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Retrieval Cue and Delay Interval Influence the Relationship Between Prospective Memory and Activities of Daily Living in Older Adults

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Abstract

Objective—Older adults commonly experience mild declines in everyday functioning and the strategic aspects of prospective memory (PM). This study used Multiprocess Theory to examine whether the strategic demands of retrieval cue type (event- vs. time-based) and delay interval length (2- vs. 15-minute) influence the relationship between PM and activities of daily living (ADL) in older adults.

Method—Participants included 97 community-dwelling older adults recruited from the Western Australia Participant Pool. Participants were administered the Memory for Intentions Screening Test (MIST) and Prospective and Retrospective Memory Questionnaire (PRMQ) as part of a larger neurocognitive assessment. A knowledgeable informant completed the Activities of Daily Living Questionnaire (ADLQ), from which a cutpoint of 1 was used to classify participants into “ADL Normal” ($n = 37$) or “Mild ADL Problems” ($n = 60$) groups. Repeated-measures MANOVA controlling for age were conducted with ADL group as the between-subjects factor and either MIST or PRMQ cue and delay scores as the within-subjects factors.

Results—We observed a significant ADL Group by PM interaction on the MIST, with pair-wise analyses showing that the Mild ADL problems group performed worse than ADL normal participants on the 15-minute time-based scale ($p < .001$; Cohen’s $d = 0.71$). No other MIST or PRMQ cue-delay variable differed between the two ADL groups ($ps > .10$).

Conclusion—Findings indicate that decrements in strategically demanding cue monitoring and detection over longer PM delays may partly explain older adults’ mild problems in everyday functioning. Findings may inform neuropsychological interventions aimed at maintaining ADL independence and enhancing quality of life in older adults.

Keywords

prospective memory; activities of daily living; aging

Subtle declines in the independent management of activities of daily living (ADL) are common among healthy older adults (e.g., Tucker-Drob, 2011). Established risk factors for ADL problems among community-dwelling older adults include some demographics (e.g., age), depression, medical comorbidities, and certain psychosocial factors (e.g., social support, activity, and contacts) (e.g., Stuck et al., 1999). Lower neurocognitive capacity in domains such as episodic memory and executive functions is also a unique risk factor for concurrent instrumental ADL problems (IADL)(e.g., Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000) such as preparing meals, taking medication, and finance management, for example, as well as functional declines (e.g., Tucker-Drob, 2011) in older adults. This may not be surprising if we consider that successful completion of many IADLs often involve a systematic sequence of behaviors that engage cognitive abilities affected by aging. Even setting a table, for example, has executive, episodic memory, motor, and visuospatial components (Weintraub, Baratz, & Mesulam, 1982). Among these various neuropsychological processes, the strongest and most reliable cognitive predictors in older adults are deficits in executive functions (e.g., complex attention, verbal fluency, and planning) and episodic memory (e.g., Koehler et al., 2011).

Prospective memory (PM) may also play a critical role in the ADL functioning of older adults. PM describes the complex neurocognitive ability to carry out a planned action at a designated point in the future (McDaniel & Einstein, 2000), or “remembering to remember.” PM is essential for accomplishing a range of everyday tasks from simply remembering to return a telephone call, to important health-related behaviors, such as taking a prescribed medication. Older adults may be particularly susceptible to PM decline due to age-related changes of both the prefrontal cortex (e.g., Fortin, Godbout, & Braun, 2003), and the hippocampus (Haug & Eggers, 1991), which are neural systems that support PM (e.g., Burgess, Gonen-Yaacovi, & Volle, 2011). Indeed, the accurate execution of a future intention involves multiple phases that draw upon these neural systems: (1) forming an intention, (2) associating the intention with a retrieval cue (i.e., passage of time, *time-based PM*, or the occurrence of a specific event, *event-based PM*), (3) retaining this association over a delay interval during which monitoring may occur, (4) upon noticing the retrieval cue, disengaging from the ongoing task, (5) retrieving the appropriate intention, and (6) properly implementing the intention (see Kliegel, McDaniel & Einstein, 2008 for a review). The Multiprocess View, a leading theory of PM, proposes that the cognitive processes that facilitate PM across these stages will vary from automatic processes that rely on medial temporal lobe systems to highly strategic processes that rely on prefrontal systems (McDaniel & Einstein, 2000). A classic example of this distinction is whether the cue to retrieve the intention is based on the passage of time (i.e., a time-based cue) or the occurrence of an event (i.e., an event-based cue). According to the Multiprocess Process View, time-based PM tasks (e.g., taking a medication at 2 pm) are more strategically demanding than the event-based tasks (e.g., taking medication after you brush your teeth in the morning) (McDaniel & Einstein, 2007). In fact, Einstein et al., (1995) reported that older adults demonstrated poorer performance on laboratory-based tests of PM, particularly when the task requires increased strategic demands (e.g., self-initiated executive control of monitoring and cue detection) such as when the cue to perform an intended action is based on time (see also, Henry, MacLeod, Phillips, & Crawford, 2004).

Although the impact of PM on everyday functioning has been explored (e.g., Zogg, Woods, Saucedo, Wiebe, & Simoni, 2012), only a hand-full of studies have systematically investigated this important relationship in older adults. These few aging studies nevertheless provide strong evidence that poorer PM capacity and increased frequency of PM complaints are significantly associated with greater general ADL problems (e.g., Smits, Deeg, & Jonker, 1997) including medication management difficulties (e.g., McDonald-Miszczak, Neupert, & Gutman, 2009; Vedhara et al., 2004; Woods et al., 2014). Such associations between PM and ADL in aging appear to be independent of demographics, general medical burden, and other neurocognitive domains (Smits et al., 1997), including retrospective memory (Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012). Of arguably even greater clinical relevance, individuals with poorer PM and ADL problems may also experience lower health-related quality of life (Woods et al., 2015). Thus, it is important to gain a clear understanding of the cognitive architecture of the interplay between PM and ADL in order to identify potential targets for remediation and compensatory strategies to improve ADL function and quality of life in older adults.

In the context of Multiprocess Theory, consistent and generally comparable relationships have been reported between ADL and PM across both time and event based retrieval cues (e.g., Woods et al., 2008) with a few studies suggesting that PM tasks with higher strategic demands are more predictive of ADL functioning (Woods et al., 2014). The delay interval between the formation of the intention and presentation of the cue is an essential, yet relatively underexplored component of PM that varies in strategic versus automatic demands and may play an important role in the ADL functioning of older adults. The PM delay interval requires maintenance of the intention-cue pairing while simultaneously deciding when it is appropriate to disengage from ongoing activities to monitor for the cue (McDaniel, Guynn, Einstein, & Breneiser, 2004). According to the Multiprocess View, longer delay intervals impose increased demands on the executive processes that support cue detection and monitoring, which leads to poorer PM accuracy (Kliegel & Jager, 2006; Loft, Bowden, Ball, & Brewer, 2014; McBride, Beckner, & Abney, 2011; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997).

PM and delay interval has generally been studied using retrieve-execute (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000) tasks, in which the execution of an intended action is performed as soon as the prospective memory cue is encountered. Research following this paradigm shows that PM performance typically decreases (e.g., Brandimonte & Passolunghi, 1994; Loftus, 1971; Meier, Zimmerman, & Perrig, 2006) as the time between intention formation and initiation increases (cf., Einstein, Holland, McDaniel, & Guynn, 1992; Guynn, McDaniel, & Einstein, 1998; Nigro & Cicogna, 2000). Certainly the effects of delay interval may be exaggerated in aging adults, as older age is associated with moderate declines in strategically demanding PM (Henry et al., 2004). Studies of typically aging adults have found that longer delays between intention formation and retrieval cue are associated with disproportionately poorer PM across both time- and event-based tasks in the laboratory (Einstein et al., 2000; Kelly, Hertzog, Hayes & Smith, 2013; McBride, Coane, Drwal, & LaRose, 2013). Similar age-related effects are observed on delay-execute paradigms, in which the successfully retrieved intention is maintained in memory until there is another opportunity to complete it (e.g., Kliegel & Jager, 2006; McDaniel & Einstein,

2003). In the present study, we focus on the retrieve-execute approach because many daily activities involve maintaining an intention-cue pairing over long periods of time, (e.g., taking medication, preparing a meal and doing laundry) deficits in delayed PM may be particularly problematic for older adults.

Yet, we are aware of only one prior study that has examined PM delay interval in the context of instrumental ADL. In a sample of middle-aged persons infected with HIV, Poquette et al., (2013) reported that baseline deficits in long-delay time-based PM were independently predictive of medication non-adherence at one-month follow-up as measured by electronic monitoring. However, no study to our knowledge has directly investigated the association between PM delay interval and ADL in older adults. The current study sought to extend the literature by examining whether the strategic demands of retrieval cue type (event- vs. time-based) and delay interval length (2- vs. 15-minute) influence the relationship between PM and ADL in older adults. Consistent with Multiprocess Theory, it was hypothesized that the more strategically demanding levels of PM delay interval (i.e., longer delay vs. shorter delays) would be uniquely associated with ADL problems that may be especially pronounced for time-versus event-based cues.

Method

Participants

Study participants included 97 community-dwelling adults, aged 55 to 84 years, who were recruited from the Western Australian Participant Pool (RSB, director). Within this sample 17.5% of participants were aged 55–64 years, 57.7% fell between 65–74 years of age, and 24.7% were between 75–84 years old. Participants were excluded if they scored < 24 on the Mini Mental State Examination (MMSE; Folstein, S. Folstein, & McHugh, 1975). As the MMSE has been found to be insensitive to mild cognitive impairment (Mamikonian et al., 2009), the cognitive health of this older sample was confirmed using the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, Tierney, Mohr, & Chase, 1998). No participant had an RBANS Total Scale Score that fell greater than 1.5 SD below the published normative mean (NB. the RBANS was not used as an exclusion criterion, rather this analysis was simply a confirmation of the veracity of the MMSE exclusion). Participants were also excluded if they reported histories of neuromedical (e.g., seizure disorder, stroke, at least moderate traumatic brain injury) or severe psychiatric (e.g., psychosis) disorders that might affect cognition. Participants' basic demographic, medical, mood, and neurocognitive characteristics are summarized in Table 1.

The human research ethics office of the University of Western Australia approved this study. All participants provided written, informed consent and were offered \$15 in reimbursement of their travel expenses.

Activities of Daily Living

The primary criterion of interest was the Activities of Daily Living Questionnaire (ADLQ; Johnson, Barion, Bademaker, Rehkemper, & Weintraub, 2004), which was completed by a knowledgeable informant (see Table 1 for details on informants). This 28-item questionnaire

assesses a range of ADL using a 4-level rating scale to indicate the severity of dependence. The items on the ADLQ are grouped into six subscales: Self-care activities (e.g., “Dressing”, range 0 “*no problem*” – 3 “*needs help with dressing*”), Household care (e.g., “Laundry”, range 0 “*does laundry as usual*” – 3 “*no longer does laundry*”), Employment and recreation (e.g., “Employment”, range 0 “*continues to work as usual*” – 3 “*no longer works*”), Shopping and Money (e.g., “Handling cash”, range 0 “*no problem*” – 3 “*no longer handles money*”), Travel (e.g., “Driving”, range 0 “*drives as usual*” – 3 “*no longer drives*”), and Communication (e.g., “Writing”, range 0 “*same as usual*” – 3 “*never writes*”). Note that, the ADLQ provides response options that accommodate participants for whom a given ADL domain is not relevant. For example, on the Employment and Recreation item, if the individual no longer works, and their no longer maintaining employment is not reflective of decline in ability, then they may select the option that reads, “Never worked OR retired before illness OR Don’t Know.” For the purpose of this study, items endorsed in that way received a score of zero.

A cutoff of 1 reported problem(s) on any item was used to classify participants into “ADL Normal” or “Mild ADL Problems” groups. Using this cutpoint, 37 (38%) of participants were classified as ADL Normal and 60 (62%) were classified with Mild ADL Problems. Table 1 shows that these 2 groups were comparable on informant characteristics, most demographic factors and the standard clinical battery of neurocognitive measures (all p s > .10). The Mild ADL Problems group was marginally older ($p = 0.080$, Cohen’s $d = 0.39$), reported a slightly higher number of current medical conditions ($p = 0.053$, Cohen’s $d = 0.38$), and endorsed significantly greater levels of negative affect ($p = 0.019$, Cohen’s $d = 0.26$) as compared to the ADL Normal sample.

Prospective Memory Measures

MIST administration—Prospective memory was assessed using the research version of the Memory for Intentions Screening Test (MIST; Raskin, Buckheit, & Sherrod, 2010). The MIST is a standardized, performance-based measure with reasonable internal reliability (e.g., Woods, et al., 2008) and evidence of construct validity in aging (e.g., Kamat et al., 2014). This 30-minute test consists of 8 PM trials that are completed in the context of an ongoing standardized word search task. The word search is administered at the beginning of the PM test and participants continue to work on the word search until the end of the last trial. The 8 PM trials are presented and executed at pre-determined times while the participant is engaged in the word search. Thus, at any one time participants may have between 1 and 5 cue-intention pairings that are actively prescribed and always non-focal to the ongoing task. The PM trials of the MIST are balanced on cue (i.e., time-based [e.g., “In 15 minutes, tell me it is time to take a break”] and event-based [e.g., “When I show you the red pen, sign your name on your paper”]), delay (i.e., 2-min and 15-min delays in between prescription and execution of the intention), and response modalities (i.e., action versus verbal intentions). Following the last PM trial, participants completed a free recall task in which they were asked to recount, without prompts, as many tasks that they could recall that were included in the MIST trials. Participants were instructed to provide as much detail as possible for all of the tasks, including what they were asked to do (referring to the response) and when then were asked to do it (referring to either the time based or event based cue).

Participants were provided with this example at the time of testing: “For example, if one of the items was write the word “Happy” on your paper in 10 minutes, you would tell me both ‘write the word happy’, AND ‘after 10 minutes’.” Finally, participants were administered an 8-item, 3-choice recognition post-test, which we coded in alignment with the cue-delay scales described above.

MIST scoring—To test the hypotheses posed in this study we used 4 MIST cue-delay dependent variables of interest: (1) 2-min time-based PM; (2) 15-min time-based PM; (3) 2-min event-based PM; (4) 15-min event-based PM. Responses for each MIST trial were coded from 0–2, such that the 4 delay-cue subscale scores ranged from 0–4, with higher scores reflecting better performance. Individual trials that are completely correct are scored as 2 points, while omission errors receive 0 points. Trials in which the participant is missing either the correct time, *or* failed to perform the correct intention were awarded 1 point. We also derived the following error types for each of the 4 cue-delay subscales: 1) no response (i.e., omission errors), 2) task substitution (e.g., perseverations or intrusions), 3) loss of content (e.g., acknowledging that a response is required, but failing to recall the particulars), and 4) loss of time (i.e., performing the correct response at the wrong time). Sample scores on the ongoing word search ranged from 6–36; one point is awarded for each correct word located. The Free Recall task was scored similar to the individual trials (range 0–16). Participants were awarded 2 points if they recalled both the correct cue and the correct response, and 0 points if they were unable to recount the events of a trial. Trials in which the participant failed to accurately recount either the correct cue, *or* correct intention were awarded 1 point. Scores on the item recognition task ranged from 0–8; one point was awarded for each correct response.

Prospective and retrospective memory questionnaire—PM symptoms in daily life were assessed with the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie, & Maylor, 2000). The PRMQ is a 16-item, self-report scale assessing the frequency of everyday PM (e.g., forgetting appointments if not reminded by someone else) and retrospective memory (e.g., forgetting something you were told a few minutes before) failures. Items are rated on a 5-point Likert-type scale ranging from 1 (never) to 5 (very often) and are summed to derive separate 8-item PM and RM scales. Here we focus on the short- and long-delay subscales, each of which is comprised of 4 PM items balanced on retrieval cue type, 2 time –based and 2 event-based cues. Accordingly the questions reflect 4 types of PM failures in daily life: (1) short-term self-cued; (2) long-term self-cued; (3) short-term environmentally-cued; (4) long-term environmentally-cued. Responses were coded from 0–4 for each item, such that the 4 delay-cue subscale scores ranged from 0–8, representative of increased everyday PM complaints.

Neuropsychological Assessment and Composite Scores

Participants completed a neurocognitive test battery that included the MMSE and the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, Tierney, Mohr, & Chase, 1998) as measures of global functioning. As part of this battery participants were administered three measures of executive functions: (1) Executive Clock-Drawing Task (CLOX; Royall, Cores, & Polk, 1998); (2) Backwards Digit Span from the

WAIS-III (Wechsler, 1997) and (3) Trailmaking Test (Part B – Part A) (Army Individual Test Battery, 1944; Reitan & Wolfson, 1985). Finally participants completed 3 measures of verbal fluency: (1) Letter C; (2) Actions (Piatt, Fields, Paolo, & Troster, 1999); and (3) Animal-Musical Instruments Switching from the Delis-Kaplan Executive Function Battery (DKEFS; Delis & Kaplan, 2001). In an effort to limit Type I error, we constructed executive functions and verbal fluency composite scores for analysis by converting raw test performance scores into sample-based z-scores ($N=97$), which were averaged within each neurocognitive domain. For all domains, higher scores indicate better neurocognitive performance. Findings did not differ if individual test scores were used rather than domain-based composites.

Negative affect composite—Participants completed the 9-item Patient Health Questionnaire (Kroenke, Spitzer, & Williams, 2001) and the Generalized Anxiety Disorder Scale (Spitzer, Kroenke, Williams, & Lowe, 2006). Consistent with our approach to summarizing the neurocognitive domains, raw scores from the PHQ-9 and the GAD-7 were converted to sample-based z-scores ($N = 97$) and averaged to create a negative affect composite for use in analyses. Higher scores reflect greater levels of negative affect. As with the neurocognitive composites, findings did not differ interpretively if individual scales were used rather than the negative affect composite.

Data Analysis

To investigate the primary study hypotheses, two separate repeated measures multivariate analysis of variance (MANOVA) were conducted in which ADL group (Normal vs. Mild Problem) was entered as the between-subject factor and either the MIST or PRMQ cue-delay scores were entered as within-subjects variables. Age was entered as a covariate in this model, as this variable differed by ADL group status at a critical alpha of .10 and was significantly associated with PM in the entire sample ($p < .05$). We did not include current medical conditions or the negative affect composite as covariates in these models because they were not significantly associated with PM outcomes ($ps > .10$). Independent-samples t-tests with Cohen's d effect size estimates were used for planned follow-up pairwise comparisons of the MIST and PRMQ scales between the two ADL groups. Of note, Shapiro-Wilk tests of normality revealed that the data collected in MIST and PRMQ variables were non-normally distributed ($ps < .05$). Since ANOVA is considered robust against normality violations and there is no non-parametric equivalent to a mixed-model (Schmider, Ziegler, Danay, Beyer, & Bühner, 2010; Vasey & Thayer, 1987), the current approach was deemed suitable. Moreover, the independent effects of the MIST and PRMQ scales on the continuous ADL outcome ($p < .05$) were confirmed in a series of logistic regression analyses that included the same covariates used in the MANOVAs. Note that, results did not differ meaningfully if we used a Wilcoxon signed-rank test instead of t-tests for the pairwise comparisons. All analyses were conducted using the JMP 11.2.0 statistical program and the critical alpha was set at .05.

Results

As shown in Table 2, the MIST model revealed no significant main effects of either ADL group or MIST cue-delay factors ($ps > .10$). Nevertheless, there was a significant ADL

Group by MIST cue-delay factor interaction ($p < .01$). Post-hoc analyses showed that the Mild ADL Problems group performed worse than ADL Normal participants on the 15-minute time-based scale of the MIST ($p < .001$; Cohen's $d = 0.71$), which is displayed in Figure 1. No other MIST variable differed between the two ADL groups ($ps > .10$). To investigate the possibility that episodic retrospective memory deficits may better explain these findings, we performed analyses using the Immediate (List Learning and Story Memory) and Delayed Memory (List Recall, List Recognition, Story Memory, and Figure Recall) indexes of the RBANS. As shown in Table 1 the ADL groups did not differ on the RBANS Immediate ($p > .10$; Cohen's $d = 0.19$) and/or Delayed Memory indexes ($p > .10$; Cohen's $d = 0.22$). Further, including those RBANS learning and memory variables as covariates in the primary statistical model looking at the association between PM and ADLs did not change the significance or pattern of the results detailed above. Moreover, an identical pattern of results was found when using the executive composite (and individual executive measures) instead of – or in addition to – the RBANS learning and memory scores.

ADL domain-specific analyses indicated that the household-care subscale related most strongly to the 15-minute time-based scale of the MIST ($p < .01$; Cohen's $d = 0.54$). There was a marginal association of the 15-minute time-based scale of the MIST with ADLQ transportation subscale ($p = .057$; Cohen's $d = 0.40$), however, no associations with any other ADL subscale were observed (all $ps > .10$).

In an effort to better understand the specific types of PM failures driving the association between the 15-min time-based PM scale and ADL problems, we conducted a series of planned post-hoc analyses for between-group differences in errors, ongoing task performance, recognition and free recall scores. Results are displayed in Table 2. Findings revealed that the Mild ADL Problem group committed significantly more omission errors than the ADL Normal group ($p = .004$, $d = .60$). There were no significant differences between groups on the 3 other error types (i.e., loss of time, loss of content, task substitutions), recognition, free recall, or performance on the ongoing word search (all $ps > .10$). In an effort to confirm that these findings were not an artifact of the non-normal distribution of the MIST's error variables, we also generated binomial error scores based on the presence of 1 or more errors on either of the 15min time-based trials. Four separate chi-square analyses were conducted to examine the association between each error type and the ADL group. Results revealed a significant difference ($p = .01$) in the proportion of PM errors made (omission errors) between ADL groups, such that the ADL problem group was approximately 3 times (odds ratio = 3.09; CI 95% (1.27, 7.48)) more likely to commit an error of omission compared to the ADL normal group. There were no significant differences between ADL groups in the proportion of errors ($ps > .10$) made across the remaining three error types (loss of content, loss of time, task substitution). Thus, the pattern of results for the categorical error scores was the same as reported for the continuous error scores.

Results of a separate MANOVA examining the PRMQ revealed no significant main effects of either ADL group or PRMQ cue-delay scales ($ps > .10$). There was also no significant interaction between ADL group and PRMQ scale in this model ($p > .10$). No covariates reached the level of statistical significance ($ps > .10$). Relevant model statistics are displayed in Table 3.

Discussion

While there is increasing evidence to support the importance of PM to everyday functioning in older adults, the specific architecture of PM that underwrites this relationship remains unclear. The present study used Multiprocess Theory to examine the influence of both PM retrieval cue (i.e., time-vs. event-based) and delay interval length on ADL problems in 97 community-dwelling older adults. Consistent with our expectations, results revealed differential associations between strategic versus automatic PM and ADL. That is, individuals in the Mild ADL problem group demonstrated poorer performance than ADL normal participants on the 15-minute delay time-based scale of the MIST; however, there were no significant differences between groups on the relatively more automatic MIST scales that included event-based cues or shorter delay intervals. The association of long-delay, time-based PM with ADL status was of a medium-to-large magnitude and independent of demographics, general medical status, and other neurocognitive domains (e.g., retrospective memory and various executive functions) that were either comparable across the study groups or covaried in the statistical models. These findings are consistent with prior reports that PM capacity uniquely predicts ADL disability in older adults (e.g., Smits et al., 1997) and extends that research by providing insight into the specific components (i.e. retrieval cue type and time interval delay) of PM that contribute to ADL function.

In the context of Multiprocess Theory, these data suggest that the mild problems with ADL may be partly attributable to deficits in the strategic aspects of PM as longer-delay time-based PM tasks place increased demands on strategic monitoring and cue detection. At the level of error analysis, the Mild ADL problem group demonstrated elevated rates of omission errors (i.e., no response to cue), but not loss of content (i.e., successful cue detection, but failure of retrospective memory), loss of time (early or late, but accurate response to cue) or task substitutions (i.e., successful cue detection but with an intrusive or perseverative response) errors. Moreover, there was no ADL group effect on scores from the ongoing word search task or in the post-test recognition. This pattern of findings suggests that the poorer long-delay time-based PM performance of the ADL Problem group was not an artifact of an encoding deficit or simply forgetting the PM task between initial intention formation and cue presentation. Instead, these data support the idea that the mild ADL problems observed in older adults may be a function of diminished resources for strategic online cue-detection and monitoring of time-based cues over moderately long intervals. We considered that an episodic memory component may have contributed to the pattern of deficits observed on the longer PM tasks, however, results of our secondary analyses of RBANS subscales and MIST error types data support our interpretation that the observed PM findings are not an artifact of retrospective memory. Further, previous studies (Doyle et al., 2013; Morgan, Weber, Rooney, Grant, & Woods, 2012; Raskin et al., 2011; Weinborn, Woods, Nulsen, & Park, 2011) using these same PM tasks have demonstrated that long-delay time-based PM is more strongly related to executive dysfunction than retrospective memory in clinical samples. Taken together, we are confident that the interpretation of our primary findings regarding PM cue and delay are not better explained by simple failures in retrospective memory.

Another novel contribution of this study to the extant literature is the exploration of ADL domains that might specifically rely upon PM in older community-dwelling adults. Our post-hoc analyses indicated that the long-delay time-based PM scale was most strongly related to ADL domain of household-care, a finding that was accompanied by a medium effect size. The ADLQ household-care domain includes the following tasks: preparing meals, setting the table, housekeeping, home maintenance, home repairs, and laundry. Successful completion of household ADL such as these often involves a systematic sequence of cognitively demanding behaviors that involve monitoring time-based cues over moderately long delays. For example, doing the laundry involves longer points of intermission between formation of the intention and the time at which the action is planned (e.g., remembering to transfer the load from the washer to the dryer), during which time other cognitive resource demanding activities may be ongoing (e.g., washing dishes). By way of comparison, more basic ADL such as bathing and dressing, tend to involve sequences of more immediate, habitual consecutive behaviors and thus do not show strong associations with PM. As earlier mentioned, Einstein et al., (2000) emphasized the difference between retrieve- and delay-execute PM tasks; future studies may benefit from use of the delay-execute paradigm in investigations of ADL as it may better reflect the PM demands of everyday life. Additionally, future studies may wish to examine other higher-level ADL domains commonly affected in older adults including medication management and unemployment (Poquette et al., 2013), healthcare appointment attendance (Jacks et al., 2015), and automobile driving (e.g. Ott et al., 2013).

The null association between self-reported PM symptoms (as measured by the short- and long-delay PRMQ scales) and informant-reported ADL problems contrasts with prior studies showing strong and independent associations between these constructs (e.g., Woods et al., 2012). One possible explanation for this finding is that older adults lack accuracy in their self-report of PM symptoms, perhaps due to limited awareness, impaired retrospective recall, or negative affect. Indeed many investigators have called into question the construct validity of self-report PM measures (e.g., Uttl & Kibreab, 2011). However, this explanation cannot account for the strong and positive findings observed previously in studies of older adults. Another possibility is that older adults are able to compensate for PM capacity deficits (as measured in the laboratory) in their daily lives (as measured by the PRMQ) and thus do not experience PM failures that threaten ADL (e.g., Rendell & Thomson, 1999) though again this interpretation does not neatly align with the prior literature. A final explanation might be that prior studies used self-report measures of both PM and ADL, which could have inflated the associations due to shared-method variance. Thus it is possible that informant reports of daily PM measures would have mapped on better to informant reports of ADL used in this study.

The current study is not without its limitations. While informant report is a reliable and valid indicator of manifest ADL functions (e.g., Miller, Brown, Mitchell, & Williamson, 2013), our independent variable was nevertheless comprised of a single informant report questionnaire. Use of a multimodal ADL assessment approach that includes self-report, informant-report, and performance-based measures may provide a more comprehensive measurement of the inherent complexity of everyday functioning in future studies (see Blackstone et al, 2012). Additionally, the current study employed a cross-sectional design,

which limits our ability to determine whether PM is a harbinger of ADL decline or tracks in concert with subtle ADL changes that can accompany aging. Longitudinal studies are necessary to better understand the inter-individual patterns of PM changes and associated consequences for various aspects of everyday functioning (e.g., Tucker-Drob, 2011). As recent findings suggest that PM decline may be an early indicator of incident neurocognitive disorders (e.g., Sheppard et al., in press), these data warrant further investigation of potentially moderating effects of compensatory strategies to maintain independence and enhance daily functioning in older adults.

It can also be argued that the fixed time-delay intervals (2- and 15-min) within this clinical measure pose a threat to the internal validity of the current study. As a well-validated, standardized clinical measure of PM, the MIST lacks the item content randomization and order counter-balancing rigor that could be afforded by an experimental paradigm. Furthermore, while the 2- and 15-minute delays map well onto some daily activities (e.g., household chores), other important ADLs and health behaviors (e.g., attending a medical appointment) have longer delay intervals for which the cognitive architecture of monitoring may greatly differ for older adults (Kvavilashvil, Cockburn, & Hornbrot, 2013). Indeed, the so-called “aging-PM paradox” (Rendell & Thomson, 1999) suggests that while age-related deficits in strategic PM are quite prominent in the laboratory, older adults actually perform many naturalistic PM tasks better than their younger counterparts (e.g., Kamat et al., 2014). This may be attributable to a variety of factors, including generational differences in motivation, structured lifestyles, which may require less engagement of cognitive resources, and use of compensatory strategies.

There are a few important psychometric considerations relevant to the interpretation of this study’s findings. First, the delay-cue subscales of the MIST were comprised of only two items each, which may limit the internal consistency of these measures. This is a common challenge in PM task development, in which having sufficiently lengthy delay intervals in between the cue formation and execution is critical, but simultaneously places limits on the number of repetitions that are logistically feasible in a laboratory setting. Nevertheless, the subscale findings from this study are consistent with results of prior work in HIV disease (e.g., Morgan, Weber, Rooney, Grant, & Woods, 2012) and substance abuse (Weinborn et al., 2011) populations, thus suggesting some reliability in the performance of these subscales across different disease populations. A second psychometric limitation has to do with ceiling effects on the MIST, which may have dampened our ability to detect ADL differences on the short-delay scales. As noted by Raskin et al., (2011), the MIST was designed to err toward ceiling effects among healthy adults rather than introducing floor effects in clinical populations. Nevertheless, posthoc analyses of the current data showed that the proportion of individuals earning a perfect score (i.e., 4) on the 4 PM subscales did not significantly differ between the ADL groups ($p > .10$). Finally it is possible that the low frequency of problems on some ADL subscales (e.g., self-care) may have created floor effects that masked potential relationships with PM. This is a common challenge in research on aging, as most community-dwelling older individuals are quite capable of daily activities, especially basic functions such as dressing and bathing. The extent to which PM failures influence more basic ADL functions may be more effectively examined in clinical populations for whom such problems are more prevalent and severe (e.g., dementia).

With an increasing prevalence of older adults, maintaining functional independence throughout late adulthood has emerged as an important issue of relevance to neuropsychological research and practice. The current study highlights the complexity of PM capacity and mild problems in the independent management of ADL in community-dwelling older adults, which could have notable downstream effects on quality of life (Woods et al., 2015). Recent studies have investigated different theory-driven approaches designed to improve PM function; for example, Insel et al., (2013) used a multifaceted PM intervention informed by Multiprocess Theory to improve medication adherence by reducing reliance on strategic monitoring and cue detection. By reinterpreting a strategically demanding long-delay time-based PM task as an event-based task, retrieval is accomplished through associative, autonomic processes that are spared with age, rather than through self-initiated processes that rely on prefrontal systems that are vulnerable to age-related decline. Additionally, future studies may wish to examine the relationship of other cognitive constructs as they relate to PM and ADLs. For example, goal maintenance, a cognitive construct supported by the prefrontal cortex (PFC) (Paxton, Brach, Racine, & Braver, 2008) exhibits some conceptual overlap with PM; in fact, goal maintenance has shown to diminish with longer delays in older adults (Braver, Satpute, Keys, Racine, & Barch, 2005). Given the parallels of PM and goal maintenance, future studies may wish to examine the relationships between goal maintenance, PM and ADLs among aging populations. It is also important that development of future PM-based remediation strategies consider this complex construct in its multiphasic form. To that end, Fish et al., (2015) described a compelling study in which they used errorless learning to facilitate the encoding component of PM, which supports strategic processing by strengthening the cue-intention pairing to enhance cue detection and recall after a delay. Ultimately, multimodal approaches that target multiple phases of PM with both cognitive and behavioral strategies may be most effective in minimizing the influence of strategic PM failures on ADL in older adults.

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Figure 1.

Scores on 2- and 15 - minute performance-based prospective memory (PM) trials by retrieval cue type on the Memory for Intentions Screening Test across levels of activities of daily living (ADL) functioning in 97 older community-dwelling adults. Error bars reflect standard error.

*** $p = .001$; Cohen's $d = 0.71$.

Figure 2.

Short- and long-delay prospective memory (PM) symptoms grouped by retrieval cue type (Environmental and Self) across levels of activities of daily living (ADL) functioning in 97 community-dwelling older adults. PRMQ = Prospective and Retrospective Memory Questionnaire.

Table 1

General Descriptive Data for the Overall Study Sample and Subgroups With and Without Mild Problems with Activities of Daily Living (ADL).

Variable	Total sample (N = 97)	ADL normal (n = 37)	Mild ADL problems (n = 60)
<i>Activities of Daily Living</i>			
Informant Characteristics			
Spouse (%)	79.2%	75.7 %	81.4%
Hours/wk spent with participant	96.2 (53.0)	91.1 (55.9)	99.4 (51.4)
Years known participant	40.1 (14.3)	39.6 (12.6)	40.3 (15.4)
ADLQ Total Score (of 100)	4.5 (5.9)	0 (0)	7.2 (6.1)
Self care	1.8 (4.4)	0 (0)	2.9 (5.3)
Household care	7.3 (10.4)	0 (0)	11.9 (11.0)
Employment and recreation	7.6 (14.4)	0 (0)	12.4 (16.6)
Shopping	2.5 (6.1)	0 (0)	4.1 (7.4)
Travel	4.3 (9.1)	0 (0)	6.9 (10.8)
Communication	3.0 (7.4)	0 (0)	4.8 (8.9)
<i>Biopsychosocial Variables</i>			
Age (years) [†]	69.6 (6.4)	68.1 (5.5)	70.5 (6.8)
Education (years)	14.3 (3.1)	14.1 (3.2)	14.5 (3.1)
Gender (% male)	39.2%	29.7%	45%
Chronic medical conditions [†]	1.4 (1.4)	1.1 (1.2)	1.6 (1.4)
PHQ-9 ^{**} (of 15)	2.0 (3.0)	1.3 (2.8)	2.4 (3.0)
GAD-7 (of 16)	1.7 (3.0)	1.5 (3.1)	1.8 (2.9)
<i>Neurocognitive Variables</i>			
MMSE total score (of 30)	28.6 (1.3)	28.7 (1.4)	28.6 (1.3)
RBANS total score	103.9 (11.8)	105.9 (12.6)	102.7 (11.2)
<i>Executive composite</i>			
Digit backwards (Longest Span)	4.6 (1.2)	4.8 (1.4)	4.5 (1.1)
TMT part B – part A (sec)	39.5 (24.5)	37.9 (25.7)	40.5 (23.9)
Executive Clock Drawing Task	1.3 (2.1)	1.4 (2.5)	1.2 (1.9)
<i>Verbal fluency composite</i>			
Category Switching [†]	15.0 (3.9)	16.7 (4.4)	15.9 (3.5)
Letter (C)	17.2 (5.0)	17.2 (5.0)	17.2 (5.1)
Actions	19.4 (5.2)	20.1 (6.2)	19.0 (4.6)

Notes. Values are means (SD) except as noted. ADLQ = Activities of Daily Life Questionnaire. PHQ-9 = Patient Health Questionnaire-9. GAD-7 = Generalized Anxiety Disorder Assessment-7. MMSE = Mini Mental State Examination. RBANS = Repeatable Battery for the Assessment of Neuropsychological Status. TMT = Trailmaking Test.

[†] $p < .10$.

^{**} $p < 0.001$.

Table 2

Ongoing Task Performance, Recognition, and Error Types on 15-min Time-Based (TB) trials of the MIST in Subgroups With and Without Mild Problems with Activities of Daily Living.

15-min TB PM	ADL Normal (n=37)	Mild ADL Problem (n=60)	<i>p</i>	Cohen's <i>d</i>
Error Type				
Omission **	0.3 (0.5)	0.7 (0.8)	.004	0.60
Loss of Time	0.1 (0.3)	0.1 (0.2)	.142	0
Task Substitution	0.3 (0.6)	0.2 (0.4)	.140	0.20
Loss of Content	0.7 (0.7)	0.8 (0.7)	.313	0.14
Recognition	1.5 (0.6)	1.4 (0.7)	.236	0.15
Ongoing Word Search	13.7 (5.8)	13.5 (4.2)	.842	0.04

Notes: Data represents means (SD). MIST = Memory for Intentions Screening Test. PM= Prospective Memory.

**
p < .01.

Table 3

Repeated Measures MANOVA Results for Prospective Memory (PM) and Activities of Daily Living (ADL) in 97 Older Community Dwelling Adults.

Variable	<i>df</i>	F	<i>p</i>	<i>n</i> ²
MIST				
PM	3	1.1	.347	.035
ADL	1	0.9	.333	.010
PM x ADL **	3	4.3	.007	.123
Covariates				
Age *	1	4.0	.049	.041
PRMQ				
PM	3	0.9	.440	.029
ADL	1	1.2	.286	.012
PM x ADL	3	0.7	.579	.021
Covariates				
Age	1	1.3	.259	.014

Notes. MIST = Memory for Intentions Screening Test. ADL= Activities of Daily Living Questionnaire. PRMQ= Prospective and Retrospective Memory Questionnaire.

**
p < .01.

*
p < .05.