; Winblad et al., 2004; Benavides-Varela et al., 2015), this is a novel approach to a PM task and an association between numerical processing and PM has not been previously identified.

A strong relationship between age-related declines in PM and verbal intelligence has been found (Uttl, 2011). The participants of the current study showed age and cognitive impairment-related deficits in measures of language. In addition, slow verbal speed has been found to mediate increased PM interference in individuals with AD in contrast to motor speed mediation effects in normal aging (Gao et al., 2013). By reducing the language requirements of the task, the cognitive impairment-associated deficits in PM may have been attenuated in the current study compared to previous research. Future studies should continue to evaluate the use of ongoing tasks and PM cues that are not as heavily reliant on language processing. For example, Uttl (2006) utilized visual and auditory cues in the context of an ongoing card-sorting task to investigate age effects on PM.

The current study also employed another novel paradigm to examine another methodological factor which may attenuate age-related declines, the use of a more ecologically valid PM task. Within this more naturalistic paradigm, the impact of the strength of the

association between the cue and the action were also manipulated. The utilization of both traditional laboratory-based and more naturalistic paradigms within the same study are important given the age-PM paradox that has previously been found (Maylor, 1996; Henry et al., 2004). Given that existence of this paradox remains in dispute (Delprado, Kinsella, Ong, and Pike, 2013), future studies should continue to compare PM tasks of varying levels of ecological validity, particularly while manipulating variables such as focality and cue frequency. Unfortunately, due to the sample sizes limiting the power to detect relationships between the tasks, the current results cannot reliably inform this debate.

Although this study makes several important contributions to the literature, it does have other limitations beyond the sample size. The reliability of PM measures, particularly those using binary (pass/fail) scoring, has been found to be poor to moderate (Grant, Uttl, & Cnudde, 2015). One of the proposed solutions is to increase the number of cues, but this can limit the validity of the measure as one of PM as opposed to vigilance. Vigilance measures tend to have moderate to high reliability but are not valid measures of PM. It may be that the current study provides an adequate compromise by measuring a variety of cue frequencies that span the range from PM proper to vigilance. Nevertheless, future studies should continue to assess the reliability and validity of these measures with larger and different populations.

The generalizability of the current sample to the larger population is also somewhat limited, as both the older adults and individuals with MCI were highly educated (all older adult groups had mean years of education > 15). It has been argued that education can serve as a protective factor in maintaining cognitive reserve (Stern, 2012; Meng & D'arcy, 2012) and, therefore, the PM abilities of this highly educated sample may be more resilient to the effects of aging and cognitive impairment. Furthermore, enhanced cognitive reserve, coupled with the

ecological validity of the task in Study 3, may have helped to produce the minimal differences in PM found between groups in this task.

There are other factors which may have attenuated the differences between groups and may help to explain some of the unexpected results. For example, it was highly unexpected to find greater accuracy for the older adults compared to younger adults in the absence of differences in interference costs in the non-focal 5 PM cue block. Differences in motivation and effort between younger and older adults may play a strong role. Previous studies have shown that if there are no incentives in PM tasks, young subjects are less motivated to perform (Aberle et al., 2010; Rendell & Craik, 2000). In contrast, cognitively healthy older adults are usually more motivated and may adopt a more cautious strategy to compensate for age-related declines in PM by maintaining the accuracy of the performance at the cost of slower response (Seya & Mori, 2007). This pattern of responses was seen in the current results for some cue frequencies (5 PM cues) but not others (10 PM cues).

A number of specific factors have been proposed to play a role in the motivational differences between groups. For instance, generational differences in attitudes, age differences in personality dimensions such as conscientiousness, and age differences in lifestyle factors can allow contribute to engagement with the research tasks. Furthermore, undergraduate students have been shown to exercise variable engagement with neuropsychological testing, with poor effort frequently exhibited on symptom validity tests (4% to 30%; An, Zakanis, & Joordens, 2012; Ross, Poston, Rein, Salvatore, Wills, & York, 2016) This is especially likely to be the case for undergraduate students completing studies for course credit, as in the current study. Furthermore, those who volunteer to participate in research in the absence of course credit, as the older adult populations did in the current study, are more likely to have higher education, social

status, intelligence, and to display greater interest in the topic of research, all of which may increase their motivation to perform well (Heiman, 2002).

Similar to the motivational factor, the perceived importance of the tasks impacts the manner in which individuals approach PM tasks (Walter & Meier, 2014), particularly when the tasks impose large demands on monitoring resources (Kliegel et al., 2004). Older adults have been found to be particularly susceptible to manipulations of the importance of the ongoing versus PM tasks (Hering, Phillips, & Kliegel, 2014). According to this study, when older adults were asked to emphasize the PM task over the ongoing task, they achieved equivalent PM accuracy to younger adults in contrast to age-related declines when the ongoing task was emphasized. Notably, when the PM task was of higher importance there was also a cost to the ongoing task, suggesting a speed/accuracy tradeoff. This reinforces the measurement of interference costs, in addition to accuracy, as a key strength in the current study. However, the current study was ambiguous with respect to emphasizing one task over the other. Future studies would benefit from manipulating the importance of the task in the context of the other characteristics manipulated in the current study in order to determine the impact on PM performance in these populations.

Although the inclusion of interference costs helped to provide a more complete understanding of PM abilities, there are also limitations with the current approach. If participants are engaged in the dynamic use of monitoring processes, it would be expected that interference costs would vary throughout the task blocks. Furthermore, because participants may rely on spontaneous retrieval of intentions in focal PM tasks, they may realize that monitoring is not necessary to perform the PM intention after detecting the target several times. Other research suggests that task interference may emerge after, but not before, the first target cue (Scullin,

Einstein, & McDaniel, 2009). Performing task interference analyses across sections of each task block (e.g., quartiles) would allow for an examination of the consistency of monitoring across task blocks and whether monitoring changes are associated with changes in PM performance.

Despite the inclusion of interference and post-PM cue monitoring costs, the choice of dependent variables in the current study may be considered another limitation. As research into PM and the proposed theoretical frameworks continues to evolve, the range and selection of dependent variables will need to progress. For instance, future studies should continue to examine which of the factors specified by the DMPT influence the reliance on relatively automatic PM retrieval processes, how they interact, and via what dependent variables (e.g., pre-cue or post-cue interference costs, PM cue trial reaction time, PM accuracy). For example, manipulations of the salience of the cue or the distinctiveness of the cues from the background context (e.g., Einstein et al., 2000, Einstein & McDaniel, 1990) may lead to different degrees of reliance on spontaneous retrieval processes when using focal and non-focal cues, which may be captured by different dependent variables measuring PM performance.

There are also other alternative explanations for the PM performance data that are less compatible with the DMPT. For example, participants may have been superficially processing the ongoing task to the information level required for a numerical decision (i.e., selecting the higher number) but not to the informational level required to initiate reflexive retrieval of PM responses (Maylor, 1998; Moscovitch, 1994). In addition, it may be that there are differences in the difficulty of monitoring for a particular digit (non-focal cue) or more digits in a number (focal cue). If it is easier to monitor for the focal cues, then task interference in the focal condition would be expected to be significantly attenuated relative to interference in the non-focal condition. Evaluating the speed of cue detection in the absence of PM requirements would

help to reveal any differences in monitoring difficulty. For example, having participants respond as quickly as possible to whether a presented number is a target (or not) in some blocks of trials or whether a presented number contained a target digit (or not) in other blocks (e.g., Scullin, et al., 2010). Taken together, it is clear that there are a number of avenues of future research to explore.

To date, research on PM interventions has been limited mostly to clinical samples (e.g., TBI; Fleming, Shum, Strong, & Lightbody, 2005; Kinsella et al., 2009; Radford, Lah, Thayer, Say, & Miller, 2012; Raskin & Sohlberg, 1996; Shum, Fleming, Gill, Gullo, & Strong, 2011), but, taken together, the results have shown that patients have the potential to benefit from compensatory PM training (Hering, Rendell, Rose, Schnitzspahn, & Kliegel, 2014). In particular, the use of implementation intentions has shown promise in improving PM performance (for a meta-analysis, see Chen et al., 2015).

An implementation intention is an encoding strategy in which participants visualize or verbalize the anticipated PM cue and link the response to the cue (e.g., 'When I see the number "3", then I will press the "SPACEBAR"'.). This process is thought to strengthen the association between the cue and intention (Cohen et al., 2008; McDaniel, Howard, & Butler, 2008) and therefore could have differential effects on PM performance depending on the focality of the cue. Indeed, a recent study found that the use of implementation intentions improved the PM performance of individuals with very mild AD with focal PM cues but not with non-focal PM cues.

Improving the encoding of the intention addresses one component of the processes underlying PM which also include the retention, recall, and execution of the intention. Kliegel, Altgassen, Hering, & Rose (2011) proposed a framework for a theory-driven training approach in

the area of PM. Specifically, it was recommended that the processes underlying PM be disentangled to reveal the critical components that may benefit from training in a given population. The current study followed this recommendation as it applies to older adults and individuals with MCI or early AD in Study 3. As a result, an understanding of PM has been advanced in these populations which can be used to inform intervention studies that can provide a more tailor-made approach to the development of training programs. Continuing to extend this intervention research in the context of manipulating the frequency of cues, and utilizing both laboratory-based and more naturalistic PM tasks are important next steps in this line of research. Furthermore, the results of the current studies can help to inform the methodologies of such future research.

Summary

This dissertation explored prospective memory in aging and cognitive impairment. In the first two studies, the PM performance of cognitively healthy younger and older adults, individuals with MCI, and individuals with early AD were assessed using a novel PM task that varied the relationship between the ongoing task and the PM cue (i.e., the focality of the cue) and the frequency of cues. Several important findings were generated. First, the results of Study 1 revealed significant differences in performance for younger and older adults and supported some but not all, of the hypotheses generated by the Dynamic Multi-Process Theory. Second, in Study 2, there were again different patterns of PM performance for each population depending on the focality and frequency of cues. Importantly, there were findings that directly contradicted the hypotheses of the DMPT, especially for the MCI population, which is likely related to changes in neuropathophysiology. Taken together, these studies showed the importance of considering even subtle changes in the frequency of PM cues. Furthermore, these changes in cue frequency appear

to lead to different strategies being employed by different populations depending on the specific characteristics of the PM task.

In addition, in Study 3, a more naturalistic or ecologically valid PM paradigm was utilized and results generally supported the hypothesis that a stronger association between the PM cue and response supports PM recall. Furthermore, deficits in PM in individuals with MCI and early AD in this task were largely accounted for by poor learning and retrospective memory. Nevertheless, after accounting for these factors, early AD was associated with weaker PM recall for cues with a weak association to the response compared to cognitively healthy older adults and individuals with MCI.

Overall, this dissertation furthers our understanding of prospective memory by making important theoretical, methodological, and clinical contributions to this field of study. In particular, the findings provide an important examination of the DMPT and indicate that the patterns of PM performance predicted by this framework may not generalize across all populations. Furthermore, the studies suggest new avenues of PM research into the characteristics of PM tasks that should be manipulated to a gain a more complete understanding of this ability. Finally, PM is crucial to the maintenance of functional independence because of the high demands on prospective functioning when following medical regimes and in health behavior, especially for those in late adulthood with cognitive impairment.

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Appendix A

History Questionnaire

ID:

Demographics:

. Date of Birth (D/M/Y):_____ 2.

Age:_____

3. Gender: *(circle response)* (1) Male (2) Female

4. Handedness: *(circle response)* (1) LEFT (2) RIGHT (3) BOTH

5. Present marital status: *(circle response)* (1) Single – never married
(2) Married
(3) Separated
(4) Divorced
(5) Widowed
(6) Cohabit

Language

6. Place of Birth:_____

7. Languages Spoken (in order of fluency):_____

8. Primary Language/Language of choice:_____

9. Language at home:_____ 10. At Work:_____

11. Language of Education:_____

12. At what age did you first learn English/French? _____

13. At what age did you become fluent in it?_____

14. How would you rate, from 1 to 5–, your level of proficiency in the languages you speak?

Language	Rating (**L**istening, **R**eading, **S**peaking, **W**riting):
1. _____	L:____ R:____ S:____ W:____
2. _____	L:____ R:____ S:____ W:____
3. _____	L:____ R:____ S:____ W:____
4. _____	L:____ R:____ S:____ W:____

15. .How many years of education do you have at this time? (i.e., what is the highest level achieved?)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Elementary Secondary Cegep Undergrad Graduate Professional

16. In what field did you complete your degree? _____

Medical History

17. Do you have now, or have you had in the past -*(please circle your response)*
- Visual problems: A) Nearsighted / Farsighted B) Glasses / Contact lenses C) Cataract: Left / Right D) Colour blind: NO / YES - Trouble hearing: E) NO / YES F) Hearing Aid: Left / Right

18. Have you ever been unconscious, had a head injury or had blackouts?
A) NO / YES B)
Cause:_____ C)
Duration:_____ D)
Treatment:_____ E)
Outcome:_____

19. Have you been seriously ill or hospitalized in the past 6 months?
A) NO / YES B)
Cause:_____ C)
Duration:_____

Do you have now, or have you had in the past (conditions susceptible or influencing cognitive functions)...

20. a) A stroke? b) [s] Transient ischemic attack (mini-stroke)?	NO / YES NO / YES	
21[s]. Bypass surgery?	NO / YES	
22[S] Heart disease?	NO / YES	Nature (myocardial infarction [MI], angina, narrowing of arteries):
23 [S] High blood pressure?	NO / YES	Is it controlled? NO / YES What medication? _____
24 [S]. High cholesterol?	NO / YES	Is it controlled? NO / YES What medication? _____
25 [S]. a) Diabetes? b) Insulin dependent?	NO / YES	Type 1 / Type 2 Age of onset: _____ Treatment: _____
26. Seizures?	NO / YES	Age Onset: _____ Frequency: _____ Cause: _____ Treatment: _____
27. Epilepsy?	NO / YES	
28. Thyroid disease?	NO / YES	
29. Frequent headaches?	NO / YES	Tension / migraine
30. Dizziness?	NO / YES	
31. Trouble walking Unsteadiness?	NO / YES NO / YES	
32. Serious illness (e.g. liver disease)?	NO / YES	
33. Neurological disorders? (e.g. lupus)	NO / YES	
34. Exposure to toxic chemicals (that you know of)?	NO / YES	
35. Depression?	NO / YES	Did you seek assistance or feel the need to do so? _____ Is it controlled? _____
36. Anxiety?	NO / YES	Did you seek assistance or feel the need to do so? _____ Is it controlled? _____
37. Other psychological difficulties?	NO / YES	

38. Medication: Please list the medication you are currently taking and any other medication that you have taken in the past year.

Type of medication		Reason for consumption	Duration of consumption and dose
A			
B			
C			
D			
E			
F			

39. Do you smoke[S]?

NO / YES

If YES, How many packs a day (or average quantity)? ____

40. Current problems: Are you currently troubled by any of the following–?

a) Concentration / Attention problems?

NO / YES

Nature: _____

b) Memory problems?

NO / YES

Nature: _____

c) Difficulties finding words?

NO / YES

Nature: _____

41. How would you rate your health? *(circle response)*

. poor 2) fair 3) good 4) very good 5) excellent

Appendix B

Consent Form A

ÉLISABETH BRUYÈRE RESEARCH INSTITUTE
INFORMED CONSENT STATEMENT FOR:

Prospective Memory in aging and cognitive impairment

You are invited to participate in a research study on memory. You were selected as a possible subject because you are experiencing memory problems, or you will serve as part of the control group. We ask that you read this form and ask any questions you may have before you agree to be in the study.

The study is being conducted by Mike Van Adel, a PhD student at the University of Ottawa and Professor Vanessa Taler, Élisabeth Bruyère Research Institute and School of Psychology, University of Ottawa.

PURPOSE OF STUDY
This study will look at how people remember to do things in the future, how this is linked with other cognitive abilities, and how this changes as we get older. This purpose of the study is to obtain a better understanding of people's ability to remember to do things in the future so that we can help identify those with difficulties and provide appropriate strategies to manage these difficulties.

NUMBER OF PEOPLE TAKING PART IN THE STUDY:
If you agree to be in the study, you will be one of 80 subjects who will be participating in this research.

PROCEDURES FOR THE STUDY:
If you agree to be in the study, you will do the following things:

. Your hearing will be screened. This part of the experiment takes about ten minutes. If you do not have adequate hearing to complete the tasks we will terminate the testing session. This test will therefore be conducted at the outset of the session.
. Watch a video and attempt to recall to the examiner a series of activities that you are asked to remember while viewing the video.
. Complete a series of tests of memory and cognitive function.

This study takes place in one sessions of about one and a half hours.

RISKS OF TAKING PART IN THE STUDY:
While in the study, you may experience fatigue or boredom, and you may feel uncomfortable answering some of the questions. While completing the forms at home, you can skip any questions that you do not want to answer. While doing the tasks in the lab, you can tell the tester

that you feel uncomfortable or do not want to answer any question. There is also a risk of loss of confidentiality.

BENEFITS OF TAKING PART IN THE STUDY:
There are no direct benefits to you if you take part in this study. The results of this study will help us to understand changes in language and communication function that occur as people get older or develop memory problems.

CONFIDENTIALITY
We will do all that we can to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your identity will not be disclosed in any reports of the study. Data will be stored securely and will be available only to persons conducting the study, unless you specifically give permission in writing to do otherwise. Your will have a subject number that is used on all test materials that is only known by the researchers. Your subject number and name will only be linked on a document that is stored separately from all other materials and is only accessible to the researchers. No references to the study will contain any information which could link you to any particular findings, or even to your participation. Should it be determined that there are any findings of clinical significance, you will be informed of these findings and your physician will be notified only with your permission.

Information from this study will also be included in a database that will allow sharing of neurocognitive and demographic data across Dr. Taler's studies. The data shared will include: neuropsychological test results, demographic information as specified in the Health Questionnaire (Appendix A), results of at-home tests and diagnosis. Identifying information will not be shared between studies or disclosed. *For patients of the Memory Disorders clinic at Élisabeth Bruyère Continuing Care, by signing the attached Informed Consent Form, you allow us to access to your medical records as they relate to this study.* Dr. Taler or a trained research assistant or student under her supervision will gather data about your performance on any cognitive or neuropsychological tests you completed in the Memory Disorders Clinic.Your responses will be available to the researcher (Dr. Taler) and to trained research assistants and will be destroyed after 15 years.

COSTS
There are no costs to you associated with taking part in this study.

PAYMENT
You will be paid $10.00 per hour for taking part in this study, including time spent at home completing questionnaires or given school credit if you are participating through the Integrated System of Participation in Research from the University of Ottawa. You will also be reimbursed in cash for parking and travel costs, at the rate of 30 cents per kilometre between your home and the testing site. If you withdraw from the study before the end, you will be paid for the time you spent doing the study. The amount of compensation received will be tracked by the finance department at Bruyère Continuing Care via your SIN number so that a T4A is appropriately issued, though they will not have access to the document linking your subject number and name.

CONTACTS FOR QUESTIONS OR PROBLEMS
If you have questions about this study, you may contact Mike Van Adel at the Elisabeth Bruyère Research Institute, Office 230Y, phone number 613-562-6262, x 1082 or Dr. Vanessa Taler at the Elisabeth Bruyère Research Institute, Office 230Y, phone number 613-562-6262, x 1082.

If you have any ethical questions about this study, you can contact the Chair of the Research Ethics Board at the Elizabeth Bruyère Health Center, Ms. Dorothy Kessler: telephone 613-562-6262 ext. 1420, or the Protocol Officer for Ethics in Research at the University of Ottawa, at 613-562-5387.

VOLUNTARY NATURE OF STUDY
Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. You may withdraw consent and stop participation *at any time* without it affecting your present or future care. You will be given continued and meaningful opportunities to decide whether or not to continue to participate.

SUBJECT'S CONSENT
I have read this consent form and had any questions I have answered. I give my consent to participate in this research study. I will be given a copy of this informed consent form to keep for my records.

Participant's signature: _____ Date: _____
(must be dated by the participant)

Signature of person obtaining consent: _____ Date: _____

Consent Form B

ÉLISABETH BRUYÈRE RESEARCH INSTITUTE
INFORMED CONSENT STATEMENT FOR:

Prospective Memory in aging and cognitive impairment

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PURPOSE OF STUDY
This study will look at how people remember to do things in the future, how this is linked with other cognitive abilities, and how this changes as we get older. This purpose of the study is to obtain a better understanding of people's ability to remember to do things in the future so that we can help identify those with difficulties and provide appropriate strategies to manage these difficulties.

NUMBER OF PEOPLE TAKING PART IN THE STUDY:
If you agree to be in the study, you will be one of approximately 30 subjects who will be participating in this research.

PROCEDURES FOR THE STUDY:
If you agree to be in the study, you will do the following things:

1. Your hearing will be screened. This part of the experiment takes about ten minutes. If you do not have adequate hearing to complete the tasks we will terminate the testing session. This test will therefore be conducted at the outset of the session.
2. Watch a video and attempt to recall to the examiner a series of activities that you are asked to remember while viewing the video.
3. Look at strings of numbers on the computer and decide which one is higher as fast and accurately as you can.
4. Complete a series of tests of memory and cognitive function.

This study takes place in one sessions of less than two hours.

RISKS OF TAKING PART IN THE STUDY:
While in the study, you may experience fatigue or boredom, and you may feel uncomfortable answering some of the questions. While completing the forms at home, you can skip any questions that you do not want to answer. While doing the tasks in the lab, you can tell the tester that you feel uncomfortable or do not want to answer any question. There is also a risk of loss of confidentiality.

BENEFITS OF TAKING PART IN THE STUDY:
There are no direct benefits to you if you take part in this study. The results of this study will help us to understand changes in language and communication function that occur as people get older or develop memory problems.

CONFIDENTIALITY
We will do all that we can to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your identity will not be disclosed in any reports of the study. Data will be stored securely and will be available only to persons conducting the study, unless you specifically give permission in writing to do otherwise. Your will have a subject number that is used on all test materials that is only known by the researchers. Your subject number and name will only be linked on a document that is stored separately from all other materials and is only accessible to the researchers. No references to the study will contain any information which could link you to any particular findings, or even to your participation. Should it be determined that there are any findings of clinical significance, you will be informed of these findings and

your physician will be notified only with your permission.

Information from this study will also be included in a database that will allow sharing of neurocognitive and demographic data across Dr. Taler's studies. The data shared will include: neuropsychological test results, demographic information as specified in the Health Questionnaire (Appendix A), results of at-home tests and diagnosis. Identifying information will not be shared between studies or disclosed. *For patients of the Memory Disorders clinic at Élisabeth Bruyère Continuing Care, by signing the attached Informed Consent Form, you allow us to access to your medical records as they relate to this study.* Dr. Taler or a trained research assistant or student under her supervision will gather data about your performance on any cognitive or neuropsychological tests you completed in the Memory Disorders Clinic.Your responses will be available to the researcher (Dr. Taler) and to trained research assistants and will be destroyed after 15 years.

COSTS
There are no costs to you associated with taking part in this study.

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VOLUNTARY NATURE OF STUDY
Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. You may withdraw consent and stop participation *at any time* without it affecting your present or future care. You will be given continued and meaningful opportunities to decide whether or not to continue to participate.

SUBJECT'S CONSENT
I have read this consent form and had any questions I have answered. I give my consent to participate in this research study. I will be given a copy of this informed consent form to keep for

my records.

Participant's signature: _____ Date: _____
(must be dated by the participant)

Signature of person obtaining consent: _____ Date: _____

Appendix C

PM Video Task Outline

"Today, you are going on a vacation to see some friends and there is expected to be good weather for the next few days. It is now time to leave Ottawa, but you still have some shopping to do. To do this, you go to a mall."

Tasks:
"This is the organization of your shopping"

First of all,

1. So that you don't miss your bus, you have to leave in 20 minutes the mall, even if you have not finished your shopping. Therefore, you should stop the movie after 20 minutes. (TB20)

2. Also remember to confirm your arrival to your friends. Call them in 10 minutes. (TB10)

For your trip you need,

3. Buy a sandwich for the trip at Michel's Bakery. (EBF-D) – strong

4. Buy leather cleaner at Little Burgundy. (ELF-D) – weak

5. Get your bus tickets at OC Transpo. (EBF) – strong

6. Buy a small bottle of water at the Newstand. (EBF) – weak

7. Buy an assortment of chocolates for your friends at Godiva. (EBF) – strong

8. Return in 5 minutes to get your packet of chocolates. (TB5)

9. Buy sunglasses at Laurier Optical. (EBF-D)- strong

10. Think of buying some magazines when you pass Bell Canada Store. (ELF-D) – weak

11. Buy candies for the kids of your friends at Miss Tiggy Winkles. - weak