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Prospective memory on a novel clinical task in older adults with mild cognitive impairment and subjective cognitive decline

Laura A. Rabin^{1,2,3}, Susan Y. Chi¹, Cuiling Wang^{2,4}, Joshua Fogel⁵, Sarah J. Kann³, and Avner Aronov³

¹Department of Psychology, Brooklyn College, Queens College, and The Graduate Center of The City University of New York, USA

²Department of Neurology, Albert Einstein College of Medicine, New York, USA

³Department of Psychology, Brooklyn College of The City University of New York, New York, USA

⁴Department of Epidemiology and Population Health, Albert Einstein College of Medicine, New York, USA

⁵Department of Finance and Business Management, Brooklyn College of The City University of New York, New York, USA

Abstract

Despite the relevance of prospective memory to everyday functioning and the ability to live independently, prospective memory tasks are rarely incorporated into clinical evaluations of older adults. We investigated the validity and clinical utility of a recently developed measure, the Royal Prince Alfred Prospective Memory Test (RPA-ProMem), in a demographically diverse, non-demented, community-dwelling sample of 257 older adults (mean age = 80.78 years, 67.7% female) with amnesic mild cognitive impairment (aMCI, $n = 18$), non-amnesic mild cognitive impairment (naMCI, $n = 38$), subjective cognitive decline (SCD, $n = 83$) despite intact performance on traditional episodic memory tests, and healthy controls (HC, $n = 118$). Those with aMCI and naMCI performed significantly worse than controls on the RPA-ProMem and its subtasks (time-based, event-based, short-term, long-term). Also, those with SCD scored significantly lower than controls on long-term, more naturalistic subtasks. Additional results supported the validity and inter-rater reliability of the RPA-ProMem and demonstrated a relation between test scores and informant reports of real-world functioning. The RPA-ProMem may help detect subtle cognitive changes manifested by individuals in the earliest stages of dementia, which may be difficult to capture with traditional episodic memory tests. Also, assessment of prospective memory can help guide the development of cognitive interventions for older adults at risk for dementia.

Keywords

Prospective memory; Mild cognitive impairment; Subjective cognitive decline; Everyday memory; Cognitive rehabilitation

INTRODUCTION

Prospective memory (PM), or the ability to remember to perform previously planned actions at specific times (time-based PM) or after certain events occur (event-based PM) (Einstein & McDaniel, 1990; McDaniel & Einstein, 2011), is of importance for older adults' maintenance of independent and successful living. Tasks such as remembering to take medication at the prescribed time, keep a doctor's appointment, turn off the stove, and wish a loved one a happy birthday all depend upon PM (Sinnott, 1989; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012; Zogg, Woods, Saucedo, Wiebe, & Simoni, 2012). Various cognitive abilities, including episodic memory, working memory, attention, and executive functions, are required to support the retrospective and/or prospective components of PM tasks (Einstein & McDaniel, 1990). The retrospective component (remembering *that* and *what* to do) is more dependent upon episodic memory abilities to recall the content of the intention as well as the original intention-cue association (Groot, Wilson, Evans, & Watson, 2002; Karantzoulis, Troyer, & Rich, 2009; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999). The prospective component (realising *when* to do something and initiating the correct action), relies upon executive functions and internal control mechanisms to monitor the passage of time, shift from an ongoing activity to execution of a delayed intention, and inhibit the ongoing task. As there is a high level of cognitive demand required for PM functioning (e.g., Henry, MacLeod, Phillips, & Crawford, 2004), it is not surprising that individuals with mild cognitive impairment (MCI), often considered to represent a borderline condition between healthy cognitive ageing and dementia (Petersen et al., 1999, 2001; Winblad et al., 2004), score lower on PM tasks than elderly controls (van den Berg, Kant, & Postma, 2012).

To our knowledge, there are 14 published empirical investigations of PM in MCI (Blanco-Campal, Coen, Lawlor, Walsh, & Burke, 2009; Costa et al., 2010; Costa, Perri, et al., 2011; Delprado et al., 2012; Delprado, Kinsella, Ong, & Pike, 2013; Karantzoulis et al., 2009; Kazui et al., 2005; Pino, Poletti, & Caffarra, 2013; Schmitter-Edgecombe, Woo, & Greeley, 2009; Tam & Schmitter-Edgecombe, 2013; Thompson, Henry, Rendell, Withall, & Brodaty, 2010; Thompson, Henry, Withall, Rendell, & Brodaty, 2011; Troyer & Murphy, 2007; Wang, Guo, Zhao, & Hong, 2012), two comprehensive review articles (Costa, Caltagirone, & Carlesimo, 2011; van den Berg et al., 2012), and a number of studies of PM in "mild" or "preclinical" dementia (Jones, Livner, & Backman, 2006; Will et al., 2009). This literature is heterogeneous with regard to type of PM tasks used, recruitment strategies, and diagnostic criteria implemented for MCI, leading to inconsistency in findings. Nonetheless, almost all studies find that individuals with MCI perform significantly worse than older adult controls on clinical, experimental, and naturalistic PM tasks (Blanco-Campal et al., 2009; Costa et al., 2010; Costa, Perri, et al., 2011; Delprado et al., 2012, 2013; Karantzoulis et al., 2009; Tam & Schmitter-Edgecombe, 2013; Troyer & Murphy, 2007; Thompson et al., 2010;

Schmitter-Edgecombe et al., 2009; Wang et al., 2012). In addition, while failure of a retrospective task component may impact PM performance, a failure of the prospective task component also impacts performance (i.e., individuals with MCI may fail to activate a prospective intention even when memory of the intention is preserved) (Costa, Carlesimo, & Caltagirone, 2012; Costa, Caltagirone, et al., 2011; Costa, Perri, et al., 2011; Pino et al., 2013; Schmitter-Edgecombe et al., 2009; Thompson et al., 2010). Some studies show greater deficit on time-based as compared to event-based PM tasks for cognitively healthy elderly subjects (Delprado et al., 2012) or those with MCI (Costa et al., 2010; Delprado et al., 2012; Troyer & Murphy, 2007). However, these findings are inconsistent and performance differences may simply be related to differences in task difficulty as opposed to differences in cue type (Delprado et al., 2012; Henry et al., 2004; Thompson et al., 2010; van den Berg et al., 2012). The limited research investigating PM by amnesic or non-amnesic MCI subtype (Petersen, 2004) generally does not support meaningful differences in PM performance by neuropsychological profile (Schmitter-Edgecombe et al., 2009; Thompson et al., 2010), although one study found that individuals with dysexecutive MCI were more impaired than aMCI in retrieving the prospective intention on a time-based task (Costa et al., 2010). Finally, there is some support for the idea that PM tasks add discriminative power in the detection of MCI or very mild dementia beyond that of traditional episodic memory tasks (Blanco-Campal et al., 2009; Duchek, Balota, & Cortese, 2006; Jones et al., 2006), in part because they tax additional cognitive abilities such as executive control processes (Huppert & Beardsall, 1993).

Despite attention to PM in MCI, to our knowledge no research investigates PM in older adults with intact neuropsychological functioning but with significant cognitive complaints. Subjective cognitive decline (SCD) in otherwise apparently cognitively healthy older adults is associated with an increased likelihood of biomarker abnormalities consistent with AD pathology (Amariglio et al., 2012; Mosconi et al., 2008; Saykin et al., 2006; Scheef et al., 2012; Visser et al., 2009) and risk of future cognitive decline (Dufouil, Fuhrer, & Alperovitch, 2005; Jessen et al., 2010, 2014b; Reisberg, Shulman, Torossian, Leng, & Zhu, 2010; van Oijen, de Jong, Hofman, Koudstaal, & Breteler, 2007). SCD may indicate a pre-MCI condition during which neurodegenerative changes do not produce overt memory dysfunction on formal testing but result in memory lapses that are mild or intermittently present, leading to a subjective feeling of decline. Thus, SCD may provide an earlier diagnostic opportunity than MCI.

Also, despite the relevance of PM to older adults' everyday functioning and the potential for PM tasks to detect the earliest signs of pathological cognitive decline (Blanco-Campal et al., 2009; Huppert & Beardsall, 1993), PM tasks are rarely incorporated into neuropsychological test batteries (Rabin, Barr, & Burton, 2005). Possible reasons for the infrequent assessment of PM include a lack of knowledge by neuropsychologists about the PM construct, insufficient standardisation or evidence of psychometric soundness of available PM tasks, and the perceived relative ease of administration and interpretation of traditional episodic memory tasks (Burgess, 2012; Woods et al., 2008). In addition, while scores on PM tasks are positively correlated with scores on tests of retrospective memory, executive functioning, attention, and working memory (Costa et al., 2010; Delprado et al., 2012; Schmitter-Edgecombe et al., 2009; Thompson et al., 2010; Troyer & Murphy, 2007; van den

Berg et al., 2012), these scores also correlate with scores on tests of other cognitive abilities such as fluid intelligence, general cognitive ability, and perceptual speed (Huppert, Johnson, & Nickson, 2000; Salthouse, Berish, & Siedlecki, 2004). It is challenging to isolate the cognitive processes involved in PM, which suggests that PM is a “nonspecific” construct (Carlesimo & Costa, 2011).

There are several objective clinical measures of PM including the Memory for Intentions Screening Test (MIST; Raskin, 2009; Raskin, Buckheit, & Sherrod, 2010), subtests of the Rivermead Behavioural Memory Test (Wilson, Cockburn, & Baddeley, 2003), the Six Elements Task from the Behavioural Assessment of the Dysexecutive Syndrome (Wilson, Alderman, Burgess, Emslie, & Evans, 1996), the Cambridge Prospective Memory Task (Wilson et al., 2005), Virtual Week (Rendell & Craik, 2000), and the Royal Prince Alfred Prospective Memory Test (RPA-ProMem; Radford, Lah, Say, & Miller, 2011). The RPA-ProMem is the most recent clinical PM task, and it attempts to improve upon limitations associated with some earlier instruments by including both short- and long-term time- and event-based tasks. It has three parallel test forms, permits the use of strategies to facilitate remembering, does not require “filler” tasks such as word puzzles that cost valuable time during an evaluation, and has an administration time of less than 10 minutes. Further, the RPA-ProMem differentiates among healthy controls and neurological patients and correlates with both patient and informant report of everyday memory ability (Radford et al., 2011). To our knowledge, the RPA-ProMem has not yet been validated in an older adult population.

Our primary goal is to evaluate the validity and clinical utility of the RPA-ProMem in a demographically diverse sample of community-dwelling, non-demented older adults. First, consistent with previous PM research, we hypothesise that RPA-ProMem scores will be significantly lower for aMCI participants than healthy controls. Second, consistent with some prior research suggesting that aMCI and naMCI are equally impaired on PM tasks (Schmitter-Edgecombe et al., 2009), and because PM tasks generally rely upon executive functioning in addition to retrospective memory abilities, we hypothesise that RPA-ProMem scores will be significantly lower for naMCI participants than healthy controls. Third, because PM failure may be a sensitive neuropsychological marker of incident dementia (Blanco-Campal et al., 2009; Huppert & Beardsall, 1993), we hypothesise that RPA-ProMem scores will be significantly lower for SCD participants than for healthy older adult controls despite SCD participants’ intact functioning on traditional episodic memory tests. Fourth, based on its design features, we hypothesise that the RPA-ProMem will have strong psychometric properties including: (a) a significant correlation with an existing, validated clinical PM task (i.e., the MIST), to provide evidence of convergent validity; (b) strong inter-rater reliability (as the RPA-ProMem is an objective task with clearly defined scoring criteria); (c) significant correlations with scores on self- and informant-report questionnaires about PM functioning and functional activities (given the RPA-ProMem’s proposed relevance to everyday PM ability); and (d) correlations with neuropsychological test scores across cognitive domains (in light of previous research suggesting that PM is a “non-specific” cognitive construct).

METHODS

Participants and procedure

Participants were a subset of individuals ($n = 257$) recruited from the Einstein Aging Study (EAS), a community-based longitudinal study of ageing individuals aged 70 and older residing in the Bronx, NY (Katz et al., 2012; Lipton et al., 2003). Potential participants were recruited through systematic sampling from Medicare or voter registration lists for Bronx County. Exclusion criteria for the EAS included severe audiovisual disturbances or medical or psychiatric conditions that interfered with the ability to complete study assessments, non-English speaking, being institutionalised, and nonambulatory status. For the current study we also excluded EAS participants with a diagnosis of dementia. We obtained ethical approval to conduct the study and provided informed consent according to procedures approved by the Institutional Committee for the Protection of Human Subjects. Participants were assessed on two occasions, separated by approximately two weeks, as they presented for their annual EAS visit. During the first visit (i.e., Day 1), participants completed neuropsychological measures (described below), a neurological examination, and physical measures (see Katz et al., 2012). During the second visit (i.e., Day 2), participants completed the PM tests and self-report questionnaires described below. Informant questionnaires were either sent home with participants on the day of the assessment or mailed to informants. Informants were instructed to return the completed questionnaires using a pre-paid envelope addressed to the principal investigator. A telephone number was provided in case informants had questions about questionnaire items or the study itself. Participants were transported to and from the testing facility via car service, provided with lunch, and compensated \$25.

Mean age of participants was 80.78 years ($SD = 5.53$), mean years of education was 14.45 ($SD = 3.41$), 67.7% of participants were female, 60.0% identified as white, 30.4% identified as African American, 5.4% as Hispanic white, 1.5% as Hispanic black, 0.4% as Asian, and 2.3% identified as “other”. For the current study, race/ethnicity was dichotomised as white/non-white. For those with informant report data, 32.3% identified as participants’ spouses or romantic partners, 40.9% identified as participants’ sons or daughters, and 26.8% identified as friends or relatives.

Participants were designated as healthy controls (HC, $n = 118$), subjective cognitive decline (SCD, $n = 83$), or mild cognitive impairment (MCI, $n = 56$) using a novel psychometric approach to classification (Rabin, Wang, Katz, & Lipton, 2014). First, to determine the presence or absence of neuropsychological deficits we conducted a principal components analysis among robust norms (i.e., only included participants without dementia for 3 years and did not include the participants in the current study). Thirteen neuropsychological tests, administered on Day 1, were utilised: (1) verbal episodic memory/word learning – free recall from the Free and Cued Selective Reminding Test (FCSRT; Buschke, 1984); (2) verbal episodic memory/story recall – Logical Memory I subtest of the Wechsler Memory Scale – Revised (WMS-R; Wechsler, 1987); (3) verbal fluency/word generation according to an initial letter – Letter Fluency (Spreen & Strauss, 1998); (4) verbal fluency/naming exemplars from a category – Category Fluency (Rosen, 1980); (5) confrontation naming – short form of the Boston Naming Test (BNT, Kaplan, Goodglass, & Weintraub, 1983); (6–

7) visuomotor tracking, divided attention, and cognitive flexibility – Trail Making Test Parts A and B (Reitan 1958); and select subtests of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997) including (8) visuospatial organisation – Block Design; (9) psychomotor processing speed – Digit Symbol-Coding; (10) auditory attention and working memory – Digit Span; (11) general fund of knowledge – Information; (12) vocabulary level – Vocabulary; and (13) verbal abstraction of categories – Similarities. Confirmatory factor analysis was then performed and yielded three underlying factors: *memory* (FCSRT, Category Fluency, Logical Memory), *executive/processing speed* (Block Design, Digit Symbol-Coding, and Trail Making Test Parts A & B), and *global/verbal* (Boston Naming, Information, Similarities, Vocabulary, Digit Span, and Letter Fluency). Cognitive domain scores were calculated for participants in the current study as the average of the Z-scores of each test in the domain, using means and standard deviations from the robust sample (described above) stratified by age group of age 70–79 and 80 and above (subsequently referred to as the memory factor Z-score, executive/processing speed factor Z-score, and global/verbal factor Z-score).

MCI was classified in participants whose cognitive domain scores fell considerably lower ($> 1 SD$) than the mean of the robust sample on one or more cognitive factors and who also had a cognitive complaint on either the Cognitive Impairment Questionnaire of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD; Heyman, Fillenbaum, & Nash, 1997), a yes/no rating scale of current functioning across several cognitive domains, or on the cognitive item from the short form of the Geriatric Depression Scale (GDS), a depressive symptom scale of 15 yes/no items (Sheikh & Yesavage, 1986). MCI was further subdivided into mutually exclusive subtypes of: the amnesic subtype (aMCI, $n = 18$) in participants whose cognitive domain scores were $> 1 SD$ below the mean of the robust sample on the memory domain only or the memory domain and one or more of the other domains; and the nonamnesic subtype (naMCI, $n = 38$) for participants whose cognitive domain scores were $> 1 SD$ below the mean of the robust sample on the executive and/or global domains. More specifically, average cognitive factor Z-scores for the aMCI group were: memory factor Z-score mean = -1.48 ($SD = 0.44$), executive/processing speed factor Z-score mean = -0.10 ($SD = 1.13$), and global/verbal factor Z-score mean = -0.68 ($SD = 1.18$). Average cognitive factor Z-scores for the naMCI group were: Memory Factor Z-score mean = -0.15 ($SD = 0.49$), Executive Factor Z-score mean = 0.31 ($SD = 0.93$), and Global/Verbal Factor Z-score mean = -1.34 ($SD = 0.55$).

SCD was classified in cognitively intact participants, i.e., cognitive domain scores for all three domains did not fall considerably lower ($> 1 SD$) than the mean of the robust sample, but participants exceeded an optimal cut off point for self- and/or informant-complaints. We utilised cognitive complaints items with known reliability and predictive validity for dementia (Rabin et al., 2012) to derive scores that were the proportion of positive responses. Subsequently, we derived an optimal cut off point from a receiver operating characteristic (ROC) analysis, stratified by young-old (age 70–79) and old-old (age 80 and above) groups, which used the robust sample and was based on the cross-sectional association between the self- or informant-complaint and MCI. The cut-off point was the value that maximised the Youden index (Youden, 1950), or equivalently, maximised the sum of sensitivity and

specificity. The optimal cut-off for self-complaint score was 12.5% for the younger group and 22.2% for the older group. The optimal cut-off for the informant-complaint score was 21.0% for the younger group and 10.0% for the older group. Of participants classified as SCD, 56.6% ($n = 47$) had self-report complaints that exceeded the optimal cut-off score, 18.1% ($n = 15$) had informant complaints that exceeded the optimal cut-off score, and 25.3% ($n = 21$) had both self and informant complaints that exceeded the optimal cut-off score. Average cognitive factor Z-scores for the SCD group were: memory factor Z-score mean = 0.70 ($SD = 1.01$), executive/processing speed factor Z-score mean = 0.90 ($SD = 0.83$), and global/verbal factor Z-score mean = 0.55 ($SD = 0.75$).

HC was classified in cognitively intact participants (i.e., cognitive domain scores for all three domains did not fall considerably lower than the mean of the robust sample) who also did not exceed the optimal cut-off point for self and/or informant complaints. Average cognitive factor Z-scores for the HC group were: Memory Factor Z-score mean = 0.76 ($SD = 0.90$), Executive Factor Z-score mean = 0.77 ($SD = 0.73$), and Global/Verbal Factor Z-score mean = 0.52 ($SD = 0.74$).

Prospective memory tests and self- and informant-report questionnaires

The Royal Prince Alfred Prospective Memory Test (RPA-ProMem; Radford et al., 2011) consists of two time-based and two event-based PM tasks administered over the course of a neuropsychological test battery with one set of time- and event-based tasks completed in the laboratory and another set completed in a naturalistic setting. A digital clock is placed within view, and participants are instructed that they are going to be asked to “remember to do some things at a later stage of the assessment” and that they can use “any techniques” to help them remember. For the first and second tasks, conducted in the laboratory, the examiner states: “In 15 minutes time, I would like you to remind me to move my car so I don’t get a ticket” (Task 1) and “When my cell phone rings, tell me you would like a drink” (Task 2). Instructions for the third and fourth tasks, which are executed outside the laboratory, are given towards the end of the testing session: “When you arrive home today, I want you to phone and leave a message on my voice mail, telling me what time it is” (Task 3) and “Return this postcard to me on [date is set one week from testing date] with your name and a description of what you are having for dinner that night” (Task 4). Immediately after instructions for Tasks 3 and 4, participants receive the examiner’s phone number on a business card and a stamped, addressed, and labelled postcard. The RPA-ProMem includes three alternate forms and only Version 3 was used in the current study.

Scores for each of the four parts of the RPA-ProMem range from 0 to 3. Subscale scores for the event-based (Parts 2 and 3), time-based (Parts 1 and 4), short-term (Parts 1 and 2), and long-term (Parts 3 and 4) tasks range from 0 to 6, and total scores range from 0 to 12. Scoring criteria for parts 1 and 2 are: a score of 3 indicates a correct response at the correct time (i.e., a 2–5 minute delay or 2–5 minutes ahead of time); a score of 2 indicates either a correct response at an incorrect time (i.e., 2–5 minutes delay or ahead of time) or incorrect response at a slightly incorrect time (up to 2 minutes delay or ahead of time); a score of 1 indicates a correct score but at a delay of greater than 5 minutes or 5 minutes ahead of time; a score of 0 indicates either no response or an incorrect response at an incorrect time (greater

than 2 minutes delay or ahead of time). Scoring for part 3: a score of 3 indicates a phone call at the correct time within a two hour window period with a correct message; a score of 2 indicates either a call at the correct time with an incorrect message or a call at the incorrect time with a correct message; a score of 1 indicates a call at the incorrect time with an incorrect message; a score of 0 indicates no call made up to two days after test administration. Scoring for part 4: a score of 3 indicates a postcard sent on the correct day with the correct information; a score of 2 indicates either a postcard sent on an incorrect day with correct information or a postcard sent on the correct day with the incorrect information; a score of 1 indicates a postcard sent on the incorrect day with the incorrect information; a score of 0 indicates no postcard sent up to 2 weeks after test administration.

A single rater scored all of the RPA-ProMem test protocols. The rater had access to the complete protocols, which included responses recorded verbatim by the study examiners at the time of the assessment, along with precise timing of responses and a hard copy of the postcards returned by mail by participants. A second rater, also with access to the complete protocols, independently rescored the protocols. Basic psychometric properties for the RPA-ProMem are reported in Radford et al. (2011) for individuals aged 18–64 that included 20 healthy volunteers and 20 neurological patients (e.g., with history of stroke, epilepsy, tumour/cyst, traumatic brain injury). Inter-rater reliability was strong (intraclass correlation coefficient = .90), alternate form reliability was satisfactory ($\rho = .71$), and the RPA-ProMem demonstrated sensitivity to PM deficits in the neurological patients with informant reported everyday memory problems (Radford et al., 2011).

The Memory for Future Intentions Test (MIST; Raskin, 2004, 2009) consists of eight PM tasks (four time-based and four event-based tasks with delay intervals of either 2 minutes or 15 minutes). There is also one out-of-the-laboratory task that is optional and was not administered. The time-based tasks include instructions such as, “In 15 minutes tell me it’s time to take a break,” while the event-based tasks include instructions such as, “When I show you a red pen, sign your name on the paper.” Between administrations of tasks, participants are instructed to complete a word search puzzle (i.e., distractor task). Tasks are scored as follows: 0 indicates no response or an incorrect response; 1 indicates a correct response at the incorrect time or an incorrect response at the correct time; and 2 indicates a correct response at the correct time or upon appearance of an event. MIST total scores range from 0 to 48. There are two alternate forms but only Form A was used in the current study. The MIST has been validated extensively in healthy and clinical populations (Raskin, 2009; Woods et al., 2008).

The Comprehensive Assessment of Prospective Memory, Section B (CAPMB) is a subjective measure of PM that includes both self-report (CAPMB) and informant-report (CAPMBI) versions (Chau, Lee, Fleming, Roche, & Shum, 2007). The CAPMB includes 39 items related to PM failures within the broad categories of instrumental activities of daily living (IADL) such as “forgetting to buy an item at the grocery store,” “forgetting to take tablets at the prescribed time,” and basic activities of daily living, such as “not locking the door when leaving home,” or “accidentally forgetting to brush your teeth.” Items are rated on a scale of 1–5, with 1 indicating that the test-taker has “no problem at all” and 5 indicating that the test-taker has a “very serious problem” with the PM failure. There is also

a “not applicable” option utilised when a participant “has not had to do the task,” and such responses are excluded from CAPMB scores. Notably, CAPMB instructions request that respondents try to answer as many questions as possible without using the “not applicable” option. Average scores are calculated based on responses to all items (i.e., CAPMB total and CAPMBI total) and range from 1 to 5.

The Functional Activities Questionnaire (FAQ; Pfeffer, Kurosaki, Harrah, Chance, & Filos, 1982) is a commonly used IADL scale with utility for distinguishing between healthy older adults and those with dementia and between individuals with MCI and mild AD (Castilla-Rilo et al., 2007; Teng et al., 2010). The FAQ was completed by informants who rated participants’ current ability on 10 categories of IADLs (e.g., writing cheques, paying bills, keeping financial records, shopping alone). Performance in each category was rated as: 0 indicating normal performance or never did the activity but could now; 1 indicating has difficulty, but does by self or could do by self; 2 indicating requires assistance; or 3 indicating dependence. FAQ total scores range from 0 to 30, with higher scores reflecting greater impairment.

Statistical analysis

Descriptive statistics of mean and standard deviation were used for the continuous variables, and frequency and percentage were used for the categorical variables. The Pearson chi-square test was used to compare the categorical variables. Inferential statistics used as appropriate either analysis of variance (ANOVA) to compare the normally distributed continuous variables or the Kruskal-Wallis test to compare the continuous variables with skewed distributions (i.e., GDS). Post hoc comparisons used the Bonferroni correction for the ANOVA analyses and the Mann-Whitney test for the Kruskal-Wallis test analyses. For the between group comparisons on objective measures of memory, both ANOVA and analysis of covariance (ANCOVA) were conducted, adjusting for the significantly different variables from the demographic comparisons. Post hoc comparisons for the ANCOVA analyses used the Bonferroni correction for the estimated marginal means. Effect sizes of partial eta-square are reported for the ANCOVA analyses. The intraclass correlation coefficient was used to measure inter-rater reliability. As appropriate, correlation analyses of Pearson, Spearman, or point-biserial were conducted. All *P*-values were two-tailed with an alpha level of .05. SPSS Version 22 was used for the analyses.

RESULTS

Descriptive data for the RPA-ProMem whole sample were as follows: total score: $M = 8.14$ ($SD = 2.76$), time-based: $M = 3.70$ ($SD = 1.75$), event-based: $M = 4.44$ ($SD = 1.60$), short-term: $M = 3.97$ ($SD = 1.69$), and long-term: $M = 4.17$ ($SD = 1.76$). Table 1 shows the comparisons for the demographic characteristics of the sample. There were no significant differences for age or sex between the groups. There were overall significant differences between the groups for mean years of education, percentage of non-white race/ethnicity, and mean GDS score. Post hoc comparisons showed that the naMCI group had a significantly lower mean number of years of education than those in the HC ($p < .001$) or SCD ($p < .001$) groups. The naMCI group had a significantly higher percentage of participants of non-white

race/ethnicity than the HC ($p < .001$) and SCD ($p < .001$) groups. The SCD group had a significantly higher mean number of depressive symptoms than the HC group ($p = .02$), although average levels for all groups were well below the values associated with clinical depression.

Table 2 compares participant groups on both prospective and episodic memory tasks. Figure 1 shows a box plot for the participant groups of HC, SCD, aMCI, and naMCI in terms of their RPA-ProMem total scores. All of the variables of RPA-ProMem total score, RPA-ProMem time- and event-based scores, RPA-ProMem short- and long-term scores, MIST total score, and FCSRT free recall score statistically differed in both ANOVA and also ANCOVA analyses that adjusted for education, race/ethnicity, and GDS score. The one exception was that MIST significantly differed with ANOVA but no longer significantly differed with ANCOVA that adjusted for education, race/ethnicity, and GDS score. Post hoc comparisons were as follows: For the RPA-ProMem total score, HC had a significantly greater mean than both aMCI ($p < .001$) and naMCI ($p = .002$) and SCD had a significantly greater mean than aMCI ($p = .003$). For both the RPA-ProMem time- and event-based tasks, HC had a significantly greater mean than aMCI for both the time- ($p = .04$) and event-based ($p < .001$) tasks, and HC had a significantly greater mean than naMCI for both the time- ($p = .02$) and event-based ($p = .02$) tasks. In addition, for the event-based task, SCD had a significantly greater mean than aMCI ($p < .001$). For the RPA-ProMem short-term task, both HC ($p < .001$) and SCD ($p < .001$) had a significantly greater mean than aMCI. In addition, HC had a significantly greater mean than naMCI ($p = .03$). For the RPA-ProMem long-term task, HC had a significantly greater mean than the SCD ($p = .03$), aMCI ($p = .02$), and naMCI ($p = .02$). For FCSRT, HC ($p < .001$), SCD ($p < .001$), and naMCI groups ($p < .001$) all had a significantly greater mean than aMCI.

Inter-rater reliability for the RPA-ProMem total score was .97 ($p < .001$). Table 3 shows the correlation matrix for total scores on RPA-ProMem, MIST, CAPMB, CAPMBI, and FAQ. As expected, there was a positive medium significant correlation for the objective PM tasks of RPA-ProMem with the MIST. There were small significant negative correlations for the RPA-ProMem and informant reports of PM on the CAPMBI and informant reports of IADL on the FAQ, indicating that poorer PM performance was associated with higher levels of informant-reported difficulties. The subjective report questionnaires were significantly correlated with each other in the expected direction. There was a small positive significant correlation of self-report of PM on the CAPMB with informant report of PM on the CAPMBI, a small significant positive correlation of informant report of PM on the CAPMB with informant report of IADL on the FAQ, and a medium significant positive correlation of informant report of PM on the CAPMBI with informant report of IADL on the FAQ. Table 4 shows correlations between the RPA-ProMem total score and cognitive factor scores in the whole sample. Consistent with previous research, there were statistically significant positive medium correlations for PM score with the three cognitive domain composite Z-scores of memory, executive/processing speed, and global/verbal.

DISCUSSION

We found that those with amnesic mild cognitive impairment (aMCI) performed significantly worse than healthy controls (HC) on the RPA-ProMem. This supports our first hypothesis. There is a growing literature on the value of PM tasks as an early indicator of cognitive decline in older adults. Reasons include the high frequency of reported PM difficulties in this population and the association between PM difficulties and compromised activities of daily living and quality of life (Kliegel & Martin, 2003; Schmitter-Edgecombe et al., 2009; Sinnott, 1989; Woods et al., 2012). Recent analytic reviews support a PM deficit in aMCI as compared to elderly controls and call attention to the need for additional valid and reliable clinical measurements (Costa, Caltagirone, et al., 2011; van den Berg et al., 2012). Our results for nondepressed, demographically diverse older adults are consistent with previous studies of PM in aMCI, which show reliable evidence of PM decrements regardless of type of task used.

Consistent with our second hypothesis, participants with naMCI scored significantly lower than HC on all RPA-ProMem subtasks and there were no statistically significant differences between aMCI and naMCI on the RPA-ProMem. This result is consistent with some (Schmitter-Edgecombe et al., 2009) but not all (Costa et al., 2010; Wang et al., 2012) previous work and is not surprising in light of research implicating a broad fronto-temporal network in the cognitive processes required for successful PM (e.g., for encoding, maintenance, retrieval, and execution of the prospective intention). Thus, even though individuals with naMCI by definition have normal performance on retrospective memory tests, they would be expected to have performance deficits on PM tasks because of the numerous cognitive processes involved in the execution of such tasks. Consistent with our classification criteria, those with naMCI scored within the normal range on the FCSRT (Table 2), a widely used measure of short-term, declarative verbal memory, which provides an index of memory not confounded by difficulties in attention or aspects of executive functioning such as strategy use. While these design features may account for the FCSRT's strong association with incident AD (Grober, Lipton, Hall, & Crystal, 2000; Sarazin et al., 2007), performance on clinical PM tasks might show associations with incident dementia of other forms (e.g., vascular dementia or dementia with mixed pathologies), and this possibility should be explored in future longitudinal research.

We found partial support for our third hypothesis, which stated that SCD participants would score lower than HC on the RPA-ProMem despite their intact performance on traditional episodic memory tests. Relative to HC, the SCD group showed statistically decreased mean performance on the long-term, more naturalistic RPA-ProMem subtasks. However, although SCD had lower mean values than HC on RPA-ProMem total score and for all the other RPA-ProMem subtasks, this did not meet the level of statistical significance. Our finding for the long-term subtasks is significant considering the accumulating evidence that older adults who present with significant memory complaints despite intact functioning on traditional retrospective memory tests may represent a pre-MCI condition with neuropathological signs of AD (Amariglio et al., 2012; Jessen et al., 2010, 2014b; Saykin et al., 2006). This suggests that it is important to identify tasks that capture the subtle cognitive changes manifested by these individuals, which are difficult to quantify in the laboratory. PM tasks that tap into

everyday memory ability may confer unique information at the SCD stage – above and beyond what is available through traditional neuropsychological instruments, which often bear little resemblance to real-world functioning. In addition, relative to retrospective episodic memory, which involves explicit prompts to recall past events or information, PM is more dependent on complex metacognitive activity and internal control mechanisms such as task monitoring and switching, updating of intentions, and response inhibition (Henry et al., 2004; McDaniel & Einstein, 2011; Salthouse et al., 2004). These features may render PM more vulnerable than retrospective memory to early cognitive changes associated with neurodegenerative diseases.

Results suggest that if the test interval between encoding and executing the prospective intention is lengthy, individuals with SCD may perform below the level of HC. This decrement on long-term, naturalistic tasks may characterise a PM profile that discriminates SCD from HC. Future research might focus on this task component and address issues such as the length of time that individuals with SCD are able to retain a delayed intention and the variables (cognitive, psychological, organisational) that make successful task execution more likely. This research could establish a unique role for PM tasks in the diagnosis and description of SCD, the potentially earliest identifiable stage of AD and other dementias. In addition, it might guide the development of interventions that target modifiable behaviours and beliefs, such as strategy use, task motivation, memory self-efficacy, and organisational or time management skills in older adults with SCD. The use of strategies, for example, has been used to explain the finding that healthy older adults perform PM tasks successfully in naturalistic contexts yet demonstrate poorer levels of performance on lab-based tasks compared to younger adults (i.e., the age-PM paradox) (Maylor, 1996).

If SCD truly represents a pre-MCI condition, then this diagnostic stage may offer a therapeutic window of opportunity where focused interventions (see Kinsella et al., 2009; Kliegel, Altgassen, Hering, & Rose, 2011; Zogg et al., 2012) could provide a meaningful boost to PM. For example, individuals could be trained to create more salient links between specific cues and intentions to improve PM at the encoding stage (Zogg et al., 2012). Additionally, individuals can learn over time to link an event (e.g., making breakfast) with a specific response (e.g., taking morning medication). Thus, making the correct response strengthens the cue-response connection until the cue automatically leads to the intended behaviour. Also, goal management training, where individuals are taught to re-direct attention to activities necessary to achieve important goals, is effective in patients with traumatic brain injury and can facilitate PM at the monitoring stage (Levine et al., 2000). At the cue detection and retrieval stage, individuals can be taught to select cues that are meaningful and distinctive enough to trigger intended actions by reducing self-initiated retrieval demands (McDaniel & Einstein, 2007). For example, a brightly coloured Post-it note affixed to a centrally located phone serves as a reminder to phone one's physician. If interventions are successful, benefits to memory might generalise to other domains of functioning as individuals with SCD begin to feel more confident and less negative or fearful about their current and future cognitive abilities.

Our fourth hypothesis was that the RPA-ProMem would have strong psychometric properties rendering it useful in clinical and research settings. Consistent with our

prediction, RPA-ProMem total scores correlated with MIST total scores. As the MIST has already been shown to differentiate between healthy older adults and those with MCI (Karantzoulis et al., 2009; Raskin, 2009), this adds to the convergent validity support for the RPA-ProMem. We also found strong inter-rater reliability, consistent with initial findings reported for the RPA-ProMem by Radford et al. (2011). As hypothesised, RPA-ProMem total scores had significant weak to moderate correlations with composite cognitive domain scores in the broad areas of memory, executive functioning, and global cognition/verbal intellectual skills. This is not surprising given the plurality of neural networks required for execution of PM tasks including primarily neocortical areas in the prefrontal lobes (e.g., Brodmann's area 10 and the dorsolateral prefrontal cortex), in addition to other cortical areas such as the mesio-temporal and parietal lobes, and subcortical structures such as the thalamus (Bisiacchi, Cona, Schiff, & Basso, 2011; Cheng, Tian, Hu, Wang, & Wang, 2010; McDaniel & Einstein, 2007; West, 2007).

Finally, RPA-ProMem total scores were not significantly correlated with self-report scores of everyday PM on the CAPMB. Others have reported similar findings (Foster, McDaniel, Repovs, & Hershey, 2009; Woods et al., 2007; Zeintl, Kliegel, Rast, & Zimprich, 2006), and much has been written about the lack of association between self-reports of cognition and objective performance-based neuropsychological test performance (Gilewski & Zelinski, 1986; Herrmann, 1982; Moritz, Ferahli, & Naber, 2004). Importantly, however, RPA-ProMem total scores were significantly correlated with informant reports of both PM and IADLs. This is an interesting finding in light of recent research suggesting that informant-based cognitive reports may be better predictors of objective cognitive performance and function than self-reports and may enhance identification of very early neurodegenerative decline (Carr, Gray, Baty, & Morris, 2000; Gifford et al., 2013; Rabin et al., 2012). At the earliest stages of cognitive decline, informants may observe subtle changes in their loved ones' everyday functioning that are difficult to quantify but may be tapped by naturalistic PM tasks.

Limitations, strengths, and future directions

Several limitations should be considered. Effect sizes were modest for the RPA-ProMem and therefore the clinical utility of this task and its ability to discriminate between various diagnostic groups will need to be demonstrated in future research. However, effect sizes tend to be smaller for studies that use naturalistic PM measurements as compared to lab-based tasks (van den Berg et al., 2012), and certain task features may account for the small effect sizes, such as the relatively brief nature of the test (i.e., a limited range of scores). Although we investigated several psychometric features of the RPA-ProMem, we were unable to assess others (e.g., test-retest reliability, alternate form reliability) and hope to do so in future work with this measure. In addition, the current study represents the first attempt to utilise the RPA-ProMem with an older adult population, and follow-up research should determine whether the (preliminary) normative data presented in Table 2 generalise to other samples of non-demented older adults. At that point, cut-off points or ranges for "abnormal" versus "normal" PM performance may be established. Importantly, the current study was cross-sectional, and longitudinal follow-up is necessary to determine the predictive value of PM scores for diagnostic outcomes in each of our participant groups.

The current study has certain strengths. With the exception of previous research by Thompson and colleagues (2010, 2011), all prior studies of PM in MCI recruited participants through memory clinic/hospital settings, and thus our study extends previous findings to a community-based sample. Moreover, we used a novel psychometric approach to classification of both MCI and SCD, which may be preferable to clinical consensus approaches because it is impacted less by clinical judgement and can facilitate standardisation of diagnostic criteria for MCI across settings. It is important to note, however, that little is known about the optimal approach to the measurement and classification of SCD (Jessen et al., 2014a). The field presently lacks a standardised definition, and approaches to the classification of SCD vary widely - from using responses to a single question about memory functioning (e.g., Jessen et al., 2010, 2014b), to utilising multiple measures reviewed by a clinical consensus panel (e.g., Saykin et al., 2006), to recent attempts to use item response theory (which estimates latent subjective impairment levels and is thought to increase measurement precision) (e.g., Snitz et al., 2012). It will therefore be imperative to determine the cognitive and diagnostic outcomes of our participants to determine the validity of our psychometric method of classifying SCD.

In terms of additional future directions, it would be instructive to determine the specific PM processes driving low scores on the RPA-ProMem. For example, in an attempt to distinguish between attentional/executive versus automatic-reflexive processes in successful PM performance, one could inquire about how participants remember to complete the long-term RPA-ProMem tasks (e.g., whether they used a specific strategy or if the intention “popped into mind”). Equally valuable might be to probe perceived reasons for forgetting. Participants could be questioned about what occurred in the intervening period that may have led to PM failure such as whether they went directly home after the assessment, whether they conversed with anyone about their intention, whether anything occurred during the week that made them less likely to remember (e.g., stressful event such as illness), and whether they may have been more motivated to remember if the task was personally relevant (e.g., if participant compensation was linked to task completion). It would also be useful to investigate the association between strategy use and task performance along with any differential patterns of strategy use across participant groups and across RPA-ProMem subscales. Such knowledge could guide the development of targeted interventions to improve PM efficiency.

Conclusions

The RPA-ProMem is easy to incorporate into neuropsychological test batteries and shows promise for clinical use with older adults with varying degrees of cognitive complaints and impairment. We propose the utilisation of PM tasks as an alternative to exclusive reliance on retrospective measures. Going forward, it will be important to replicate the current findings and establish whether PM tasks are sensitive to group differences between cognitively healthy older adults and those with SCD, and whether PM difficulties predict diagnostic progression from SCD to MCI to dementia. Overall, our results encourage the use of naturalistic PM tasks and informant rating scales alongside self-reports to maximise the information derived about PM functioning during assessments of individuals in preclinical dementia stages and to guide the development of practical interventions.

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Figure 1.
Box plot of RPA-ProMem total scores by participant group.

TABLE 1

Demographic characteristic comparisons between the participant groups

Variable	HC <i>M (SD)</i> or % (#) (<i>n</i> = 118)		SCD <i>M (SD)</i> or % (#) (<i>n</i> = 83)		aMCI <i>M (SD)</i> or % (#) (<i>n</i> = 18)		naMCI <i>M (SD)</i> or % (#) (<i>n</i> = 38)		p-value
Age (years)	80.31	(5.52)	81.45	(5.13)	81.56	(6.98)	80.42	(5.72)	.47
Sex (female)	65.0%	(78)	66.7%	(54)	61.1%	(11)	81.57	(31)	.25
Education (years)	15.04	(3.13)	15.11	(3.22)	13.56	(4.44)	11.84	(2.91)	<.001
Race/ethnicity (non-white)	37.3%	(44)	28.9%	(24)	44.4%	(8)	71.1%	(27)	<.001
GDS (<i>n</i> /15)	1.25	(1.61)	2.13	(2.72)	2.00	(2.33)	1.42	(1.46)	.02

HC = healthy control, SCD = subjective cognitive decline; aMCI = amnesic mild cognitive impairment, naMCI = nonamnesic mild cognitive impairment; *M* = mean, *SD* = standard deviation; GDS = Geriatric Depression Scale, short form.

TABLE 2

Comparison of objective memory measures between participant groups

Variable	HC M (SD) (n = 118)	SCD M (SD) (n = 83)	aMCI M (SD) (n = 18)	naMCI M (SD) (n = 38)	ANOVA p-value	ANCOVA p-value	Post-hoc comparisons	Partial Eta Square
RPA-ProMem (n/12)	8.98 (2.23)	8.10 (2.69)	5.61 (3.65)	6.79 (2.73)	< .001	< .001	HC>aMCI, naMCI; SCD > aMCI	.11
Time-based (n/6)	4.11 (1.58)	3.63 (1.80)	2.83 (1.82)	3.00 (1.76)	.001	.004	HC>aMCI, naMCI	.05
Event-based (n/6)	4.87 (1.22)	4.47 (1.63)	2.78 (2.12)	3.79 (1.66)	< .001	< .001	HC>aMCI, naMCI; SCD > aMCI	.11
Short-term (n/6)	4.31 (1.45)	4.18 (1.66)	2.33 (2.20)	3.24 (1.57)	< .001	< .001	HC>aMCI, naMCI; SCD > aMCI	.10
Long-term (n/6)	4.68 (1.48)	3.92 (1.79)	3.28 (2.19)	3.55 (1.86)	< .001	.001	HC>SCD, aMCI, naMCI	.07
MIST (n/48)	27.92 (11.59)	26.67 (11.52)	21.17 (9.68)	20.38 (8.50)	.001	.134	—	.03
FCSRT (n/48)	33.76 (4.90)	33.05 (4.88)	24.44 (5.27)	33.16 (5.39)	< .001	< .001	HC, SCD, naMCI > aMCI	.19

HC = healthy control, SCD = subjective cognitive decline; aMCI = amnesic mild cognitive impairment, naMCI = nonamnesic mild cognitive impairment; M = mean, SD = standard deviation; RPA-ProMem = Royal Prince Alfred Prospective Memory Test, total score; MIST = Memory for Intentions Screening Test, total score; FCSRT = free recall from the Free and Cued Selective Reminding Test; ANCOVA adjusted for race/ethnicity, education, and depressive symptoms. ANCOVA analyses adjusted for education, race/ethnicity, and Geriatric Depression Scale (GDS) short form score. Bonferroni correction was used for post hoc comparisons using estimated marginal means.

TABLE 3

Correlation matrix for prospective memory measures

Variable	1	2	3	4	5
1. RPA-ProMem	1.00				
2. MIST	.35***	1.00			
3. CAPMB	-.09	-.12	1.00		
4. CAPMBI	-.23**	-.09	.26**	1.00	
5. FAQ	-.21**	-.09	.21*	.41***	1.00

RPA-ProMem = Royal Prince Alfred Prospective Memory Test total score, MIST = Memory for Intentions Screening Test total score, CAPMB = Comprehensive Assessment of Prospective Memory, Part B self-report version average score, CAPMBI = Comprehensive Assessment of Prospective Memory, Part B informant report version average score, FAQ = Functional Activities Questionnaire total score.

Sample size for MIST = 253; CAPMB = 231; CAPMBI = 162; FAQ = 170. Spearman's rho was used for correlations involving the CAPMB, CAPMBI, and FAQ.

* $p < .05$,
** $p < .01$,
*** $p < .001$

TABLE 4

Correlation analyses of the RPA-ProMem with cognitive factor scores

Variable	RPA-ProMem	<i>p</i> -value
Memory Factor Composite Z-score	.28	<.001
Executive/Processing Speed Factor Composite Z-score	.37	<.001
Global/Verbal Factor Composite Z-score	.33	<.001

RPA-ProMem = Royal Prince Alfred Prospective Memory Test total score; Factor Scores were derived from confirmatory factor analysis (described in Methods section).