LONGITUDINAL EFFECTS OF AGING ON PROSPECTIVE MEMORY

A Thesis

Presented to

The Faculty of the Department

of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Kelli L. Sullivan

December, 2018

LONGITUDINAL EFFECTS OF AGING ON PROSPECTIVE MEMORY

_____
Kelli L. Sullivan

APPROVED:

_____
Steven Paul Woods, Psy.D.
Committee Chair

_____
Clayton Neighbors, Ph.D.

_____
Paul J. Massman, Ph.D.

_____
Antonio D. Tillis, Ph.D.
Dean, College of Liberal Arts and Social Sciences
Department of Hispanic Studies

LONGITUDINAL EFFECTS OF AGING ON PROSPECTIVE MEMORY

An Abstract of a Thesis

Presented to

The Faculty of the Department

of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Kelli L. Sullivan

December, 2018

ABSTRACT

Older adults demonstrate worse prospective memory (PM) performance compared to younger individuals, which may interfere with everyday activities such as remembering to take medications on time and turning off the stove after cooking. However, the longitudinal trajectories of time-based and event-based PM in older age are not known. Participants included 329 community-dwelling older adults (50 to 90 years old) who completed a baseline evaluation and up to three follow-up visits, approximately 2.2 years apart. Participants completed the time-based and event-based PM tasks of the Memory for Intentions Test (MIsT), a naturalistic 24-hr PM task, and the Prospective and Retrospective Memory Questionnaire (PRMQ). Participants were also administered the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) and clinical measures of executive functions. Generalized linear mixed models were used to analyze longitudinal changes in each PM variable, controlling for baseline age. Participants demonstrated significant declines in event-based but not time-based laboratory PM over time. Changes in event-based PM performance were associated with changes on measures of retrospective memory, attention, and semantic fluency, while changes in time-based PM performance were associated with changes in executive functions and semantic fluency. No significant changes were observed in naturalistic PM performance, and PM symptoms were found to decline over time. These results indicate that older adults may be particularly susceptible to age-related declines in more automatic, event-based PM tasks compared to time-based PM tasks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Prospective memory (PM) is a form of declarative memory that involves the ability to remember and execute delayed intentions (McDaniel & Einstein, 2000). Also known as "remembering to remember," PM is relevant to everyday activities such as taking medication at the appropriate time, returning a telephone call, or remembering to buy groceries on the way home from work. Aging is associated with worse PM (e.g., Henry, MacLeod, Phillips, & Crawford, 2004), which in turn increases the risk of problems in everyday functioning. Performance-based and self-reported PM are consistently associated with functional outcomes among older adults, such as medication management (Woods et al., 2014), activities of daily living (ADLs; Tierney, Bucks, Weinborn, Hodgson, & Woods, 2016; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012) and quality of life (Woods et al., 2015). Therefore, it is important to understand how performance-based and self-reported PM may change with advancing age, and how these PM changes may impact everyday functioning.

Neuropsychology of PM

PM is a complex neurocognitive process that involves several steps. According to Kliegel, Martin, McDaniel, & Einstein's (2002) neuropsychological model, PM involves (1) formation of an intention, (2) maintenance of the intention over a period of delay, (3) initiation of the intended action, and (4) execution of the intention. During the intention formation phase, the individual must associate the planned intended action with the corresponding PM cue. The intention maintenance phase involves keeping this intention in mind while performing an ongoing task, and depending on the situation, may require the individual to monitor the environment for the PM cue. Next, the intention initiation phase

involves detecting the PM cue and disengaging from the ongoing task in order to initiate the intention at the appropriate moment. Finally, the execution phase involves completing the intended action as planned.

PM cues are typically classified into two categories: time-based cues, in which the individual must complete a task at a specific time (e.g., take medication at 3:00 P.M.) or event-based cues, in which the individual must complete a task in response to an external event (e.g., deliver a message upon seeing a friend). According to the multiprocess model of PM (McDaniel & Einstein, 2000), PM cues place demands on varying degrees of strategic and/or automatic processing. During PM tasks with high strategic demands, individuals must actively monitor the environment for the PM cue, while in PM tasks that are more automatic, individuals are spontaneously reminded of the deferred intention upon processing the PM cue. For example, a PM cue that is nonfocal to the ongoing task may require more strategic monitoring to detect the retrieval cue than a more salient, focal PM cue in which the intention "pops into mind" when the cue is encountered (Kliegel, Jäger, & Phillips, 2008). Time-based PM cues, which may rely on internally initiated time monitoring, are typically considered to require more strategic processing than PM based on external, event-based cues (e.g., d'Ydewalle, Bouckaert, & Brunfaut, 2001). However, event-based PM tasks can vary in their strategic monitoring demands, depending on a variety of factors, including the salience of the PM cue and engagement in the ongoing task.

Laboratory studies of older adults have provided information about the neurocognitive functions that support the strategic and automatic processes of PM. A study of older adults (McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999) found that participants who demonstrated high performance on tasks of executive functions and

working memory, which are supported by the prefrontal cortex, performed better on an event-based PM task than those who did not. In contrast, high performance on tasks of learning and retrospective memory, which are supported by the medial temporal lobe, was not significantly related to performance on the event-based PM task. A similar study (McFarland & Glisky, 2009) found that individuals with high performance on tasks of executive functions performed better on a time-based PM task, but performance on tasks of learning and memory was only related to time-based PM among older adults who also demonstrated high performance on tasks of executive functions. Of note, older adults with poor performance on the tasks of executive functions were significantly worse at the time-based PM task than younger adults, suggesting that problems with executive functions may be responsible for age-related declines in strategic PM performance (McFarland & Glisky, 2009). Additional laboratory studies of older adults have demonstrated that PM performance is associated with clinical measures of retrospective memory, working memory, and executive functions, but not with tasks of language, speed of information processing, or visuospatial skills (Kamat et al., 2014; Martin, Kliegel, & McDaniel, 2003; Tam & Schmitter-Edgecombe, 2013).

Neuroimaging research has supported the theory that PM tasks with greater demands on strategic versus automatic processing may rely on different neural networks. Specifically, PM tasks that are highly strategic may rely more strongly on prefrontal systems, whereas PM tasks that are more automatic depend more heavily on medial temporal areas. A recent meta-analysis of 24 functional magnetic resonance imaging (MRI) and positron-emission tomography (PET) studies found that the maintenance of PM intentions, which may require strategic monitoring for the PM cue, relies on a dorsal frontoparietal network, while the

retrieval phase, which is more automatic, relies on a distinct ventral frontoparietal network (Cona, Scarpazza, Sartori, Moscovitch, & Bisiacchi, 2015). Additionally, a structural MRI study of older adults found that medial temporal lobe volume was associated with performance on a focal PM task, but not on a nonfocal PM task (Gordon, Shelton, Bugg, McDaniel, & Head, 2011). Taken together, these studies support the notion that PM tasks with high strategic demands rely more heavily on frontal lobe processes, while PM tasks that involve more automatic processing rely more heavily on the medial temporal lobes.

Aging and PM

Among older adults, age-related changes in brain structure and function can disrupt the neurocognitive functions that support PM. Evidence from neuroimaging studies suggests that aging preferentially impacts prefrontal systems, with greater age-related volume changes in prefrontal areas compared to other cortical regions (e.g., Raz et al., 1997). These age-related changes in prefrontal regions are associated with poorer performance on tasks of executive functions in older adults (e.g., Gunning-Dixon & Raz, 2003). The medial temporal lobes are also disrupted by aging (e.g., Jack et al., 1997), and these changes are associated with declines in episodic memory performance (e.g., Golomb et al., 1994). Thus, while PM tasks with high strategic demands may be expected to demonstrate the greatest age-related declines, PM tasks that are more automatic may be disrupted by age-related neural changes as well.

Cross-sectional studies have provided evidence on how aging may impact various types of PM. Meta-analyses of PM and aging (e.g., Henry et al., 2004; Kliegel et al., 2008; Uttl, 2011) have consistently concluded that older adults demonstrate worse performance on laboratory PM tasks compared to younger individuals, and that these differences are greater

for PM cues that require a high degree of strategic monitoring (e.g., time-based or nonfocal PM cues). In particular, age-related changes in prefrontal processes (e.g., West, 1996) may make it more difficult for older adults to execute PM tasks with high strategic demands, while more automatic PM tasks are less detrimentally impacted by aging. Additionally, among older adults, age is associated with worse laboratory PM performance. Several cross-sectional studies (e.g., Kamat et al., 2014; Kvavilashvili, Kornbrot, Mash, Cockburn, & Milne, 2009; Uttl, Graf, Miller, & Tuokko, 2001) have suggested that PM performance declines with increasing age, and that young-old adults (e.g., age 60) may demonstrate better laboratory PM than old-old adults (e.g., age 80). However, the exact trajectory of how PM changes in older age is not known.

In addition to standard laboratory tasks, PM can also be assessed with more naturalistic PM tasks and self-report measures of PM symptoms, which may provide additional information about the extent to which older adults experience PM lapses in their daily lives. Although older adults demonstrate worse laboratory PM performance compared to young adults, they often demonstrate comparable, or better, performance on naturalistic PM tasks (e.g., Rendell & Thomson, 1999). Indeed, two meta-analyses of naturalistic PM found that older adults performed better on everyday PM tasks compared to their younger counterparts (Henry et al., 2004; Uttl, 2008). This "age-PM paradox" may be related to several factors, such as motivation, use of compensatory strategies, or level of activity, which may differ between younger and older adults (e.g., Rendell & Thomson, 1999). Despite the paradoxical effects of age, naturalistic PM performance may still be related to laboratory PM performance among some older adults (Kamat et al., 2014). Additionally, although subjective PM symptoms are predictive of functional outcomes in older adults (e.g., Woods et al.,

2014), they are not reliably associated with objective PM performance and may be heavily influenced by mood and personality (e.g., Rönnlund, Vestergren, Mäntylä, & Nilsson, 2011; Zeintl, Kliegel, Rast, & Zimprich, 2006). Studies of everyday PM complaints in younger and older adults have typically failed to find effects of age (e.g., Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Smith, Della Sala, Logie, & Maylor, 2000). Thus, the effects of aging on PM seem to vary depending on the way that PM is measured.

There is substantial evidence that older adults perform worse on laboratory PM tasks and comparably, or better, on naturalistic PM tasks compared to younger individuals. However, almost all studies of aging and PM to date have used cross-sectional designs, which can be confounded by cohort effects. We are aware of only one longitudinal investigation of PM among typically aging, nonclinical adults. Serrani (2010) conducted a longitudinal study of 46 community-dwelling adults who had completed secondary education and were aged 65 to 67 at baseline. Each participant was evaluated every two years over a 10-year period. The participants were asked to complete four event-based and two time-based PM trials during ongoing numeric selection and semantic selection tasks. Specifically, participants were asked to tap the table when specific words were presented in the ongoing task (i.e., event-based cues) and after 10 and 15 minutes had passed (i.e., time-based cues). The event-based PM cues were focal to the ongoing task and likely required less strategic monitoring than the time-based PM cues. Serrani (2010) found that older adults significantly declined in event-based ($ps < .01$) and time-based ($ps < .01$) PM performance over a period of 10 years. Moreover, baseline performance on tests of working memory and attention were significant, independent predictors of PM decline, while performance on tests of retrospective memory and executive functions were not. Of interest, the sample demonstrated

a steep decline in event-based PM beginning around age 70, while declines in time-based PM were more gradual and began around age 73. Working memory and executive functions demonstrated similar trajectories to time-based PM, with relatively gradual declines after age 73. Serrani's (2010) finding that working memory and executive functions decline alongside time-based PM is consistent with prior literature which found that PM tasks with high strategic demands rely on prefrontal areas (e.g., Cona et al., 2015) and correlate with measures of executive functions (e.g., Kamat et al., 2014). However, the finding that participants were more likely to decline in event-based PM performance than time-based PM is surprising given the existing literature on PM and aging. Specifically, given their presumably high demands on strategic monitoring, the time-based PM tasks would be expected to be more sensitive to aging than the focal, event-based PM tasks in this study. Notably, participants who had difficulty executing event-based or time-based PM tasks at their baseline evaluations were excluded from the analysis comparing declines in these two types of PM. Thus, it is possible that some participants had difficulty executing time-based PM tasks at the beginning of the study, and had therefore declined earlier on time-based compared to event-based PM. As the first longitudinal investigation of PM in nonclinical older adults, this study provides some valuable insight, suggesting that both time- and event-based PM decline with age, and that these declines may be related to changes in working memory and executive functions. However, this study did not include measures of PM symptoms or naturalistic PM performance. The study also included a relatively small sample of adults with a restricted age range, and participants only completed two time-based PM trials at each evaluation. As such, further research will be necessary to determine the generalizability of these findings.

Longitudinal studies of the neurocognitive functions that support PM may provide some additional information regarding expected changes in PM with age. Cross-sectional studies have consistently found age-related declines in a variety of neurocognitive domains, including retrospective memory and executive functions, beginning in early adulthood (see Salthouse, 2010b for a review). However, longitudinal studies on this topic have been less consistent. While several long-term studies have found longitudinal declines in tasks of memory and executive functions (e.g., Zahodne et al., 2011; Zelinski & Burnight, 1997), other longitudinal studies have found improvements in neurocognitive performance over time (e.g., Rönnlund, Nyberg, Bäckman, & Nilsson, 2005; Van Dijk, Van Gerven, Van Boxtel, Van der Elst, & Jolles, 2008). Although the reason for this discrepancy is unclear, practice effects are thought to be largely responsible for the lack of neurocognitive decline in some longitudinal studies of aging (e.g., Salthouse, 2009). However, practice effects tend to decrease with age, and adults over age 60 often demonstrate neurocognitive declines in longitudinal studies (e.g., Rönnlund, et al., 2005; Salthouse, 2010a). Therefore, given PM's associations with retrospective memory and executive functions, it is likely that older adults would demonstrate longitudinal declines in PM performance, in spite of potential practice effects.

However, not all older adults are expected to experience the same incidence or rate of neurocognitive decline. In longitudinal studies, older age at baseline is associated with increased risk of neurocognitive decline (e.g., Korten et al., 1997; Taylor, Miller, & Tinklenberg, 1992). Cognitive reserve has also been studied as a predictor of neurocognitive aging. Cognitive reserve refers to the theory that individuals with higher IQ, educational attainment, or socioeconomic status may be more resilient to the effects of aging and less

likely to demonstrate neurocognitive impairment, even in the presence of brain pathology (e.g., Stern, 2009). There are several different theories for how cognitive reserve affects neurocognitive functioning, including passive (e.g., increased efficiency) and active (e.g., compensatory) processes. Although the exact mechanisms of cognitive reserve remain to be determined, individuals with lower cognitive reserve typically demonstrate neurocognitive decline at an earlier age compared to those with higher cognitive reserve (Stern, 2009). Extending these findings to the present study, adults who are older or have lower cognitive reserve would be expected to demonstrate the greatest decline in PM over time.

Aims and Hypotheses

The aim of the current study was to build upon the results found by Serrani (2010) to examine the direct effects of aging on PM among a sample of older Australian adults. First, this study examined how various measures of PM changed longitudinally. Specifically, this study tested the hypothesis that both time-based and event-based PM would decline with advancing age. Time-based PM was hypothesized to be more susceptible to the effects of aging than event-based PM, due to its reliance on strategic executive processes. In contrast to PM measured in the laboratory, naturalistic PM performance was hypothesized to improve with age, and self-reported PM was not expected to relate strongly to advancing age. Secondly, this study examined demographic and neurocognitive factors that might predict PM changes from the baseline evaluation. It was hypothesized that older age and lower cognitive reserve at baseline would predict greater PM decline. Additionally, it was expected that poorer retrospective memory, attention, and executive functions at baseline would predict age-related PM declines. In contrast, visuospatial and language abilities, which are less closely tied to PM, were not expected to predict PM change. Thirdly, this study

investigated whether neurocognitive and functional outcomes change along with PM over time. Specifically, it was hypothesized that retrospective memory, executive functions, attention, ADLs, and quality of life would decline alongside PM. Visuospatial and language abilities were not expected to change in the same manner as PM.

Method

Participants

Participants included community-dwelling adults aged 50 years or older who were recruited via flyers and word of mouth for the Healthy Ageing Research Program at the University of Western Australia. Baseline data were collected from 329 participants (50 to 90 years of age) between August 2008 and September 2016. Descriptive data for the baseline sample are provided in Table 1. Participants were asked to return for up to three follow-up evaluations, approximately two years apart (M = 2.2 years, SD = 1.0, range = 0.7–6.7). One hundred sixty participants returned for one follow-up visit, 72 of those participants returned for a second follow-up, and 29 participants returned for three follow-ups. All participants provided written, informed consent, and the study was approved by the University of Western Australia human research ethics office.

Participants were asked to complete a demographic and medical history questionnaire. In order to ensure that our analyses reflect longitudinal changes in typically aging adults, participants were excluded from analyses if they reported a diagnosis of mild cognitive impairment (MCI) or dementia or scored less than 24 on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) at the baseline evaluation. Participants with a history of major psychiatric disorders (e.g., schizophrenia, bipolar

disorder) or neurological conditions (e.g., traumatic brain injury, stroke, seizure disorder) reported at the initial visit were also excluded. Participants with chronic medical conditions that are common among community-dwelling adults (e.g., hypertension, diabetes) were included in the study in order to maintain a representative sample of older adults.

PM Measures

Laboratory-based PM. Participants completed the research version (Woods et al., 2008) of the Memory for Intentions Test (MIsT; Raskin, Buckheit, & Sherrod, 2010), which is a well-validated laboratory measure of PM. The same version of the MIsT (i.e., Form A) was administered at each visit. During this test, participants complete an ongoing word search task and must interrupt the word search to complete PM tasks in response to time-based and event-based cues. Throughout the MIsT, participants are asked to complete four time-based (e.g., "In 15 minutes, tell me that it is time to take a break") and four event-based (e.g., "When I show you a postcard, self-address it") PM tasks. Each PM task has either a 2-minute or 15-minute delay between the task instruction and execution. Participants are permitted to use a digital clock behind them to keep track of time, but they are not explicitly encouraged to do so. For each of the time-based PM trials, participants can earn 1 point for responding at the correct time and 1 point for providing the correct response. For each of the event-based PM trials, participants can earn 1 point for responding to the appropriate event-based PM cue and 1 point for providing the correct response. Thus, each participant received a score ranging from 0 to 8 for both the time-based and event-based PM scales of the MIsT.

Naturalistic PM. Following the laboratory trials of the MIsT, participants were provided with instructions for a 24-hour delayed naturalistic PM task. For this task, participants are asked to remember to call the examiner in 24 hours to report how many hours

they had slept the previous night. Participants were permitted, but not explicitly encouraged, to use mnemonic strategies (e.g., setting an alarm) for this task. In order to capture the PM component of this task, participants were given a score of 'pass' if they called the examiner, even if they made an error (e.g., called at the wrong time or did not report hours of sleep). Participants were given a score of 'fail' if they did not call the examiner.

Self-reported PM. Participants also completed the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000), which is a 16-item self-report questionnaire assessing everyday prospective and retrospective memory problems. Each symptom is rated on a Likert-type scale from 1 ("Never") to 5 ("Very Often"), such that higher scores reflect more everyday memory problems. The PRMQ PM scale was calculated as the sum of responses for the eight items assessing PM problems (range = 8–40), and the PRMQ retrospective memory subscale was calculated as the sum of the eight items assessing retrospective memory problems (range = 8–40).

Neuropsychological Assessment

RBANS. Participants completed the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998), which is a brief, standardized assessment of neurocognitive functioning. The same version of the RBANS (i.e., Form A) was administered at each evaluation. The RBANS includes 12 subtests: List Learning, Story Memory, Figure Copy, Line Orientation, Picture Naming, Semantic Fluency, Digit Span, Coding, List Recall, List Recognition, Story Recall, and Figure Recall. These 12 RBANS subtests correspond to five neuropsychological domains: Immediate Memory, Visuospatial/Constructional, Language, Attention, and Delayed Memory. Note that, while age-adjusted index scores can be obtained for each of the RBANS domains, our analyses

focused on raw scores in order to evaluate how individual performance on these tasks would change with age. Raw scores on each of the 12 subtests were converted to *z*-scores based on the *M* and *SD* of all participants who completed the RBANS at the baseline visit ($n = 308$). This method was chosen in order to provide a common metric for the *z*-scores across follow-up visits. Subtest *z*-scores were then averaged to create five domain composite scores.

Immediate memory. The immediate memory domain score was calculated using the List Learning and Story Memory subtests of the RBANS. In the List Learning subtest, a list of 10 words is read aloud by the examiner, and participants are asked to recall as many words as possible. This task is repeated with the same list of words over four learning trials. For the Story Memory task, the examiner reads a short story and asks the participant to repeat the story from memory. The same story is repeated during a second trial.

Visuospatial/constructional. The visuospatial/constructional domain score consists of Figure Copy and Line Orientation. In the Figure Copy subtest, participants are presented with a complex visual figure and asked to copy it onto a blank sheet of paper. In the Line Orientation task, participants are presented with 13 numbered lines at different angles in a semi-circular pattern. Participants are given 10 trials of two lines and must indicate which of the 13 numbered lines they match.

Language. The language domain score includes the Picture Naming and Semantic Fluency subtests. In the Picture Naming task, participants are asked to name a series of line drawings. For Semantic Fluency, participants are asked to name as many fruits and vegetables as they can in one minute.

Attention. The attention score is calculated using the Digit Span and Coding subtests of the RBANS. In the Digit Span subtest, the examiner reads strings of numbers and asks the

participant to repeat them in the same order. For Coding, participants are provided with a key that lists the numbers 1 through 9, each paired with a simple geometric design. Participants are given a page of geometric designs and asked to write the corresponding number below each design as quickly as possible.

Delayed memory. The delayed memory domain score includes List Recall, List Recognition, Story Memory, and Figure Recall. For List Recall, participants are asked to recall the list of words that they heard during the List Learning subtest. For List Recognition, the examiner reads a list of 20 words and asks the participant to indicate whether or not each word was on the earlier list. For Story Recall, participants are asked to recall the story presented earlier, and for Figure Recall, participants are asked to draw the complex figure from the Figure Copy subtest.

Executive functions. Executive functions were assessed with the executive clock-drawing task (CLOX; Royall, Cordes, & Polk, 1998), Trail Making Test (TMT) parts A and B (Reitan & Wolfson, 1985), letter C fluency (Benton, Hamsher, & Sivan, 1994), and action (verb) fluency (Woods et al., 2005). In the CLOX task, participants are asked to draw a clock (CLOX1) and then copy a clock that the examiner has drawn (CLOX2). The CLOX executive index (calculated as CLOX2 – CLOX1) is used as a measure of executive dysfunction. TMT part A is a timed task in which participants are asked to connect a series of numbered dots as quickly as possible. In TMT part B, participants are asked to switch between connecting numbers and letters in order as quickly as possible. For the letter C fluency task, participants are asked to name as many words as they can that begin with the letter C in one minute. Participants are instructed not to name proper nouns or the same word with different endings. In the action fluency task, participants are instructed to name as many

different action words as they can in one minute. A composite executive functions score was calculated by converting the raw scores for CLOX executive index, TMT B time, letter C fluency, and action fluency to sample-based *z*-scores and then averaging them. A higher *z*-score reflects better executive functions.

Everyday Functioning Measures

Activities of daily living. Participants completed the Activities of Daily Living Questionnaire (ADLQ; Johnson, Barion, Rademaker, Rehkemper, & Weintraub, 2004) at each visit. This 28-item self-report questionnaire assesses six subscales of activities: self-care, household care, employment and recreation, shopping and money, travel, and communication. Each item is rated on a four-level scale (e.g., "Employment" is rated from 0: "Continues to work as usual" to 3: "No longer works"). Each item also has a response option for questions that are not applicable (e.g., "Never worked OR retired before illness OR don't know"). For this study, items rated as not applicable or unknown were scored as 0. The total score for the ADLQ was calculated as the sum of responses across the 28 items (range = 0–84). Higher scores reflect more difficulty with ADLs.

Quality of life. Participants completed the World Health Organization Quality of Life 8-item questionnaire (WHOQOL-8), which is an abbreviated version of the WHOQOL-BREF (Power, 2003). The WHOQOL-8 includes questions about quality of life over the past two weeks, which are rated on a five-level scale (e.g., "How satisfied are you with your health?" is rated from "Very Dissatisfied" to "Very Satisfied"). The total score for WHOQOL-8 was summed across the eight items (range = 8–40), such that higher scores reflect better quality of life.

Cognitive Reserve

Participants completed a measure of oral word reading in order to estimate premorbid verbal IQ. Due to a change in the study protocol, participants received either the National Adult Reading Test (NART; Nelson & Willison, 1991) or the Australian version of this test (AUSNART; Hennessey & MacKenzie, 1995). Estimated premorbid IQ was calculated using the NART or AUSNART test manuals, depending on the version administered. Education and estimated premorbid IQ scores at the baseline visit were strongly correlated ($\rho = 0.54$, $p < .001$). Estimated premorbid IQ scores and years of education were then converted to sample-based *z*-scores based on the *M* and *SD* of the entire sample at the baseline visit. Cognitive reserve was calculated by averaging the *z*-scores for estimated premorbid IQ and years of education at each participant's baseline visit.

Affective Distress

Due to a change in the study protocol, participants completed either the Patient Health Questionnaire-9 (PHQ-9; Kroenke, Spitzer, & Williams, 2001) or the Geriatric Depression Scale 15-item Short Version (GDS-15; Sheikh & Yesavage, 1986) as a measure of depressive symptoms. Participants also completed either the Generalized Anxiety Disorder 7-item scale (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006) or the 20-item Geriatric Anxiety Inventory (GAI; Pachana et al., 2007). Participants were considered to have elevated affective distress if they obtained a score of 5 or greater on the PHQ-9, GDS-15, or GAD-7, or a score of 9 or greater on the GAI.

Data Analysis

Longitudinal PM change. Generalized linear mixed models (GLMM) were conducted in STATA IC version 14.2 to investigate longitudinal changes in PM. GLMM was

chosen because it offers several advantages compared to other methods of analysis (e.g., repeated-measures analysis of variance [ANOVA]). Specifically, GLMM uses all available data, allows for visits that are unbalanced (i.e., unevenly spaced) between individuals, and can accommodate non-normally distributed outcomes. Four models were run with each PM measure (time-based MIsT PM, event-based MIsT PM, MIsT 24-hr task, and PRMQ PM scale) as the dependent variables. Time in years from the baseline visit ("study time") was used as the primary indicator of change, controlling for participant age at the baseline visit. All models included a random intercept. Demographic and medical variables (i.e., sex, number of chronic medical conditions, and elevated affective distress) that were significantly associated with a PM variable at any visit at the $p < .10$ level were included in the initial models as covariates. Likelihood-ratio tests were conducted to determine whether including time as a random effect would improve model fit. Restricted maximum likelihood estimation was conducted where possible, because this method provides unbiased covariance estimates**.** For models with negative binomial and logistic outcomes, maximum likelihood estimation was used.

Predictors of PM change. Additional GLMM analyses were conducted in order to determine demographic and neurocognitive predictors of longitudinal PM change. First, the interaction of baseline age and study time was added to the models, to test the hypothesis that older age is associated with greater longitudinal decline in PM. In order to determine whether lower cognitive reserve is associated with greater decline in PM, cognitive reserve and its interaction with study time were added to the models. To investigate whether baseline retrospective memory (i.e., immediate memory, delayed memory, PRMQ retrospective memory scale), attention, or executive functions were associated with changes in PM, each

neurocognitive measure and its interaction with study time were added to separate models as fixed effects. Analyses were also conducted with baseline language and visuospatial/constructional scores, and their interactions with study time, in order to confirm the specificity of baseline retrospective memory, attention, and executive functions as predictors of PM change. When the interactions were not significant, the interaction terms were dropped from the models. Finally, models were conducted including all significant neurocognitive predictors from prior analyses, in order to determine independent predictors of longitudinal change in each PM variable.

Correlates of PM change. Among participants with at least two visits, analyses of neurocognitive and everyday functioning changes associated with changes in PM were conducted using JMP Pro 14. For the time- and event-based PM scales of the MIsT and the PRMQ PM scale, residualized change scores were calculated for each participant, by regressing the participant's last score on each measure onto the first score they obtained on the measure. Since some participants were missing PM variables at some visits, residualized change scores in neurocognitive and everyday functioning variables were calculated using data from the same study visits from which the PM changes were calculated. Residualized change scores for the majority of variables of interest (i.e., time-based MIsT PM, event-based MIsT PM, delayed memory, executive functions, and ADLQ) were non-normally distributed, and therefore nonparametric correlations were used to determine whether changes in laboratory or self-reported PM were associated with changes in neurocognitive or everyday functioning variables. Results did not differ if parametric correlations were used for normally distributed variables.

To determine neurocognitive and everyday functioning changes associated with changes in performance on the MIsT 24-hr task, participants were classified into three groups based on whether their performance improved, remained stable, or declined from the first administration of the naturalistic task until the last administration of the task. Separate logistic regressions were used to determine whether residualized changes in any neurocognitive variables over the same study visits were associated with MIsT 24-hr change group (improved, stable, or declined). Then, ANOVAs were used to determine whether MIsT 24-hr change group predicted change in scores on the ADLQ or WHOQOL-8. Results did not differ if Kruskal-Wallis tests were used for non-normally distributed variables. The critical alpha was set to .05 for all analyses.

Results

Baseline scores on the PM measures are displayed in Table 2. Time-based MIsT PM and the PRMQ PM scale had approximately normal distributions. Event-based MIsT PM was negatively skewed, such that 85.5% of scores on this measure were a 6, 7, or 8 (possible range = 0–8). Therefore, for all GLMM analyses, event-based MIsT PM scores were transformed such that 0 represented the highest possible score and 8 represented the lowest score. Event-based MIsT PM was then treated as a negative binomial outcome variable. MIsT 24-hr task was a dichotomous variable and was analyzed using logistic models.

Higher numbers of chronic medical conditions were associated with worse time-based MIsT PM and more PRMQ PM symptoms at visits 1 and 2, and number of medical conditions was therefore included in the initial models as a covariate. Elevated affective distress was associated with worse event-based MIsT PM at visit 1 and more PM symptoms

on the PRMQ at visits 1, 2, and 3. Female sex was associated with a higher likelihood of passing the MIsT 24-hr task at visit 1.

Longitudinal PM Change

To investigate longitudinal changes in time-based MIsT PM, a model was conducted with study time, baseline age, and number of chronic medical conditions as fixed effects. Number of medical conditions did not predict time-based MIsT PM (β = –0.03, *SE* = 0.05, *p* = .508) and was therefore not included in subsequent models. A model with only study time and baseline age as fixed effects (Table 3, Model 1) revealed that older age ($p < .001$) was associated with worse time-based MIsT PM performance, while the effect of study time was not significant ($p = .680$; Figure 1).

Next, a model for event-based MIsT PM was conducted with study time, baseline age, and elevated affective distress as fixed effects. Affective distress was not associated with event-based MIsT PM (β = 0.15, *SE* = 0.15, *p* = .325) and was not included in subsequent models. A model with study time and baseline age as fixed effects (Table 4, Model 1) revealed that longer study time was associated with worse event-based MIsT PM ($p = .047$; Figure 1), while older age was only marginally associated with worse event-based PM performance ($p = .080$).

A model for the MIsT 24-hr task included study time, baseline age, and female sex as fixed effects (Table 5, Model 1). Female sex was marginally associated with performance on the MIsT 24-hr task ($p = .069$) and was therefore retained in the model. Neither study time ($p = .683$) nor baseline age ($p = .584$) was associated with MIsT 24-hr task performance (Figure 2).

Finally, study time, baseline age, number of chronic medical conditions, and affective distress were entered as fixed effects in a model of the PRMQ PM scale. Number of medical conditions was not associated with the PRMQ PM scale (β = 0.15, *SE* = 0.12, *p* = .200) and was therefore removed from the model. In a model with study time, baseline age, and affective distress as predictors of the PRMQ PM scale (Table 6, Model 1), the presence of affective distress ($p < .001$) and shorter study time ($p = .049$; Figure 3) were associated with more reported PM symptoms, while baseline age was not a significant predictor ($p = .559$).

Of note, likelihood-ratio tests revealed that adding study time as a random effect did not significantly improve the fit of any of these models (*p*s > .10).

Predictors of PM Change

Demographic predictors. In order to determine whether older individuals experienced greater longitudinal changes in time-based MIsT PM, baseline age, study time, and their interaction were included in a model as fixed effects. There was no significant interaction of age and study time (β = –0.00, *SE* = 0.00, *p* = .863). Next, cognitive reserve and its interaction with study time were entered into a model with study time and baseline age as fixed effects. There was no significant interaction between cognitive reserve and study time (β = 0.01, *SE* = 0.03, *p* = .825). However, in a model with only study time, baseline age, and cognitive reserve as fixed effects (Table 3, Model 2), cognitive reserve was associated with time-based MIsT PM ($p < .001$). In other words, individuals who were younger and had higher cognitive reserve performed better on the time-based MIsT PM tasks overall, but baseline age and cognitive reserve did not affect longitudinal changes in time-based MIsT PM.

In a model with baseline age, study time, and their interaction as predictors of event-based MIsT PM, the interaction was not significant (β = 0.00, *SE* = 0.00, *p* = .328). Additionally, there was no significant interaction of study time and cognitive reserve (β = 0.03, *SE* = 0.03, *p* = .244) when entered into the model. In a model with study time, baseline age, and cognitive reserve as predictors of event-based MIsT PM (Table 4, Model 2), study time (*p* = .027) and cognitive reserve (*p* = .036) were significant, but baseline age was not (*p* = .107). Thus, participants with higher cognitive reserve had better event-based MIsT PM overall, and participants tended to decline on event-based PM over time, but cognitive reserve was not associated with event-based PM decline.

In a model with baseline age, study time, their interaction, and female sex as predictors of MIsT 24-hr performance, the interaction of baseline age and study time was not significant (β = 0.01, *SE* = 0.01, *p* = .302). There was also no interaction of study time and cognitive reserve on MIsT 24-hr task (β = –0.05, *SE* = 0.07, *p* = .449) when entered into a model. In a model with study time, baseline age, female sex, and cognitive reserve as fixed effects (Table 5, Model 2), cognitive reserve was not a significant predictor of MIsT 24-hr task performance (*p* = .194).

In a model with baseline age, study time, their interaction, and affective distress as predictors of the PRMQ PM scale, the interaction of age and study time was not significant (β = 0.01, *SE* = 0.01, *p* = .495). In a model with cognitive reserve and its interaction with study time, the interaction was not significant (β = –0.07, *SE* = 0.07, *p* = .260). There was also no significant effect of cognitive reserve (*p* = .773) in a model with study time, baseline age, and affective distress (Table 6, Model 2).

Neurocognitive predictors. In order to determine whether baseline retrospective memory, attention, or executive functions were associated with time-based MIsT PM, each of these variables was entered into separate models with study time and baseline age as fixed effects. In separate models, performance on tasks of immediate memory (β = 0.40, *SE* = 0.08, $p < .001$), delayed memory (β = 0.52, *SE* = 0.10, $p < .001$), attention (β = 0.39, *SE* = 0.09, $p < .001$), and executive functions (β = 0.50, *SE* = 0.11, $p < .001$) were significantly associated with time-based MIsT PM, while PRMQ retrospective memory symptoms were not (β = –0.02, *SE* = 0.02, $p = .283$). There were no significant interactions between any of these neurocognitive variables and study time (*p*s > .10). Contrary to expectations, baseline language (β = 0.22, *SE* = 0.11, $p = .040$) and visuospatial/constructional skills (β = 0.22, *SE* = 0.11, $p = .040$) were also associated with time-based MIsT PM in separate models; however, their interactions with study time were not significant (*p*s > .10). In a final model with all of the significant neurocognitive predictors (Table 3, Model 3), baseline age ($p < .001$) and attention ($p = .017$) independently predicted time-based MIsT PM, while study time, immediate memory, delayed memory, visuospatial skills, language, and executive functions did not (*p*s > .10). Thus, younger age and higher scores on measures of auditory verbal attention and processing speed were associated with better time-based PM overall but did not affect longitudinal changes in time-based PM.

In separate models, baseline immediate memory (β = –0.23, *SE* = 0.07, $p = .001$), delayed memory (β = –0.30, *SE* = 0.08, $p < .001$), attention (β = –0.25, *SE* = 0.08, $p = .001$), executive functions (β = –0.22, *SE* = 0.09, $p = .022$), and the PRMQ retrospective memory scale (β = 0.03, *SE* = 0.01, $p = .021$) were significantly associated with event-based MIsT PM. None of these neurocognitive variables had significant interactions with time. Language

(β = –0.30, *SE* = 0.09, *p* = .001) and visuospatial/constructional skills (β = –0.20, *SE* = 0.08, *p* = .009) were also associated with event-based MIsT PM; however, their interactions with time were not significant. In a final model with all significant neurocognitive predictors (Table 4, Model 3), study time (*p* = .009), attention (*p* = .015), PRMQ retrospective memory scale (*p* = .029), language (*p* = .019), and visuospatial/constructional skills (*p* = .043) significantly predicted event-based MIsT PM, while immediate memory, delayed memory, and executive functions did not (*p*s > .10). Therefore, participants tended to decline in event-based MIsT PM over time, even after controlling for relevant demographic and neurocognitive variables. Individuals with better baseline scores on measures of auditory verbal attention and processing speed, picture-naming and semantic fluency, and visuospatial judgment and construction performed better on event-based MIsT PM, but these variables did not affect event-based PM declines.

In separate models, there were no significant effects of immediate memory (β = 0.21, *SE* = 0.16, *p* = .169), delayed memory (β = 0.20, *SE* = 0.19, *p* = .281), attention (β = 0.09, *SE* = 0.17, *p* = .605), executive functions (β = 0.13, *SE* = 0.20, *p* = .523), or PRMQ retrospective memory scale (β = –0.03, *SE* = 0.03, *p* = .328) on the MIsT 24-hr task. Additionally, there was no effect of language (β = –0.33, *SE* = 0.20, *p* = .093) or visuospatial/constructional skills (β = 0.20, *SE* = 0.17, *p* = .241) on MIsT 24-hr task. None of the neurocognitive variables had significant interactions with time (*p*s > .10).

In separate models, there were no significant effects of baseline immediate memory (β = –0.06, *SE* = 0.31, *p* = .846), delayed memory (β = 0.66, *SE* = 0.36, *p* = .066), attention (β = –0.32, *SE* = 0.33, *p* = .334), or executive functions (β = 0.50, *SE* = 0.41, *p* = .221) on PRMQ PM scores, and there were no significant interactions between these neurocognitive

variables and study time (*p*s > .10). There was a significant interaction of the PRMQ retrospective memory scale and study time (β = –0.04, *SE* = 0.01, *p* = .004), such that participants who reported more retrospective memory symptoms at baseline were more likely to report *decreasing* PRMQ PM symptoms over time. There was also a significant interaction of language and study time (β = –0.27, *SE* = 0.09, *p* = .004), such that participants with lower baseline language scores were more likely to report *decreasing* PM symptoms over time. There was no significant effect of visuospatial/constructional skills (β = 0.50, *SE* = 0.32, *p* = .120) and no interaction with study time (*p* > .10). In a final model with all significant predictors (Table 6, Model 3), there was a significant effect of affective distress (*p* = .001), an interaction of baseline PRMQ retrospective memory symptoms and study time (*p* = .008), and an interaction of baseline language and study time (*p* = .006), but no effect of baseline age (*p* = .641) on the PRMQ PM scale. This means that participants who reported more retrospective memory symptoms at baseline and attained lower scores on baseline tasks of picture-naming and semantic fluency tended to report greater improvements in PM symptoms over time.

Correlates of PM Change

Changes in time-based MIsT PM were associated with changes in executive functions (ρ = .28, *p* = .001) and language (ρ = .19, *p* = .024), but not with immediate memory (ρ = .12, *p* = .167), delayed memory (ρ = .11, *p* = .222), attention (ρ = .09, *p* = .289), or visuospatial/constructional skills (ρ = .10, *p* = .230). Changes in time-based MIsT PM were not associated with changes in self-reported scores on the PRMQ retrospective memory scale (ρ = –.08, *p* = .403), ADLQ (ρ = –.09, *p* = .340) or WHOQOL-8 (ρ = .08, *p* = .488).

Changes in event-based MIsT PM were associated with changes in immediate memory ($\rho = .19$, $p = .030$), delayed memory ($\rho = .24$, $p = .005$), attention ($\rho = .25$, $p = .004$), and language ($\rho = .21$, $p = .013$), but not with executive functions ($\rho = .07$, $p = .408$) or visuospatial/constructional skills ($\rho = .04$, $p = .612$). Changes in event-based MIsT PM were not associated with changes in scores on the PRMQ retrospective memory scale ($\rho = –.02$, $p = .851$), ADLQ ($\rho = –.08$, $p = .352$), or WHOQOL-8 ($\rho = .04$, $p = .694$).

Changes in PM symptoms on the PRMQ were not associated with changes in immediate memory ($\rho = .07$, $p = .387$), delayed memory ($\rho = –.13$, $p = .121$), attention ($\rho = –.04$, $p = .663$), executive functions ($\rho = –.01$, $p = .886$), language ($\rho = .05$, $p = .545$), or visuospatial/constructional skills ($\rho = –.01$, $p = .942$). Changes in the PRMQ PM scale were associated with changes on the PRMQ retrospective memory scale ($\rho = .43$, $p < .001$), but not with changes on the ADLQ ($\rho = .05$, $p = .583$) or WHOQOL-8 ($\rho = –.01$, $p = .968$).

A logistic regression with change in executive functions predicting MIsT 24-hr change group was not significant, $\chi^2(2) = 2.04$, $p = .360$. Similarly, in logistic regressions, neither immediate memory, $\chi^2(2) = 0.11$, $p = .947$, delayed memory, $\chi^2(2) = 2.52$, $p = .283$, attention, $\chi^2(2) = 1.00$, $p = .606$, language, $\chi^2(2) = 1.28$, $p = .526$, nor visuospatial/constructional skills, $\chi^2(2) = 0.63$, $p = .730$, significantly predicted MIsT 24-hr change. Changes in scores on the PRMQ retrospective memory scale significantly predicted MIsT 24-hr change groups, $\chi^2(2) = 8.95$, $p = .011$. Contrary to expectations, participants who reported *decreasing* symptoms on the PRMQ retrospective memory scale were more likely to decline on the MIsT 24-hr task. MIsT 24-hr change groups did not significantly differ in their changes on the ADLQ, $F(2, 86) = 0.66$, $p = .519$, or WHOQOL-8, $F(2, 54) = 2.10$, $p = .132$.

Discussion

Older adults commonly demonstrate worse PM than younger adults (e.g., Henry et al., 2004), which may put them at an increased risk of problems in everyday health behaviors, such as remembering to take their medications. However, little is known about the extent to which PM changes over time in older adults. In the current study, a large sample of nonclinical older adults demonstrated significant declines on a laboratory measure of event-based PM, but not time-based PM, over a period of approximately 2 to 5 years. No demographic or neurocognitive factors at baseline significantly predicted declines in laboratory PM performance; however, changes in retrospective memory were associated with changes in event-based PM, while changes in executive functions were associated with changes in time-based PM. Overall, these findings extend our understanding of PM and suggest that older adults may be at risk of declines in more automatic, spontaneous PM tasks compared to those that require more strategic monitoring.

Older adults demonstrated significant declines in event-based PM over time, such that the average score on the 8-point event-based PM scale of the MIsT was predicted to be 6.9 at the baseline evaluation and 6.3 when measured 8 years later, controlling for baseline age. The significant decline in event-based PM is consistent with the only prior longitudinal study of PM in older adults (Serrani, 2010), which found declines in event-based PM performance (i.e., remembering to tap the table in response to specific verbal stimuli) over periods of 5 and 10 years. The sample in Serrani's (2010) study was small (n = 46) and only included individuals aged 65 to 67 years at baseline. In the present study, we found similar declines in event-based PM using a larger sample of older adults, more rigorous statistical analyses, and a well-validated clinical measure of event-based PM (Kamat et al., 2014). Thus, evidence

from these two studies suggests that older adults are at risk of declining performance on event-based PM tasks as they age.

In contrast to the observed declines in event-based PM, participants did not demonstrate significant changes in time-based laboratory PM performance over the course of the study. The average score on the 8-point time-based PM scale of the MIsT was predicted to be 5.3 at the initial visit and 5.2 when measured 8 years later. This finding contrasts starkly with cross-sectional studies of aging and PM, which have found that older adults perform significantly worse on time-based PM tasks than younger individuals (e.g., Henry et al., 2004). This result also differs from a prior longitudinal study (Serrani, 2010) that found that older adults declined in time-based PM performance over periods of 5 and 10 years. This discrepancy could be due to differences in the study methods; for example, participants in Serrani's (2010) study were 65 to 67 years old at baseline, while the present study included a wider age range of participants (50 to 90 years of age). Thus, it is possible that Serrani (2010) captured participants at an age when they were particularly likely to demonstrate declines in time-based PM performance. However, age did not affect changes in time-based PM in the current study, which suggests that it is less likely that the age range of the sample caused this discrepancy. There were also several differences in the time-based PM tasks used in these two studies. The MIsT includes four time-based PM trials, while Serrani's study only used two trials. The four time-based PM tasks of the MIsT also had a higher retrospective memory load (e.g., "In 15 minutes, tell me that it is time to take a break") than those used in Serrani's (2010) study, in which the participants were instructed to tap the table at the appropriate time for both trials. Additionally, in the MIsT, participants can use a clock to monitor the time, while in Serrani's (2010) study, they could use a timer that was set to 0:00 at the beginning

of the experiment. Thus, the time-based PM tasks of the MIsT likely required more strategic processing than those in the prior longitudinal study of PM. Of course, baseline performance on the time-based and event-based PM trials of the MIsT may have also had an effect on the amount of decline observed during the course of the study. A Wilcoxon signed-rank test showed that participants performed better on the event-based compared to the time-based PM tasks the first time they completed the MIsT ($S = 3737.00$, $p < .001$). Therefore, one possible interpretation is that participants may have already experienced declines in time-based PM performance before enrolling in the study. For example, perhaps adults tend to experience declines in strategically demanding, time-based PM tasks during their middle-aged years and therefore were less likely to demonstrate declines by the time they enrolled in the study. Nevertheless, these results suggest that older adults tend to remain stable on highly strategic, time-based PM tasks over periods of approximately 2 to 5 years.

Overall, results of the present study combined with Serrani's (2010) study suggest that older adults may be more susceptible to age-related declines in relatively automatic PM tasks compared to those with higher strategic processing demands. The age-related PM declines seem to apply across the spectrum of PM tasks with automatic processing demands, including the event-based PM trials used by Serrani (2010), which are perhaps the most automatic tasks across these two studies, as well as the time-based PM trials of Serrani's study and the event-based PM scale of the MIsT. Taken together, these studies suggest that all except the most strategically demanding PM trials (e.g., the time-based PM trials of the MIsT) may decline over time in older age. This finding contrasts with prior cross-sectional research of PM, which found that the greatest age effects are found for more strategically demanding PM tasks (e.g., Kliegel et al., 2008). However, these findings may be consistent

with the recently proposed spontaneous retrieval deficit hypothesis (e.g., Niedźwieńska, Kvavilashvili, Ashaye, & Neckar, 2017). According to this theory, adults with amnestic MCI or mild Alzheimer's disease may actually demonstrate a greater deficit with spontaneous retrieval compared to more effortful, strategic retrieval relative to healthy control subjects. Several recent studies found support for this hypothesis, demonstrating that adults with amnestic MCI or Alzheimer's disease perform disproportionately poorly on focal compared to nonfocal PM tasks relative to healthy controls (Chi et al., 2014; McDaniel, Shelton, Breneiser, Moynan, & Balota, 2011; Niedźwieńska et al., 2017). The present study, which found longitudinal declines in the more automatic, event-based PM tasks, but not the more strategic, time-based PM tasks of the MIsT, may demonstrate a similar phenomenon. The older adults who experienced longitudinal declines in event-based PM may be demonstrating very early signs of a neurodegenerative process and may be more likely to progress to amnestic MCI over time, although none met criteria for MCI across this study. In order to test this hypothesis, future studies may consider following older adults over a longer period of time and administering carefully matched focal and nonfocal event-based PM tasks, such as those used by McDaniel et al. (2011). In this study, the focal PM cues were specific words that were presented in the ongoing task, while the nonfocal PM cues were syllables within those words (McDaniel et al., 2011). Implementing this paradigm in a longitudinal study of healthy older adults could help clarify the effects of aging on PM. Additionally, one may wish to examine the effects of Subjective Cognitive Impairment, a precursor to MCI, on automatic versus strategic PM.

Of course, attrition represents one limitation of longitudinal studies and may have biased our results. For example, it is plausible that participants who experienced declines in

PM may have had difficulty remembering to attend follow-up study appointments. This theory is supported by studies that have demonstrated an association between PM and healthcare adherence in a variety of populations (see Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012 for a review). To evaluate this possibility, two post-hoc regressions were conducted, with each of the MIsT PM scales (i.e., time-based and event-based) as baseline predictors of the total number of visits a participant completed, controlling for the year in which they were first tested. Both models were significant (ps < .001) and revealed that time-based MIsT PM significantly predicted the number of visits that a participant completed (β = 0.22, p < .001), while event-based MIsT PM did not (β = 0.09, p = .116). Specifically, higher baseline time-based PM scores were associated with a greater number of study visits completed (ρ = .19, p = .004). Additionally, since half of the participants who completed a baseline evaluation (n = 160, 51.3%) did not return for any follow-up visits, we compared those who were retained in the study versus those who were lost to follow-up. Wilcoxon rank-sum tests revealed that participants who only completed the baseline visit performed more poorly on the time-based PM tasks, $\chi^2(1) = 8.45$, p = .004, compared to those who returned for at least one follow-up visit; however, there were no differences in event-based PM performance, $\chi^2(1) = 1.29$, p = .256. Therefore, it is possible that participants from the baseline sample experienced time-based PM declines over the course of the study, but that they did not return for follow-up visits and thus created a possible type II error risk.

Although time-based PM performance did not change at the group level among participants who remained in the study, individual trajectories of change in various types of PM are still evident and important to understand. Our analyses revealed that baseline age was not associated with changes in laboratory PM performance over time. Similarly, although

higher cognitive reserve was associated with better time-based and event-based PM performance overall, cognitive reserve did not predict longitudinal PM declines. Cross-sectional research on the effect of cognitive reserve on PM has been mixed. Cherry & LeCompte (1999) tested younger and older adults of "low" and "high" ability levels, who differed in their educational attainment, occupational attainment, and vocabulary test performance. Results showed that low-ability older adults demonstrated worse event-based PM performance than low-ability younger adults, but there were no differences in PM performance between the older and younger high-ability groups (Cherry & LeCompte, 1999). This finding suggests that cognitive reserve may be protective against age-related declines in event-based PM; however, a similar study failed to replicate this effect (Reese & Cherry, 2002). The results of the current study provide further detail about demographic effects on age-related PM declines, suggesting that among nonclinical older adults, younger age and higher cognitive reserve may not necessarily be protective against PM declines. However, it is also possible that our analyses failed to reach significance because only small changes were observed in laboratory PM during the course of the study. Future research may help clarify whether cognitive reserve may slow individual declines in PM over time. In addition to cognitive reserve, studies of brain reserve (i.e., structural brain differences that may reduce the risk of cognitive decline; Katzman, 1993) would be useful in identifying older adults who are at increased risk of developing PM deficits.

Older adults' performances on event-based and time-based PM tasks were associated with a wide range of neurocognitive functions. Initial analyses revealed that baseline performance in all neurocognitive domains tested in the study (immediate memory, delayed memory, attention, language, visuospatial skills, executive functions) were associated with

both event-based and time-based PM performance. Follow-up analyses revealed that attention, language, and visuospatial skills were independent predictors of event-based PM, while attention was an independent predictor of time-based PM; however, executive functions no longer predicted event-based or time-based PM when controlling for the other neurocognitive domains. Baseline retrospective memory symptoms were also independently associated with event-based, but not time-based, PM. However, none of the neurocognitive variables predicted changes in event-based or time-based PM. Prior cross-sectional research has demonstrated associations of PM with retrospective memory and executive functions, as well as poorer PM performance in older versus younger adults (e.g., Kamat et al., 2014). From those studies, one might expect that performance in these domains would predict changes in PM over time; however, our results suggest that the neurocognitive functions associated with PM performance at a cross-sectional level may not necessarily be harbingers of age-related PM changes. Results of the present study also differ from the study conducted by Serrani (2010), which found that attention and working memory were independent predictors of PM decline over a period of 10 years. The follow-up time in the present study was much shorter, with participants remaining in the study an average of 1.7 years (range = 0–8.3). Thus, perhaps our study did not allow sufficient time to observe PM declines among those with poor performance on tasks of executive functions and retrospective memory.

Subsequent analyses of residualized change scores revealed that changes in event-based and time-based PM were associated with different neurocognitive functions. Consistent with expectations, changes in event-based PM performance were associated with changes in performance on tasks of immediate and delayed retrospective memory and attention, while changes in time-based PM tasks were associated with changes in measures of

executive functions. This finding further supports the idea that the event-based PM tasks in this study likely relied more strongly on automatic retrieval and attention processes, while the time-based PM tasks relied more on effortful, strategic processes. This information can be clinically useful and may suggest that older adults who demonstrate declining retrospective memory performance may also have difficulty executing intentions in response to specific events in their environments, while those who develop executive dysfunction may have problems completing intentions at the appropriate time. Notably, although changes in retrospective memory, attention, and executive functions were associated with changes in PM, baseline performance on these measures did not predict later PM declines. Thus, low performance in these domains may not necessarily put adults at risk of PM declines; however, changes in these domains in older age may signify individuals who are most likely to demonstrate similar declines in PM ability. Further longitudinal research that includes neuroimaging and more thorough assessments of retrospective memory and executive functions may be helpful in further examining the neuropsychological mechanisms responsible for age-related PM declines.

Contrary to expectations, changes in both event-based and time-based PM performance were also associated with changes on tests of language. Follow-up analyses of the RBANS language subtests revealed that changes in semantic fluency were associated with changes in both event-based ($\rho = .24$, $p = .006$) and time-based ($\rho = .18$, $p = .037$) laboratory PM, while changes in picture-naming were not associated with either event-based ($\rho = .08$, $p = .368$) or time-based ($\rho = .12$, $p = .152$) PM. These results suggest that the executive demands of the verbal fluency task were driving the association between the language domains of the RBANS and measures of performance-based PM. Specifically,

Troyer, Moscovitch, and Winocur (1997) found that clustering (i.e., generating words in specific subcategories) and switching (i.e., switching from one subcategory to another) were important components of semantic fluency, and that switching was related to frontal lobe functioning. One could imagine how similar processes might apply to PM tasks, in which participants are required to complete an ongoing task and switch back and forth to complete PM intentions in response to appropriate cues. Thus, this finding suggests that changes in generativity, and perhaps switching in particular, may be related to declines in PM performance in older adulthood.

Changes in ADLs and quality of life were not associated with changes in laboratory PM, even though these functional outcomes have been associated with PM in prior cross-sectional research with older adults (e.g., Woods et al., 2012; 2015). Self-reported ADL problems on the ADLQ were skewed, such that 36% of participants endorsed no ADL problems at the baseline visit. However, results did not differ if the ADLQ was scored as a dichotomous variable for those who reported 0 or ≥1 ADL problem(s). ADL scores were also generated by assigning a score of '0' to those questions that the participant marked as not applicable; however, results remained the same if the ADLQ was scored as the total score divided by the number of applicable questions. Since participants with worse time-based PM performance completed fewer study visits, these results suggest that among participants who remained in the study, any changes in PM performance may not have been large enough to substantially impact everyday life. A linear mixed model was conducted with baseline age and study time as fixed effects, a random intercept, and ADLQ designated as the outcome variable with a negative binomial distribution. Study time ($\beta = 0.07$, $SE = 0.02$, $p < .001$) and older age at baseline ($\beta = 0.04$, $SE = 0.01$, $p < .001$) were associated with more ADL

problems. Taken together, these results suggest that although older adults may experience more ADL problems with age, these changes may not be a direct result of poorer PM performance. A linear mixed model with baseline age and study time as fixed effects, a random intercept, and WHOQOL-8 as the outcome variable with a normal distribution did not show any significant effects of study time (β = 0.00, *SE* = 0.09, *p* = .987) or baseline age (β = 0.00, *SE* = 0.04, *p* = .901). Therefore, the lack of association between change in PM and quality of life may be due to the stability of the older adults' quality of life over time.

Performance on the naturalistic 24-hr PM task also remained stable over time and was not associated with any demographic, neurocognitive, or everyday functioning variables. Cross-sectional studies have demonstrated an "age-PM paradox," whereby older adults sometimes perform better on naturalistic tasks compared to their younger counterparts (e.g., Rendell & Thomson, 1999); however, this finding was not evident in the current longitudinal study. Overall, results suggest that older adults remain relatively stable in their naturalistic PM performance over periods of 1 to 5 years. Of course, the dichotomous scoring of the 24-hr task may not have provided enough variability to detect subtle naturalistic PM changes over the duration of the study. Moreover, the naturalistic task was only administered during some study evaluations, such that only 92 participants were asked to complete the task during two or more study visits. Further longitudinal research with a larger sample of participants and naturalistic measures that include multiple PM measures over a longer period of time (e.g., the Actual Week test; Au, Vandermorris, Rendell, Craik, & Troyer, 2018) would help clarify the trajectory of naturalistic PM among older adults.

Consistent with prior cross-sectional research with the PRMQ (e.g., Crawford et al., 2003; Smith et al., 2000), our initial analyses revealed that PM symptoms were not

associated with age. Interestingly, older adults also reported *decreasing* PM symptoms over the course of our study. Further analyses revealed that older adults with poor performance on language tests and more retrospective memory complaints at baseline were more likely to report fewer PM symptoms over time. These findings are counterintuitive and may be a result of type I error. However, another possible explanation is that participants with neurocognitive difficulties at the baseline evaluation may have become more accustomed to these deficits over time. There are several factors that may contribute to this adaptation to neurocognitive or emotional problems in older age. According to Baltes & Baltes's (1990) model, successful aging may be a result of (1) selection, in which older adults focus on the highest priority environments and activities; (2) optimization, which involves engaging in behaviors to strengthen one's abilities in the selected environment; and/or (3) compensation, which may include the use of external aids. Applying this model to our study, it is possible that older adults began selecting environments with lower PM demands, adjusted their behaviors in order to prioritize PM performance, or developed helpful strategies to manage everyday PM tasks. Of course, it is also possible that older adults simply became less worried about their problems over time. As is often found with self-report measures, PM symptoms were independently associated with affective distress. Thus, it is possible that these findings reflect declines in overall anxiety and depression rather than actual PM problems. Chi-square and Wilcoxon rank-sum tests revealed that participants who only completed the baseline visit had a higher prevalence of affective distress, $\chi^2(1) = 5.15$, $p = .023$, and more chronic medical conditions, $\chi^2(1) = 6.23$, $p = .013$, than those who returned for follow-up visits; however, they did not differ in terms of sex, age, or cognitive reserve (ps > .10). Thus, while the sample as a whole reported fewer PM symptoms over time, those with depression,

anxiety, and multiple medical conditions were less likely to return for follow-up evaluations. Therefore, the significant declines in PRMQ PM symptoms may be due to the attrition of participants with affective distress, rather than perceived improvements in PM ability.

Overall, this study represents the first longitudinal investigation of a variety of PM measures among older adults. Further research with a larger sample and a longer period of follow-up time may provide additional information about how various types of PM change with age. In the present study, the large age range of participants (50 to 90 years old) may have limited our ability to detect longitudinal changes in some measures of PM. Thus, future studies may wish to use an older sample (e.g., 65 years or older at baseline), in order to clarify how PM changes among older adults who are most vulnerable to neurocognitive decline. The present study also used correlations of change scores to investigate neurocognitive and functional variables that change alongside PM. Future studies may wish to use more statistically rigorous methods (e.g., latent growth analyses) in order to clarify the trajectories of PM and related neurocognitive functions over time. Finally, given that participants demonstrated significant declines in event-based laboratory PM performance, studies of intervention techniques and compensatory strategies would be an important next step. Nonetheless, results of this study further our understanding of the effects of aging on laboratory, naturalistic, and self-reported PM.

References

Au, A., Vandermorris, S., Rendell, P. G., Craik, F. I., & Troyer, A. K. (2018). Psychometric properties of the Actual Week test: a naturalistic prospective memory task. *The Clinical Neuropsychologist*, *32*(6), 1068–1083.

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences*. Cambridge: Cambridge University Press.

Benton, L. A., Hamsher, K. D., & Sivan, A. B. (1994). Controlled Oral Word Association Test. *Multilingual Aphasia Examination*. Iowa City, IA: AJA.

Cherry, K. E., & LeCompte, D. C. (1999). Age and individual differences influence prospective memory. *Psychology and Aging*, *14*(1), 60–76.

Chi, S. Y., Rabin, L. A., Aronov, A., Fogel, J., Kapoor, A., & Wang, C. (2014). Differential focal and nonfocal prospective memory accuracy in a demographically diverse group of nondemented community-dwelling older adults. *Journal of the International Neuropsychological Society*, *20*(10), 1015–1027.

Cona, G., Scarpazza, C., Sartori, G., Moscovitch, M., & Bisiacchi, P. S. (2015). Neural bases of prospective memory: A meta-analysis and the "Attention to Delayed Intention" (AtoDI) model. *Neuroscience & Biobehavioral Reviews*, *52*, 21–37.

Crawford, J., Smith, G., Maylor, E., Della Sala, S., & Logie, R. (2003). The Prospective and Retrospective Memory Questionnaire (PRMQ): Normative data and latent structure in a large non-clinical sample. *Memory*, *11*(3), 261–275.

d'Ydewalle, G., Bouckaert, D., & Brunfaut, E. (2001). Age-related differences and complexity of ongoing activities in time-and event-based prospective memory. *The American Journal of Psychology*, *114*(3), 411–423.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*(3), 189–198.

Golomb, J., Kluger, A., de Leon, M. J., Ferris, S. H., Convit, A., Mittelman, M. S., ... & George, A. E. (1994). Hippocampal formation size in normal human aging: A correlate of delayed secondary memory performance. *Learning & Memory*, *1*(1), 45–54.

Gordon, B. A., Shelton, J. T., Bugg, J. M., McDaniel, M. A., & Head, D. (2011). Structural correlates of prospective memory. *Neuropsychologia*, *49*(14), 3795–3800.

Gunning-Dixon, F. M., & Raz, N. (2003). Neuroanatomical correlates of selected executive functions in middle-aged and older adults: A prospective MRI study. *Neuropsychologia, 41*(14), 1929–1941.

Hennessy, M., & MacKenzie, B. D. (1995). AUSNART: The development of an Australian version of the NART. In: J. Fourez & N. Page (Eds.), *Treatment Issues and Long-term Outcomes: Proceedings of the 18th Annual Brain Impairment Conference*. Bowen Hills, QLD: Australian Academic Press.

Henry, J. D., MacLeod, M. S., Phillips, L. H., & Crawford, J. R. (2004). A meta-analytic review of prospective memory and aging. *Psychology and Aging, 19*(1), 27–39.

Jack, C. R., Petersen, R. C., Xu, Y. C., Waring, S. C., O'Brien, P. C., Tangalos, E. G., ... & Kokmen, E. (1997). Medial temporal atrophy on MRI in normal aging and very mild Alzheimer's disease. *Neurology*, *49*(3), 786–794.

Johnson, N., Barion, A., Rademaker, A., Rehkemper, G., & Weintraub, S. (2004). The Activities of Daily Living Questionnaire: A validation study in patients with dementia. *Alzheimer Disease & Associated Disorders*, *18*(4), 223–230.

Kamat, R., Weinborn, M., Kellogg, E. J., Bucks, R. S., Velnoweth, A., & Woods, S. P. (2014). Construct validity of the Memory for Intentions Screening Test (MIST) in healthy older adults. *Assessment*, *21*(6), 742–753.

Katzman, R. (1993). Education and the prevalence of dementia and Alzheimer's disease. *Neurology, 43*, 13–20.

Kliegel, M., Jäger, T., & Phillips, L. H. (2008). Adult age differences in event-based prospective memory: A meta-analysis on the role of focal versus nonfocal cues. *Psychology and Aging, 23*(1), 203–208.

Kliegel, M., Martin, M., McDaniel, M. A., & Einstein, G. O. (2002). Complex prospective memory and executive control of working memory: A process model. *Psychologische Beiträge, 44*(2), 303–318.

Korten, A. E., Henderson, A. S., Christensen, H., Jorm, A. F., Rodgers, B., Jacomb, P., & Mackinnon, A. J. (1997). A prospective study of cognitive function in the elderly. *Psychological Medicine*, *27*(4), 919–930.

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9. *Journal of General Internal Medicine*, *16*(9), 606–613.

Kvavilashvili, L., Kornbrot, D. E., Mash, V., Cockburn, J., & Milne, A. (2009). Differential effects of age on prospective and retrospective memory tasks in young, young-old, and old-old adults. *Memory*, *17*(2), 180–196.

Martin, M., Kliegel, M., & McDaniel, M. A. (2003). The involvement of executive functions in prospective memory performance of adults. *International Journal of Psychology, 38*(4), 195–206.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, *14*(7), S127–S144.

McDaniel, M. A., Glisky, E. L., Rubin, S. R., Guynn, M. J., & Routhieaux, B. C. (1999). Prospective memory: A neuropsychological study. *Neuropsychology*, *13*(1), 103–110.

McDaniel, M. A., Shelton, J. T., Breneiser, J. E., Moynan, S., & Balota, D. A. (2011). Focal and nonfocal prospective memory performance in very mild dementia: A signature decline. *Neuropsychology*, *25*(3), 387–296.

McFarland, C. P., & Glisky, E. L. (2009). Frontal lobe involvement in a task of time-based prospective memory. *Neuropsychologia*, *47*(7), 1660–1669.

Nelson, H. E., & Willison, J. (1991). *National Adult Reading Test (NART)*. Windsor: Nfer-Nelson.

Niedźwieńska, A., Kvavilashvili, L., Ashaye, K., & Neckar, J. (2017). Spontaneous retrieval deficits in amnestic mild cognitive impairment: A case of focal event-based prospective memory. *Neuropsychology*, *31*(7), 735.

Pachana, N. A., Byrne, G. J., Siddle, H., Koloski, N., Harley, E., & Arnold, E. (2007). Development and validation of the Geriatric Anxiety Inventory. *International Psychogeriatrics*, *19*(1), 103–114.

Power, M. (2003). Development of a common instrument for quality of life. In A. Nosikov & C. Gudex (Eds.), *EUROHIS: Developing common instruments for health surveys* (pp. 145–163). Amsterdam: IOS.

Randolph, C. (1998). *Repeatable Battery for the Assessment of Neuropsychological Status (RBANS).* San Antonio: Psychological Corporation.

Raskin, S., Buckheit, C., & Sherrod, C. (2010). *Memory for Intentions Test (MIsT).* Lutz, FL: Psychological Assessment Resources.

Raz, N., Gunning, F. M., Head, D., Dupuis, J. H., McQuain, J., Briggs, S. D., ... & Acker, J. D. (1997). Selective aging of the human cerebral cortex observed in vivo: Differential vulnerability of the prefrontal gray matter. *Cerebral Cortex*, *7*(3), 268–282.

Reese, C. M., & Cherry, K. E. (2002). The effects of age, ability, and memory monitoring on prospective memory task performance. *Aging, Neuropsychology, and Cognition*, *9*(2), 98–113.

Reitan, R. M., & Wolfson, D. (1985). *The Halstead-Reitan neuropsychological test battery: Theory and clinical interpretation (Vol. 4)*. Reitan Neuropsychology.

Rendell, P. G., & Thomson, D. M. (1999). Aging and prospective memory: Differences between naturalistic and laboratory tasks. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *54*(4), P256–P269.

Rönnlund, M., Nyberg, L., Bäckman, L., & Nilsson, L. G. (2005). Stability, growth, and decline in adult life span development of declarative memory: Cross-sectional and longitudinal data from a population-based study. *Psychology and Aging*, *20*(1), 3–18.

Rönnlund, M., Vestergren, P., Mäntylä, T., & Nilsson, L. G. (2011). Predictors of self-reported prospective and retrospective memory in a population-based sample of older adults. *The Journal of Genetic Psychology*, *172*(3), 266–284.

Royall, D. R., Cordes, J. A., & Polk, M. (1998). CLOX: An executive clock drawing task. *Journal of Neurology, Neurosurgery & Psychiatry*, *64*(5), 588–594.

Salthouse, T. A. (2009). When does age-related cognitive decline begin?. *Neurobiology of Aging*, *30*(4), 507–514.

Salthouse, T. A. (2010a). Influence of age on practice effects in longitudinal neurocognitive change. *Neuropsychology*, *24*(5), 563–572.

Salthouse, T. A. (2010b). Selective review of cognitive aging. *Journal of the International Neuropsychological Society*, *16*(5), 754–760.

Serrani, D. (2010). Memoria cotidiana en población de adultos mayores: Un estudio longitudinal de 10 años [Prospective memory in elderly population: A 10-year longitudinal study]. *Acta Colombiana de Psicología, 13*(2), 91–105.

Sheikh, J. I., & Yesavage, J. A., (1986). Geriatric Depression Scale (GDS): Recent evidence and development of a shorter version. *Clinical Gerontologist*, *5*(1/2), 165–173.

Smith, G., Della Sala, S., Logie, R. H., & Maylor, E. A. (2000). Prospective and retrospective memory in normal ageing and dementia: A questionnaire study. *Memory, 8*(5), 311–321.

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine, 166*(10), 1092–1097.

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*, *47*(10), 2015–2028.

Tam, J. W., & Schmitter-Edgecombe, M. (2013). Event-based prospective memory and everyday forgetting in healthy older adults and individuals with mild cognitive impairment. *Journal of Clinical and Experimental Neuropsychology*, *35*(3), 279–290.

Taylor, J. L., Miller, T. P., & Tinklenberg, J. R. (1992). Correlates of memory decline: A 4-year longitudinal study of older adults with memory complaints. *Psychology and Aging*, *7*(2), 185–193.

Tierney, S. M., Bucks, R. S., Weinborn, M., Hodgson, E., & Woods, S. P. (2016). Retrieval cue and delay interval influence the relationship between prospective memory and activities of daily living in older adults. *Journal of Clinical and Experimental Neuropsychology*, *38*(5), 572–584.

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. *Neuropsychology*, *11*(1), 138–146.

Uttl, B. (2008). Transparent meta-analysis of prospective memory and aging. *PLoS One, 3*(2), e1568.

Uttl, B. (2011). Transparent meta-analysis: Does aging spare prospective memory with focal vs. non-focal cues?. *PloS One*, *6*(2), e16618.

Uttl, B., Graf, P., Miller, J., & Tuokko, H. (2001). Pro- and retrospective memory in late adulthood. *Consciousness and Cognition*, *10*(4), 451–472.

Van Dijk, K. R., Van Gerven, P. W., Van Boxtel, M. P., Van der Elst, W., & Jolles, J. (2008). No protective effects of education during normal cognitive aging: Results from the 6-year follow-up of the Maastricht Aging Study. *Psychology and Aging*, *23*(1), 119–130.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin*, *120*(2), 272–292.

Woods, S. P., Moran, L. M., Dawson, M. S., Carey, C. L., Grant, I., & HIV Neurobehavioral Research Center (HNRC) Group. (2008). Psychometric characteristics of the Memory for Intentions Screening Test. *The Clinical Neuropsychologist*, *22*(5), 864–878.

Woods, S. P., Scott, J. C., Sires, D. A., Grant, I., Heaton, R. K., Tröster, A. I., & HIV Neurobehavioral Research Center (HNRC) Group. (2005). Action (verb) fluency: Test–retest reliability, normative standards, and construct validity. *Journal of the International Neuropsychological Society*, *11*(4), 408–415.

Woods, S. P., Weinborn, M., Li, Y. R., Hodgson, E., Ng, A. R., & Bucks, R. S. (2015). Does prospective memory influence quality of life in community-dwelling older adults?. *Aging, Neuropsychology, and Cognition*, *22*(6), 679–692.

Woods, S. P., Weinborn, M., Maxwell, B. R., Gummery, A., Mo, K., Ng, A. R., & Bucks, R. S. (2014). Event-based prospective memory is independently associated with self-report of medication management in older adults. *Aging & Mental Health*, *18*(6), 745–753.

Woods, S. P., Weinborn, M., Velnoweth, A., Rooney, A., & Bucks, R. S. (2012). Memory for intentions is uniquely associated with instrumental activities of daily living in healthy older adults. *Journal of the International Neuropsychological Society*, *18*, 134–138.

Zahodne, L. B., Glymour, M. M., Sparks, C., Bontempo, D., Dixon, R. A., MacDonald, S. W., & Manly, J. J. (2011). Education does not slow cognitive decline with aging: 12-year evidence from the Victoria Longitudinal Study. *Journal of the International Neuropsychological Society*, *17*(6), 1039–1046.

Zeintl, M., Kliegel, M., Rast, P., & Zimprich, D. (2006). Prospective memory complaints can be predicted by prospective memory performance in older adults. *Dementia and Geriatric Cognitive Disorders*, *22*(3), 209–215.

Zelinski, E. M., & Burnight, K. P. (1997). Sixteen-year longitudinal and time lag changes in memory and cognition in older adults. *Psychology and Aging*, *12*(3), 503–513.

Zogg, J. B., Woods, S. P., Sauceda, J. A., Wiebe, J. S., & Simoni, J. M. (2012). The role of prospective memory in medication adherence: A review of an emerging literature. *Journal of Behavioral Medicine*, *35*(1), 47–62.

Table 1

Characteristics of the Study Sample at the Baseline Visit

Variable	Baseline visit (N = 329)
Demographic and medical	
Age (years)	70.5 (7.5)
Education (years)	13.9 (3.2)
Sex (% women)	66.9
Elevated affective distress (%)	16.2
Number of chronic medical conditions	1.4 (1.4)
Neurocognitive	
Estimated premorbid IQ	108.5 (6.9)
RBANS Total Scale	102.1 (13.0)
List Learning	27.1 (5.1)
Story Memory	16.5 (3.9)
Figure Copy	16.0 (2.5)
Line Orientation	17.8 (2.2)
Picture Naming	9.5 (0.7)
Semantic Fluency	22.8 (5.6)
Digit Span	10.9 (2.4)
Coding	45.0 (9.2)
List Recall	6.0 (2.3)
List Recognition	19.3 (1.0)
Story Recall	8.6 (2.4)
Figure Recall	12.0 (3.9)
Executive functions	
Trail-Making Test part B (s)	82.0 (39.4)
Letter C fluency	16.1 (5.0)
Action (verb) fluency	18.1 (5.4)
CLOX executive index	1.6 (2.1)
PRMQ Retrospective Memory Scale	17.2 (4.2)
Everyday functioning	
Activities of Daily Living Questionnaire (ADLQ)	5.1 (5.6)
WHOQOL-8	33.4 (5.1)

Note. PRMQ = Prospective and Retrospective Memory Questionnaire; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; CLOX = executive clock-drawing task; WHOQOL-8 = World Health Organization Quality of Life 8-item questionnaire.

Table 2

Prospective Memory (PM) Measures: Baseline and Change Scores

	Baseline		Change		
Variable	*n*	Score	*n*	Study Time (years)	Score
Time-based MIsT PM	227	5.3 (1.4)	137	3.4 (1.8)	0.0 (1.4)
Event-based MIsT PM	227	6.8 (1.2)	137	3.4 (1.8)	0.0 (1.5)
MIsT 24-hr task (% called)	112	44.7	92	3.0 (1.8)	
Improve (%)					15.2
Stable (%)					56.5
Decline (%)					28.3
PRMQ PM Scale	316	18.9 (4.6)	153	3.6 (1.8)	0.0 (2.9)

Note. Change scores represent residualized change or %. MIsT = Memory for Intentions Test; PRMQ = Prospective and Retrospective Memory Questionnaire.

Table 3

Linear Mixed Models of Time-Based Prospective Memory on the Memory for Intentions Test (MIsT): Fixed-Effects Estimations

	Model 1			Model 2			Model 3		
Variable	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	**9.82**	**0.68**	**<.001**	**9.70**	**0.66**	**<.001**	**8.44**	**0.68**	**<.001**
Study time	–0.01	0.03	.680	–0.02	0.03	.411	–0.02	0.03	.564
Age	**–0.06**	**0.01**	**<.001**	**–0.06**	**0.01**	**<.001**	**–0.04**	**0.01**	**<.001**
Cognitive reserve				**0.33**	**0.08**	**<.001**			
Immediate memory							0.17	0.10	.102
Delayed memory							0.22	0.13	.107
Attention							**0.23**	**0.09**	**.017**
Language							0.01	0.11	.901
Visuospatial/constructional							0.10	0.09	.280
Executive functions							0.18	0.13	.163

Note. Bold text designates $p < .05$. Predictor variables (except study time) are from the baseline visit.

Table 4

Linear Mixed Models of Event-Based Prospective Memory on the Memory for Intentions Test (MIsT): Fixed-Effects Estimations

	Model 1			Model 2			Model 3		
Variable	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	–1.03	0.58	.075	–0.95	0.57	.097	–0.70	0.64	.270
Study time	**0.05**	**0.03**	**.047**	**0.06**	**0.03**	**.027**	**0.07**	**0.03**	**.009**
Age	0.01	0.01	.080	0.01	0.01	.107	0.00	0.01	.779
Cognitive reserve				**–0.14**	**0.07**	**.036**			
Immediate memory							–0.07	0.09	.453
Delayed memory							–0.07	0.11	.530
Attention							**–0.20**	**0.08**	**.015**
Language							**–0.21**	**0.09**	**.019**
Visuospatial/constructional							**–0.16**	**0.08**	**.043**
Executive functions							0.08	0.11	.466
PRMQ RM Scale							**0.03**	**0.01**	**.029**

Note. Bold text designates $p < .05$. Event-based MIsT scores are transformed such that lower scores reflect better performance. PRMQ = Prospective and Retrospective Memory Questionnaire; RM = retrospective memory. Predictor variables (except study time) are from the baseline visit.

Table 5

Linear Mixed Models of the 24-Hr Prospective Memory Task of the Memory for Intentions Test (MIsT): Fixed-Effects Estimations

	Model 1			Model 2		
Variable	β	*SE*	*p*	β	*SE*	*p*
Intercept	0.00	1.23	.997	–0.06	1.23	.958
Study time	–0.03	0.07	.683	–0.04	0.07	.548
Age	–0.01	0.02	.584	–0.01	0.02	.632
Female	0.51	0.28	.069	0.51	0.28	.068
Cognitive reserve				0.20	0.15	.194

Note. Predictor variables (except study time) are from the baseline visit.

Table 6

Linear Mixed Models of the Prospective Memory Scale of the Prospective and Retrospective Memory Questionnaire (PRMQ): Fixed-Effects Estimations

	Model 1			Model 2			Model 3		
Variable	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	**17.14**	**2.28**	**<.001**	**17.11**	**2.29**	**<.001**	**5.99**	**1.79**	**.001**
Study time	**–0.12**	**0.06**	**.049**	**–0.12**	**0.06**	**.048**	0.47	0.26	.066
Age	0.02	0.03	.559	0.02	0.03	.548	–0.01	0.02	.641
Affective distress	**2.04**	**0.41**	**<.001**	**2.04**	**0.41**	**<.001**	**1.21**	**0.36**	**.001**
Cognitive reserve				0.08	0.28	.773			
Language							0.32	0.27	.241
Language × study time							**0.24**	**0.09**	**.006**
PRMQ RM Scale							**0.78**	**0.04**	**<.001**
PRMQ RM Scale × study time							**–0.04**	**0.01**	**.008**

Note. Bold text designates $p < .05$. RM = retrospective memory. Predictor variables (except study time) are from the baseline visit.

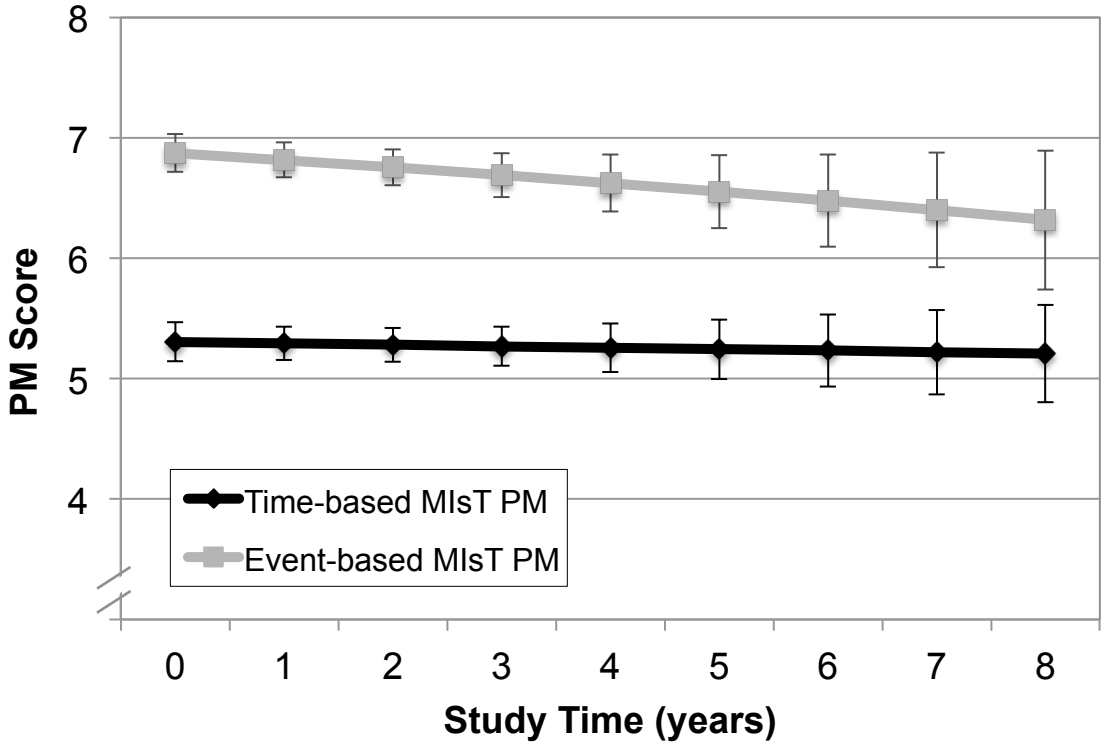

Figure 1. Predicted scores on the time-based and event-based prospective memory (PM) scales of the Memory for Intentions Test (MIsT) at time from the initial visit, controlling for baseline age. Error bars represent 95% confidence intervals.

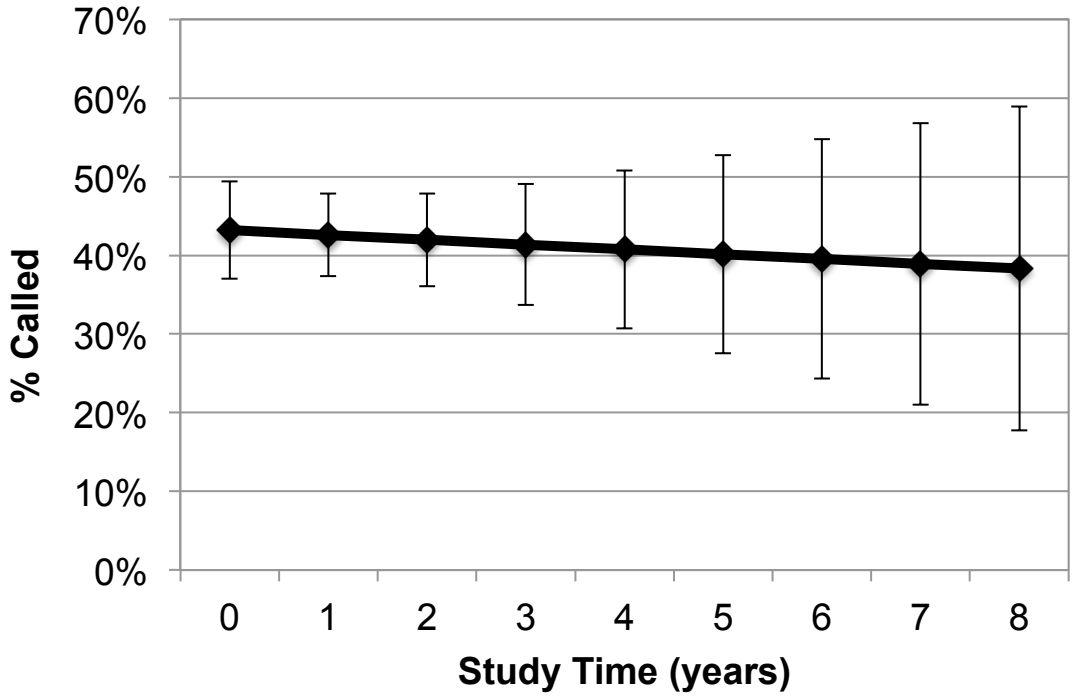

Figure 2. Predicted percentage of the sample who completed the 24-hr prospective memory phone call of the Memory for Intentions Test (MIsT) at time from the initial visit, controlling for baseline age. Error bars represent 95% confidence intervals.

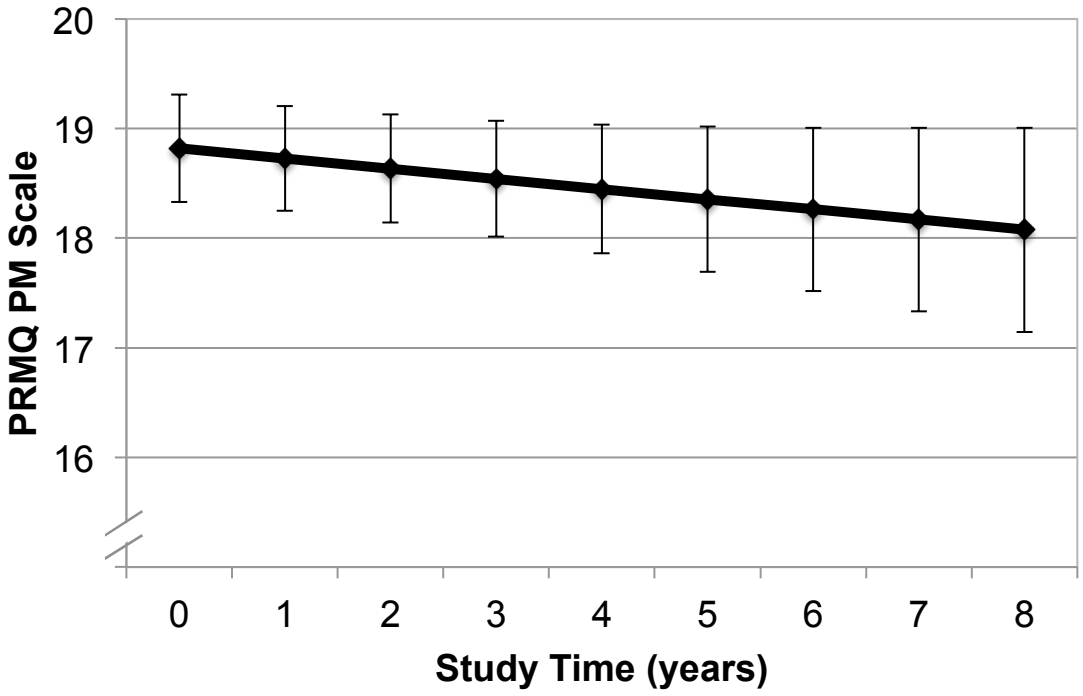

Figure 3. Predicted scores on the prospective memory (PM) scale of the Prospective and Retrospective Memory Questionnaire (PRMQ) at time from the initial visit, controlling for baseline age. Error bars represent 95% confidence intervals.