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BRIEF REPORT

Individual differences in memory and attention processes in prospective remembering

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Abstract
Successful prospective memory (PM) involves not only detecting that an environmental cue requires action (i.e., prospective component), but also retrieval of what is supposed to be done at the appropriate moment (i.e., retrospective component). The current study examined the role of attention and memory during PM tasks that placed distinct demands on detection and retrieval processes. Using a large-scale individual differences design, participants completed three PM tasks that placed high demands on detection (but low demands on retrieval) and three tasks that placed high demands on retrieval (but low demands on detection). Additionally, participants completed three attention control, retrospective memory, and working memory tasks. Latent variable structural equation modeling showed that the prospective and retrospective components of PM were jointly influenced by multiple cognitive abilities. Critically, attention and retrospective memory fully mediated the relation between working memory and prospective memory. Furthermore, only attention uniquely predicted PM detection, whereas only retrospective memory uniquely predicted PM retrieval. These findings highlight the value of independently assessing different PM components and suggest that both attention and memory abilities must be considered to fully understand the dynamic processes underlying prospective remembering.

Keywords Prospective memory · Memory · Attention · Working memory · Individual differences

Introduction

Prospective memory (PM) refers to the ability to remember to perform delayed intentions at the appropriate moment (e.g., take medication after dinner) and comprises two components: the *prospective* component of PM refers to the attention processes involved in noticing the target and becoming aware that an intended action should be initiated, whereas the *retrospective* component refers to the memory processes involved in remembering the contents of the intention and retrieving the action from long-term memory (Einstein & McDaniel, 1990). PM failures can therefore broadly be classified as attention-based failures (e.g., failing to notice medicine bottle) and memory-based failures (e.g., taking medication at the wrong time). The majority of extant research has focused on the prospective component of PM, which is likely due in part to early research in the field needing to distinguish itself from the retrospective memory literature (see Crowder, 1996) and the popularization of the laboratory-based paradigm put forth by Einstein and McDaniel (1990) that focuses primarily on target detection processes. However, memory-based PM failures can be equally consequential as attention-based failures, meaning that both are important to understand. Given this distinction, understanding the interaction of attention and memory processes is critical for both theory development and for tailoring cognitive interventions based on idiosyncratic cognitive deficits (Ball et al., 2019). The current study takes an individual differences approach to assess the relation between attention and memory components of PM and cognitive ability.

In the standard laboratory task participants respond to a PM target event (e.g., the specific word "dog" or any exemplar of the animal category) with a special response (e.g., press "F5") while performing some ongoing task (e.g., lexical decision). This task is intentionally designed to place relatively little demands on the retrospective component

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(i.e., remembering "F5") to isolate processes that influence the prospective component. For example, using category targets or dividing attention increases demands on attention while leaving memory demands relatively unchanged. This means that the corresponding reductions in PM can more clearly be interpreted as arising from demands being placed on the prospective component (Einstein et al., 2005). Retrospective memory demands are typically manipulated by increasing the number of targets to be remembered (e.g., dog vs. dog, shoe, table, chip, etc.) or reducing the association between targets and intended actions (e.g., see *dog* type "cat" vs. see *dog* type "shoe"). With similar demands on attention, the corresponding changes in PM can be more clearly attributed to decrements to the retrospective process (Cook et al., 2014; McDaniel et al., 2004; Peper et al., 2021). It is important to note, however, that there is only a single measure of PM performance (e.g., pressing "F5"). This means that even under minimal demands PM failures can occur because participants fail to notice the target (prospective component), or they notice the target, but fail to retrieve the action (retrospective component). Moreover, investigations of the factors that influence each component are usually conducted separately (but see Ballhausen et al., 2017; Meier & Zimmermann, 2015). It therefore remains unclear whether these processes are independent or rely on similar underlying mechanisms.

Previous research fitting a multinomial model to PM data has provided support that dissociable processes may underlie PM. Two primary parameters are derived from this model – the first reflecting preparatory attention processes associated with monitoring the environment for PM targets (prospective component) and the second reflecting retrospective memory processes associated with memory retrieval (retrospective component; Smith & Bayen, 2004). Research has shown that the specificity of the PM target and PM task importance selectively influence the attention parameter, whereas encoding duration and motivational incentives selectively influence the memory parameter (Horn & Freund, 2021; Smith & Bayen, 2004; Wesslein et al., 2014). However, the modeling approach can be difficult to interpret when a manipulation produces changes in both parameters (e.g., Smith & Bayen, 2005; Wesslein et al., 2014).

A different way to examine the dissociation between attention and memory processes is to determine whether different tasks produce changes in different brain regions. Simons et al. (2006) developed a set of tasks that placed high demands on the prospective component (i.e., target detection) and retrospective component (i.e., intention retrieval). For example, participants performed an ongoing letter task that involved pressing the arrow key in the direction of the longer word (see top row of Fig. 1). To manipulate the difficulty of detection versus retrieval, participants either formed an intention to press a special key if the words were semantically related (difficult detection – easy retrieval; referred to as the *PM detection* task) or to press one of two keys depending on the total count of syllables whenever both words were upper case (easy detection – difficult retrieval; referred to as the *PM retrieval* task). PM detection places demand on preparatory attention processes needed to detect PM targets, whereas PM retrieval places demand on controlled retrieval processes need to retrieve the PM target behavior (McDaniel et al., 2004; Smith, 2003). Despite differences in PM performance between the two conditions, both were associated with changes in anterior and medial prefrontal cortex (BA 10) activity associated with biasing attention between external (looking for targets) and internal (remembering the contents of the intention) focus. This suggests that the two components at least share some common underlying neural basis. However, exploratory analyses revealed a dissociation in activation between the two components whereby the PM detection and PM retrieval tasks were associated with greater anterior and posterior cingulate cortex activation, respectively. Anterior regions are associated with controlled attention, whereas posterior regions are associated with controlled retrieval (Burgess et al., 2001; Cabeza et al., 2003; Wagner et al., 2005). Together these findings suggest that there may be common (BA 10) and distinct (anterior/posterior cingulate cortex) neural bases of the two components.

Finally, to determine whether the components are dissociable researchers can assess whether individual differences in performance on one task is predictive of performance on another task thought to rely on similar underlying processes. For example, if detection versus retrieval relies more heavily on attention versus retrospective memory processes, then presumably performance on the PM detection and PM retrieval tasks should be uniquely predicted by one's attention and retrospective memory abilities. Indirect support for this claim has come from several studies showing that working memory ability is predictive of PM performance using categorical PM targets that place high demands on sustained attention or during tasks that require controlled memory search to determine whether an intention has previously been fulfilled (Ball et al., 2018; Brewer et al., 2010). However, working memory is not associated with PM performance when specific targets are used that allow for automatic retrieval of the intention. Broadly speaking, working memory refers to the attention processes needed to maintain task-relevant goals in focal awareness amidst distraction and the memory processes needed to retrieve displaced goals from long-term memory (Kane et al., 2001; Kane et al., 2004; Kane & Engle, 2003; Unsworth et al., 2012; Unsworth & Engle, 2007). This suggests that working memory is predictive of PM performance, at least in part, because the same attention and memory processes needed to perform working memory tasks are needed to successfully detect PM targets (i.e., prospective component)

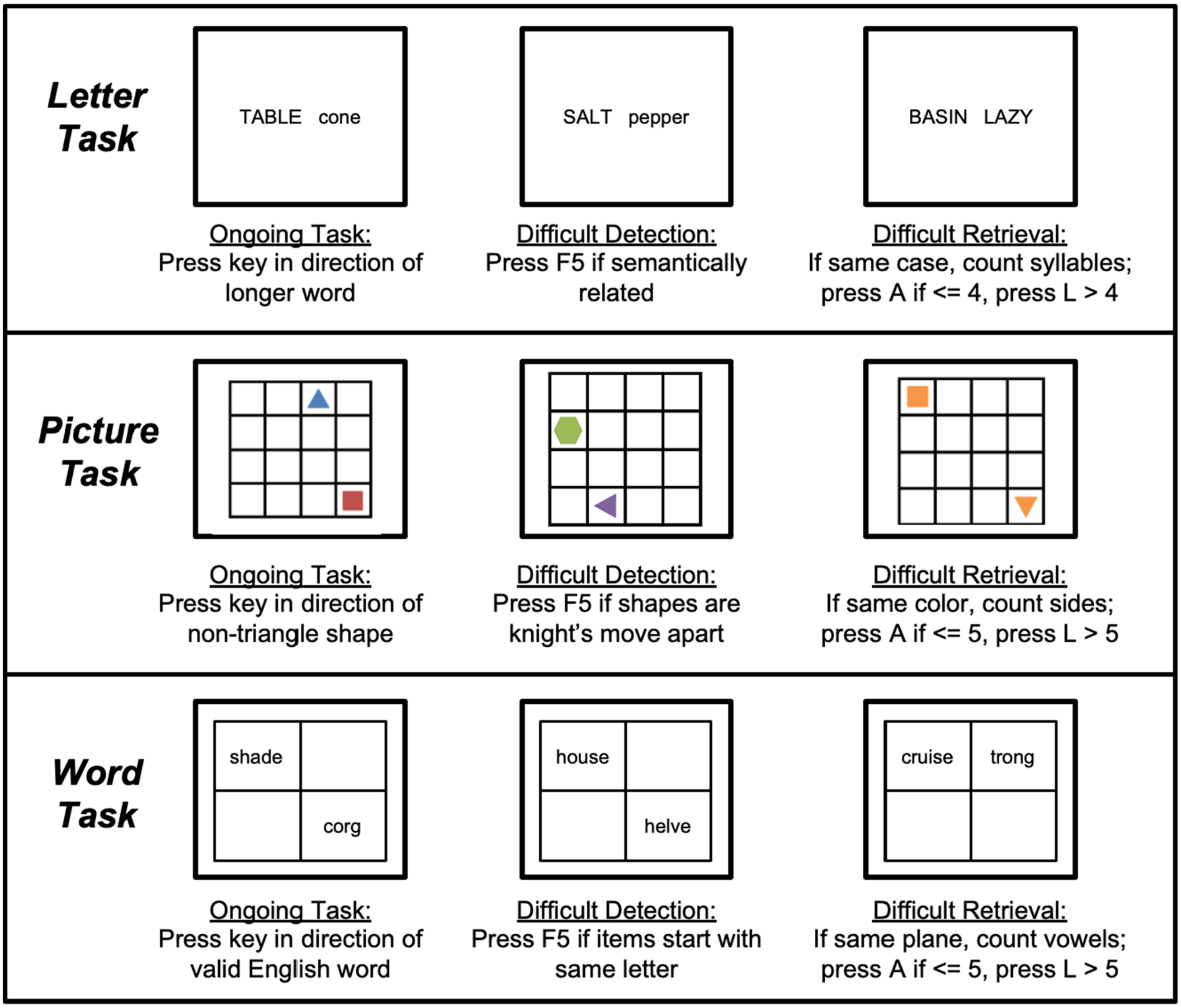


Fig. 1 Examples of prospective memory tasks used in current experiment that differed in detection versus retrieval demands

and remember the contents of the intention (i.e., retrospective component; Brewer et al., 2010). Consistent with this idea, the relation between working memory and PM is no longer significant after controlling for attention control and retrospective memory ability (Ball et al., 2019). However, PM performance in that study was comprised of multiple PM tasks that placed high demands on attention *and* retrospective memory. It remains unclear whether attention and memory processes are uniquely associated with the prospective and retrospective components, respectively.

Current study

Using a large-scale quasi-experimental design, participants completed three versions of the PM detection (difficult detection, easy retrieval) and PM retrieval (easy detection, difficult retrieval) tasks used by Simons et al. (2006). Participants also completed three working memory, attention control, and retrospective memory tasks. Latent variable structural equation modeling was used to assess the unique contributions of these cognitive processes to PM detection and PM retrieval performance. Combining differential and experimental methodologies is advantageous because this allows one to determine which task attributes (e.g., detection difficulty) changes the correlation with cognitive ability (e.g., working memory, attention, etc.). Using multiple measures of each cognitive construct controls measurement error while testing for theoretical relations among different cognitive abilities.

Based on prior research, we anticipated that working memory would be predictive of PM performance on both PM detection and PM retrieval tasks (Ball et al., 2013; Ball et al., 2018; Smith & Bayen, 2005). This would be consistent with the interpretation by Simons et al. (2006) that there is a common mechanism that biases focus between external (target detection) and internal (remembering the contents of the intention) task goals. We also anticipated that accounting for attention and memory abilities would eliminate the relation between working memory and PM performance (Ball et al., 2019). Finally, we hypothesized that attention ability would be more strongly associated with PM detection performance, whereas retrospective memory ability would be more strongly associated with PM retrieval performance. This would be consistent with exploratory analyses by Simons et al. (2006) showing dissociable neural components associated with the different components.

Methods

All research reported herein was conducted using appropriate ethical guidelines and was approved by the Institutional Review Board at the University of Texas at Arlington. We report how we determined our sample size, all data exclusions, and all manipulations.

Participants and design

The study consisted of two sessions scheduled 1 week apart, each lasting approximately 2 h. A desired sample size of at least 250 over the course of two semesters was chosen based on recommendations that 250 participants are needed to detect stable and reliable zero-order correlations (Schönbrodt & Perugini, 2013). Further, Gpower suggests that to detect moderate correlations (0.3) at $p < .05$ with .95 power a sample size of 138 participants is needed. We applied a stopping rule beyond the 250 participants that coincided with the end of the second semester. Over the course of two semesters, a total of 310 undergraduates from the University of Texas at Arlington enrolled in the study to receive participation credit towards course requirements. However, only the 279 participants completed both days. Of these participants, 13 were excluded because they did not successfully respond to any PM targets in any of the six PM tasks. The final sample consisted of 266 participants whose native language was English (mean age = 19.4 years, range 17–51, SD = 3.37; years of education = 13.51, range 13–18, SD = .99; 182 females, 81 males[1]). Gpower indicates that with 266 participants, we retain power of .95 to detect correlations at $p <.05$ with correlations as low as 0.22.

Cognitive battery

The current study was conducted in the context of a larger cognitive battery for a separate study (Ball et al., 2021). For the purpose of the current study, we only report analyses for the laboratory assessments of PM detection (PM detection), PM retrieval (PM detection), attention control (AC), retrospective memory (RM), and working memory (WM).[2]

Materials and procedure

Prospective memory tasks

The materials and procedure for the three difficult detection (PM detection) and three difficult retrieval (PM retrieval) tasks were modeled after Simons et al. (2006). The details of each task are described separately below. However, given then similar structure across the tasks, we briefly describe the commonalities here. There was a letter, word, and picture version of both the PM detection and PM retrieval tasks. These names reflect the type of ongoing task that was performed (described below). Participants would first receive instructions and practice with the ongoing task, after which they would receive the instructions for the PM intention. Following intention encoding, participants would perform a distractor task (one of the other cognitive tasks used in the cognitive battery, described later), after which they would begin the PM block without any further mention of the PM instructions. The PM block for each task contained 160 ongoing task trials in which one of six PM targets would be randomly chosen and presented every 25 trials (i.e., trial 25, 50, etc.). The DV for all tasks was the proportion of targets (out of six) that participants successfully made a PM response to.

PM detection – letter The "letter" ongoing task involved presenting participants with unrelated word pairs (e.g., TABLE – cone) to which they were to decide whether the word on the left (F key) or right (J key) of a word pair had more letters (Simons et al., 2006). All word pairs were randomly presented in opposite font case (e.g., TABLE – cone

[1] Demographic information was missing for three participants.

[2] As part of a larger battery, participants also completed several measures of laboratory PM offloading, naturalistic PM offloading, episodic memory offloading, and fluid intelligence, along with everyday memory and attention questionnaires.

or table – CONE). The PM intention was to press the "F5 key" any time the two words were semantically related (e.g., SALT – pepper). The distractor task following intention encoding was the source memory task.

PM retrieval – letter The "letter" ongoing task was identical to the one used in the PM detection task. The PM intention was that if both words in the word pair were presented in upper case (e.g., BASIN – LAZY), participants were to count the total number of syllables. If the total number of syllables was less than or equal to 4, they should press the A key, and if the number was greater than 4, they should press the L key. The distractor task following intention encoding was the antisaccade task.

PM detection – word The "word" ongoing task involved presenting participants with word and nonword pairs (e.g., shade – corg) within a 2 × 2 grid to which they were to decide whether the word on the left (F key) or right (J key) side of the grid was the valid English word. The two items were always randomly presented in opposite quadrants, meaning that if the item on the left half of the grid was presented in the lower (left) quadrant the item on the right half of the grid was presented in the upper (right) quadrant. The PM intention was to press the "F5 key" any time the two items started with the same letter (e.g., house – helve). The distractor task following intention encoding was the psychomotor vigilance task.

PM retrieval – word The "word" ongoing task was identical to the one used in the PM detection task. The PM intention was that if both the item on the left and right side of the grid were presented on the same horizontal axis (i.e., cruise – trong both presented in the upper quadrant), participants were to count the total number of vowels. If the total number of vowels was less than or equal to 5, they should press the A key, and if the number was greater than 5, they should press the L key. The distractor task following intention encoding was the degraded mask task.

PM detection – picture The "picture" ongoing task involved presenting participants with a 4 × 4 array containing two shapes, with one shape always being a triangle (Simons et al., 2006). Participants were to determine whether the triangle was to the left (F key) or right (J key) of the non-triangle shape. The PM intention was to press the "F5 key" any time the two shapes are a knight's move apart (as in chess). This configuration was detailed to the participants (e.g., "two steps in one direction and one step in another, forming an L shape") and a visual example was provided. After confirming they understood the instructions, participants performed the distractor task. The distractor task following intention encoding was the cued recall word task.

PM retrieval – picture The "picture" ongoing task was identical to the one used in the PM detection task. The PM intention was that if shapes were in the same color, participants were to count the total number of sides on the non-triangle shape. If the total number of sides was less than or equal to 5, they should press the A key, and if the number was greater than 5, they should press the L key. The distractor task following intention encoding was the cued recall number task.

Attention control tasks

Antisaccade. Participants were instructed to stare at a fixation point on-screen for a variable amount of time (200–1,800ms). A flashing white "=" was then flashed either to the left or right of fixation (11.33° of visual angle) for 100 ms. This cue was followed by the target stimulus (a B, P, or R) on-screen for 100 ms. The target was followed by masking stimuli (an H for 50 ms and an 8 which remains on-screen until a response is given). The participants' task was to identify the target letter by pressing a key for B, P, or R (the keys 1, 2, or 3). There were 50 trials. The target always appeared in the opposite location to the flashing cue. The DV for this measure was the proportion of correct responses.

Psychomotor vigilance task Participants were presented with a row of zeros on-screen and after a variable amount of time the zeros began to count up in 1-ms intervals from 0 ms. Participants were to press the spacebar as quickly as possible once the numbers started counting up (roughly 75 total trials). After pressing the spacebar, the response-time was left on-screen for 1 s to provide feedback to the participants. Interstimulus intervals were randomly distributed and ranged from 1 to 10 s. The task ended after 7 min. The DV for this measure was the average response times (RTs) for the slowest 20% of trials.

Degraded mask Participants were presented with a series of degraded stimuli rapidly on the computer screen. A random sequence of centrally located digits, ranging from 0 to 9, were presented in monochrome. The digit "0" was designated as the target (probability = 0.17), whereas the letter "D" was the nontarget. Stimuli were presented at an even rate of one per second. Participants responded to the target and nontarget stimuli by pressing the "F" or "J" key, respectively. Instructions emphasized both response speed and accuracy. There were 405 total trials. The DV for this measure was target accuracy.

Retrospective memory tasks

Cued recall – word Participants attempted to recall four lists of ten cue-target (word-word) pairs studied for 2 s each (e.g., dog – table). After a 16-s distractor task, participants were randomly provided with a cue for 5 s and they were instructed to enter the target using the keyboard. The DV for this measure was the proportion of targets recalled correctly.

Cued recall – number Participants attempted to recall four lists of ten cue-target (number-word) pairs studied for 2 s each (e.g., 542 – horse). After a 16-s distractor task, participants were randomly provided with a cue for 5 s and they were instructed to enter the target using the keyboard. The DV for this measure was the proportion of targets recalled correctly.

Picture source recognition Participants were presented with 35 pictures in one of four different quadrants on the computer screen. At test, participants were presented with 35 old and 35 new pictures in the center of the screen. Participants indicated if the picture was new or old and, if old, what quadrant it was originally presented in via key press. Participants had 5 s to press the appropriate key to enter their response. The DV for this measure was the proportion of correct quadrant decisions.

Working memory tasks

Reading span (Rspan; Redick et al., 2012; Unsworth et al., 2009). Participants were required to read sentences while trying to remember a set of unrelated letters. For this task, participants read a sentence and determined whether the sentence made sense or not (e.g., "The prosecutor's dish was lost because it was not based on fact?"). Half of the sentences made sense while the other half did not. Nonsense sentences were made by simply changing one word (e.g., "dish" from "case") from an otherwise normal sentence. Participants were required to read the sentence and to indicate whether it made sense or not. After participants gave their response, they were presented with a letter for 1,000 ms. At recall, the letters from the current set were recalled in the correct order by clicking on the appropriate letters. There were two trials of each list-length with the list-length ranging from three to seven letters, so the maximum possible score was 50. The DV for this measure was the proportion of correct items (out of 50) in the correct serial position.

Operation span (Ospan; Redick et al., 2012; Unsworth et al., 2005). Participants solved a series of math operations while trying to remember a set of unrelated letters (F, H, J, K, L, N, P, Q, R, S, T, Y). Participants were required to solve a math operation, and after solving the operation they were presented with a letter for 1 s. Immediately after the letter was presented the next operation was presented. At recall, letters from the current set were recalled in the correct order by clicking on the appropriate letters. Participants received three sets (of list-length two) of practice. There were two trials of each list-length with the list-length ranging from three to seven letters, so the maximum possible score was 50. The DV for this measure was the proportion of correct items (out of 50) in the correct serial position.

Symmetry span (Sspan; Redick et al., 2012; Unsworth et al., 2009). In this task, participants were required to recall sequences of red squares within a matrix while performing a symmetry-judgment task. In the symmetry-judgment task participants were shown an 8×8 matrix with some squares filled in black. Participants decided whether the design was symmetrical across its vertical axis. The pattern was symmetrical half of the time. Immediately after determining whether the pattern was symmetrical, participants were presented with a 4×4 matrix with one of the cells filled in red for 650 ms. At recall, participants recalled the sequence of red-square locations in the preceding displays, in the order they appeared, by clicking on the cells of an empty matrix. There were two trials of each list-length with the list-length ranging from two to five squares, so the maximum possible score was 28. The DV for this measure was the number of correct items (of 28) in the correct serial position.

Factor analytic approach

Confirmatory factor analysis (CFA) reduces spurious relations among measures based on task-specific variance or measurement error. In this approach, a theoretically derived model is specified, and the corresponding hypothetical variance-covariance matrix is compared with the true variance-covariance matrix for the observed data (Kline, 2015). A chi-square test is used to determine how well the specified model reproduces the observed data, with a nonsignificant value indicating a good fit. In addition to the chi-square test, several other goodness-of-fit indices are typically reported: root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), non-normed fit index (NNFI), and comparative fit index (CFI). The RMSEA and SRMR reflect the average squared deviation between the observed and reproduced covariances, whereas the NNFI and CFI compare the fit of the specified model to a baseline null model. RMSEA and SRMR values less than .08 and NNFI and CFI values greater than .90 and are indicative of acceptable fit (Kline, 2015). After determining that the model provided a good fit, we used the latent variable structural equation model (SEM) to assess unique contributions of cognitive ability (i.e., attention control, retrospective memory, and working memory) in predicting PM. Data missing at random was accounted for using maximum likelihood estimation.

Results

Descriptive statistics for all tasks can be found in Table 1. All measures had acceptable values of skew and kurtosis

Table 1 Descriptive statistics and reliability estimates for all measures

Construct	Task	Mean	SD	Min	Max	Skew	Kurtosis	Alpha
PM Detection	Letter	0.31	0.32	0.00	1.00	0.59	-1.03	.788
	Word	0.37	0.32	0.00	1.00	0.27	-1.26	.760
	Picture	0.29	0.28	0.00	1.00	0.69	-0.49	.693
PM Retrieval	Letter	0.43	0.33	0.00	1.00	0.18	-1.16	.760
	Word	0.58	0.36	0.00	1.00	-0.40	-1.12	.818
	Picture	0.46	0.32	0.00	1.00	0.04	-1.12	.708
Attention Control	Antisaccade	0.62	0.19	0.22	0.98	-0.11	-0.91	.854
	Psychomotor Vigilance	620	162	385	1572	2.10	7.06	.843*
	Degraded Mask	0.74	0.18	0.00	1.00	-1.25	2.42	.888
Retrospective Memory	Source	0.72	0.18	0.07	0.97	-1.34	1.91	.858
	Cued Recall (word)	0.39	0.25	0.00	0.98	0.44	-0.76	.877
	Cued Recall (number)	0.09	0.07	0.00	0.45	1.85	5.94	.522
Working Memory	Operation Span	35.09	11.65	0.00	50.00	-0.95	0.29	.976
	Reading Span	33.39	8.73	1.00	50.00	-0.65	0.73	.976
	Symmetry Span	17.59	5.74	2.00	28.00	-0.42	-0.34	.874

PM = prospective memory

*Psychomotor vigilance reliability is split-half reliability with Spearman-Brown Coefficient

(skew < |3| and kurtosis < |8|; Kline, 2015). Of note, PM performance was higher for PM retrieval tasks than PM detection tasks for all three task types (*letter*: $F(1,516) = 17.77$, $p < .001$, $\eta_p^2 = .033$; *word*: $F(1,524) = 50.60$, $p < .001$, $\eta_p^2 = .088$; *picture*: $F(1,527) = 40.32$, $p < .001$, $\eta_p^2 = .071$). Correlations for each task can be found in the Online Supplemental Material (OSM, Fig. S1).

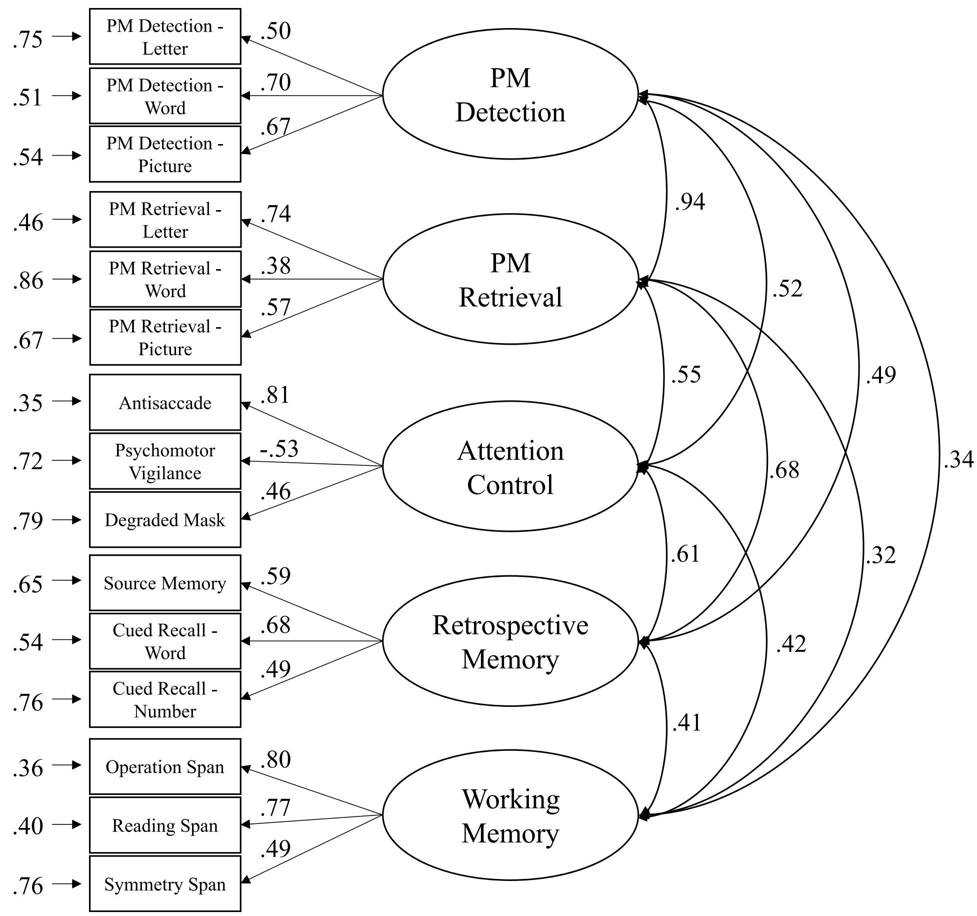
To test our first hypothesis, we fit a CFA model that included five factors (i.e., PM detection, PM retrieval, attention control, retrospective memory, and working memory). This model tests whether the theoretically specified five-factor structure appropriately fit the observed data. Importantly, this five-factor model provided an acceptable fit ($\chi^2(80) = 124.00$, $p < .001$, CFI = .95, NNFI = .93, SRMR = .05, RMSEA = .05 90% CI [.03, .06]). As can be seen in Fig. 2, consistent with our first hypothesis, all factors were positively correlated with the PM detection and PM retrieval tasks.[3] Scatterplots of the latent factor correlations can be seen in the OSM (Fig. S2).

To test our second hypotheses, we specified a structural equation model from the five-factor CFA model to determine whether the correlations between the cognitive abilities with PM were shared or unique. To do this, we tested a mediation model where working memory predicted attention control and retrospective memory, working memory predicted PM (detection and retrieval), and attention control and retrospective memory predicted PM (detection and retrieval). As can be seen in Fig. 3, working memory was no longer predictive of PM after controlling for attention and memory ability. Supporting our second hypothesis, for both PM detection and PM retrieval tasks the relation between working memory and prospective memory was fully mediated by attention and memory as indicated by the dashed line. Consistent with our third hypothesis, only attention control uniquely predicted PM performance in the PM detection task (*PM detection*: indirect effect via attention control = .14, $p = .025$; indirect effect via retrospective memory = .11, $p = .069$; $R^2 = .321$), whereas only retrospective memory uniquely predicted PM performance in the PM retrieval task (*PM retrieval*: indirect effect via attention control = .10, $p = .117$; indirect effect via retrospective memory = .23, $p = .002$; $R^2 = .485$).

General discussion

Research has shown that multiple cognitive processes contribute to prospective remembering (Einstein et al., 2005; McDaniel et al., 2004). Specifically, successful remembering involves not only realizing *that* an intention must be completed (i.e., prospective component), but also remembering

[3] Given the high correlation between the PM detection and PM retrieval tasks, we fit a second model where the PM tasks loaded onto a single factor. This model produced a similar fit to the data ($\chi^2(84) = 131.88$, $p < .001$, CFI = .94, NNFI = .93, SRMR = .05, RMSEA = .05 90% CI [.03, .06]) and a chi-square difference test revealed no significant differences between model in which the PM tasks loaded onto the same or separate factors $\Delta\chi^2$ (4) = 7.68, p = .10. While it is customary to retain the more parsimonious model with fewer factors, we elected to report analyses from the PM model with separate factors because the fit is identical between the two PM models and we have a priori reasons to analyze the two constructs separately. The data from the CFA model with a single PM factor is reported in the OSM, along with the fits of other theoretically plausible models.



$\chi 2$ (80) = 124.20, p = .001, CFI = .95, NNFI = .93, SRMR = .05, RMSEA = .05 90% CI [.03, .06]

Fig. 2 Confirmatory factor analysis. *Note.* Confirmatory factor analysis of the five-factor model for prospective memory (PM) detection (difficult detection and easy retrieval) and PM retrieval (easy detection and difficult retrieval) with the cognitive abilities of attention control, retrospective memory, and working memory. Solid lines in factor analysis indicate significant paths at $p < .05$

what is supposed to be done at the appropriate moment (i.e., retrospective component). Multinomial modeling has supported the idea that the prospective and retrospective components can be behaviorally dissociated (e.g., Smith & Bayen, 2004) and neurophysiological evidence has demonstrated that overlapping and distinct brain regions may support these different processing components (Cona et al., 2015; Simons et al., 2006). Using individual differences methodology, the current study sought to provide additional support for these claims and better specify the attention and memory mechanisms underlying remembering. The results showed that both the prospective and retrospective components of PM were jointly influenced by multiple cognitive abilities. Critically, however, only attention control uniquely predicted PM detection, whereas only retrospective memory uniquely predicted PM retrieval. These findings highlight the value of independently assessing different PM components and suggest that both attention and memory abilities must be considered to fully understand the dynamic processes underlying prospective remembering (Ball et al., 2018).

The mechanisms involved in prospective remembering have been described by various theories. The Preparatory Attentional and Memory processes (PAM) theory suggests that capacity-consuming preparatory attention processes are always needed to maintain a state of readiness to perform the PM task (Smith, 2003; Smith et al., 2007). These preparatory processes are what comprise the “prospective component” of PM and may include rehearsing task goals in working memory (Brewer et al., 2010), maintaining a prospective retrieval mode to prepare to respond to PM targets (Guynn, 2003), proactively inhibiting ongoing task responding (Ball & Brewer, 2018; Bugg et al., 2013; Strickland et al., 2018), and/or preparing to switch between ongoing task and PM responses (Smith, 2010). Assuming preparatory attention

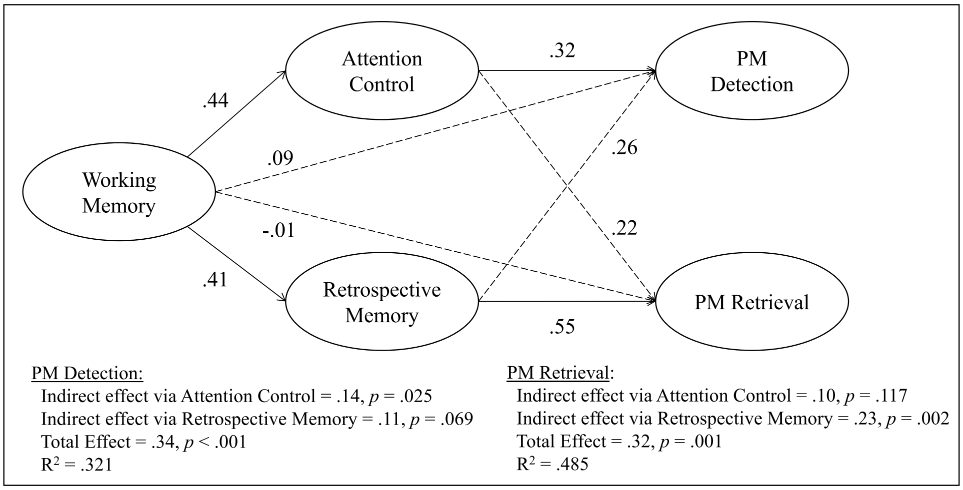


Fig. 3 Mediation analyses for prospective memory (PM) detection and retrieval tasks. *Note.* Multiple mediation analysis for PM detection (difficult detection, easy retrieval) and PM retrieval (easy detection, difficult retrieval) in which working memory predicts PM performance, while both attention control and retrospective memory mediate this relation. The circles reflect the same latent factors from the confirmatory factor analysis where each individual task (e.g., operation span) loads onto its respective latent factor (e.g., working memory), although the manifest variables are not pictured here. Solid lines in factor analysis indicate significant paths at $p < .05$, whereas dashed lines reflect non-significant paths

is engaged, the retrospective component of PM involves the enactment of retrospective memory processes to discriminate PM targets from nontargets (Smith, 2003), verify whether the context is appropriate for executing the action (Marsh et al., 2003), and retrieve the action plan (McDaniel et al., 2004). The Multiprocess Framework makes similar claims but argues that for some tasks, PM retrieval can occur via memory-dependent mechanisms without the engagement of preparatory attention (McDaniel & Einstein, 2007; Shelton & Scullin, 2017). For example, with well-specified PM targets (e.g., focal, salient, high association, etc.), disfluent processing may initiate a controlled memory search for the source of the discrepancy, or following ecphory (Tulving, 1983), an intention may be reflexively brought into mind. These theories highlight that both attention and memory are critical for prospective remembering.

In the current study, detecting targets associated with the prospective component was made difficult in the PM detection tasks (difficult detection, easy retrieval) by using what could be considered "nonfocal" targets. That is, the relevant features of the PM targets (e.g., semantically related pairs) were not relevant, or not focal, to ongoing task processing (e.g., counting the number of letters). However, once the intention was realized, participants only needed to retrieve a single response (e.g., "F5"), meaning that demands on the retrospective component were relatively minimal. Research has shown that successful detection of nonfocal PM targets typically requires proactive (Ball & Brewer, 2018) and preparatory (Smith, 2003) attention processes to monitor the environment for their occurrence. The ability to maintain these goals has often been linked to working memory capacity (Brewer et al., 2010; Smith & Bayen, 2005), a finding we replicate in the current study. Critically, however, attention control fully mediated this relation. This suggests that ability to sustain attention to prevent mind wandering (Brewer et al., 2010) and/or inhibit prepotent ongoing task responses to check for PM targets (Ball & Brewer, 2018; Schnitzspahn et al., 2013; Zuber et al., 2016) is central to difficult PM detection.

Retrieval associated with the retrospective component was made difficult by requiring participants to retrieve a relatively complex action plan consisting of multiple steps. PM targets in the PM retrieval task (easy detection, difficulty retrieval) were salient and always presented in the correct context (i.e., during the ongoing task), meaning that demands on target recognition and context verification were relatively minimal. The salient targets used in the PM detection task may have been discrepant from other ongoing task stimuli, resulting in relatively automatic noticing of the target. However, participants then had to engage in controlled retrieval to recall the appropriate steps associated with the action plan, which reduces PM performance (Meeks et al., 2015). Like the results of the PM detection task, we found that individuals with higher working memory had better PM retrieval performance. However, this relation appears to be driven by the fact those individuals also had higher retrospective memory ability. These findings suggest that the ability to retrieve the contents of the intention from long-term memory is another integral process associated with prospective remembering. This is consistent with research suggesting that retrospective memory ability facilitates execution of delayed intentions (Ball et al., 2013) and reduces commission (e.g., over-medicating) and omission (e.g., under-medicating) errors when prospective memory targets are encountered multiple times (Ball et al., 2018).

The results from Simons et al. (2006) indicate that there may be both common and distinct neural bases of the prospective and retrospective components. Similarly, prior modeling work has shown that working memory ability is associated with both attention and memory parameters (Smith & Bayen, 2005), while other studies have found that manipulations that place demands on the prospective versus retrospective components produce selective changes in either of the two associated parameters (Horn & Freund, 2021; Smith & Bayen, 2004; Wesslein et al., 2014). It is interesting to note parallels in the current study, where working memory may be common to both components whereas attention (prospective component) and retrospective memory (retrospective component) are distinct. To be clear, however, we are not suggesting that the PM detection *only* requires attention or that PM retrieval *only* requires memory. During intention formation, attention and memory are needed to attend to the relevant features of the intention ((McDaniel et al., 2015), bind the target and action into a unified representation (Cook et al., 2014), and even to mentally simulate the future contexts in which the intention should be completed (Brewer & Marsh, 2010). Once in the appropriate retrieval context (e.g., the ongoing task), preparatory attention processes are needed to initiate retrieval processes (i.e., recognition checks) (Smith, 2003; Smith et al., 2007). Or in the absence of preparatory attention, memory processes can spontaneously retrieve task goals to facilitate goal completion (Anderson et al., 2017; Bugg et al., 2013). Indeed, the correlation between the two task types were high, suggesting that both attention and memory are likely operating in both tasks. The current study highlights that the prospective and retrospective components can be behaviorally dissociated by increasing or decreasing demands on detection and retrieval processes and that both should be taken into consideration for better understanding PM (Ball et al., 2019). Future work focusing on the interaction between these processes during both encoding and retrieval of PM will allow for a more comprehensive theory of mechanisms supporting future-oriented behavior.

Finally, these results have important practical implications. As described previously, everyday PM failures can be classified as attention-based (e.g., failing to notice medicine bottle) or memory-based (e.g., taking medication at the wrong time) failures, although certainly other types of failures exist (e.g., delayed-execute, time-based, etc.). Behavioral indices of attention and memory ability can therefore be useful in helping researchers or healthcare providers identify which types of PM failures an individual might face and provide them with appropriate recommendations on how to reduce those errors. For example, a patient with schizophrenia may benefit from using implementation intentions that reduce PM attention demands (Chen et al., 2016), whereas a patient with Alzheimer's disease may benefit from electronic memory aids that reduce PM demands (King & Dwan, 2019). Notably, the results from the current study suggest that similar recommendations could even be made for healthy college-aged students with varying cognitive ability. Future research using individual differences methodology may allow for a fine-grained assessment of attention and memory abilities that can be used to adjudicate between general and specific cognitive deficits resulting in PM failures.

Altogether, this study provides evidence for the hypothesis that individual differences in PM performance are driven by distinct cognitive/neural systems. This is an important demonstration because it underscores the fact that two people with similar degrees of PM deficits may exhibit those deficits because of different cognitive limitations.

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Data availability All data are available on the Open Science Framework at: https://osf.io/4ymep/?view_only=a3d8a9ac177c4ffeba3db5e233318802

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