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Discrepancy-plus-search processes in prospective memory retrieval

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Abstract In the present study, we investigated the processes underlying prospective memory (PM) retrieval, focusing specifically on two possible spontaneous processes: discrepancy-plus-search and familiarity. Discrepancy was elicited by orthogonally manipulating the processing difficulties of the PM targets and the nontargets. Participants performed a PM task while solving anagrams with two levels of difficulty (easy or difficult). Assuming that the ease of processing easy anagrams would heighten a sense of familiarity, the familiarity view predicted better PM performance with easy anagrams as the PM targets. In contrast, the discrepancy-plus-search view predicted higher PM performance for the PM targets that were anagrams whose difficulty level mismatched that of the surrounding nontargets, as compared to PM targets whose difficulty matched that of the surrounding nontargets. This prediction was based on the idea that mismatching rather than matching difficulty levels would create discrepancy, thereby signaling significance for the target. Participants were more likely to perform the PM task for PM targets that were discrepant, supporting the discrepancy-plus-search view.

Keywords Memory · Prospective memory · Spontaneous retrieval · Discrepancy · Familiarity

Prospective memory (PM) refers to remembering to perform intended actions in the future, such as remembering to deliver a message to a colleague. An event-based PM task is defined as performing an intended action when a PM target appears and signals that it is the appropriate time to do so. Often, to perform an event-based PM task (e.g., delivering a message when one sees a colleague), one has to recognize that a stimulus (the colleague's face) is a PM target and retrieve the appropriate PM intention (a need to deliver the message). Notice that one has to recognize the PM target and retrieve the PM intention while being busily engaged in the ongoing activity (conversing with other colleagues) without any explicit retrieval request for PM. A key theoretical issue in the PM literature thus turns on the processes underlying the recognition of the PM target and the retrieval of the PM intention.

According to the multiprocess theory (McDaniel & Einstein, 2000, 2007; McDaniel, Guynn, Einstein, & Breneiser, 2004), strategic monitoring processes may support PM performance under some circumstances (e.g., when the importance of PM task is emphasized (Kliegel, Martin, McDaniel, & Einstein, 2001) or when the PM task context is specified (Cook, Marsh, & Hicks, 2005)). The theory also proposes that relatively spontaneous processes may support PM performance under other circumstances (for elaboration, see Einstein et al., 2005; McDaniel & Einstein, 2007; Scullin, McDaniel, Shelton, & Lee, 2010). The present study was designed to explore two spontaneous (nonstrategic) processes that have been proposed to contribute to PM retrieval.

One spontaneous process that could support PM retrieval is familiarity. According to McDaniel (1995), an item with high familiarity may be recognized as significant (similar to context-free recognition; cf. Mandler, 1980), thereby stimulating a search for the source of that significance. This search may in turn lead to or facilitate retrieval of the PM intention. Briefly, there are several reasons why PM targets may provide relatively high levels of familiarity. One is that encoding of

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events (items) as PM targets increases the activation of those items, as compared to nontargets. Consequently, during the subsequent PM task the higher activation of PM targets relative to the nontargets confers higher familiarity to the targets (McDaniel, 1995). Another factor that could increase familiarity for PM targets is ease of processing (Jacoby, 1983; Jacoby & Dallas, 1981; Jacoby & Whitehouse, 1989; Lindsay & Kelley, 1996). According to Jacoby and his colleagues, the ease of processing a stimulus is often interpreted as a basis for familiarity. Previous exposure to the PM targets during PM intention formation might increase the ease of perceptual (and/or semantic) processing of the PM targets when they are later encountered. Given people's tendency to interpret fluently processed items as being familiar (e.g., Jacoby & Whitehouse, 1989; Lindsay & Kelley, 1996), PM targets would be perceived as highly familiar relative to the less fluently processed nontargets that were not presented during PM intention formation. Regardless of the particular process underlying familiarity, for the present purposes the key idea is that the higher familiarity of a PM target may signal its significance (cf. Mandler, 1980).

One problem with the familiarity view is the potential lack of diagnosticity of familiarity vis-à-vis the PM target (McDaniel, 1995; McDaniel et al., 2004). Familiarity could serve as a useful signal for the significance of the PM target only if the PM target were highly familiar relative to nontargets that were encountered, which is not always the case. For instance, if the PM intention were to deliver a message to a colleague at a party with many other colleagues, both the PM target (the colleague who needs to receive the message) and the nontargets (colleagues from the same office) would be highly familiar. Accordingly, familiarity would not necessarily provide a diagnostic signal for the PM target.

As an alternative, the discrepancy-plus-search view has been proposed (McDaniel & Einstein, 2000; McDaniel et al., 2004). This view is based on Whittlesea and Williams's (1998, 2001a, b) theory that people are chronically sensitive to situations in which the actual processing quality of a stimulus differs from the expected processing quality of that stimulus. When a discrepancy is perceived between the actual and the expected processing quality, the cognitive system attempts to resolve this discrepancy by attributing the discrepancy to a viable source. The particular attribution will vary depending on the context; in much previous work, the context (an explicit memory test) led to an attribution that the stimulus was a memory target (Whittlesea & Williams, 2001a, b).

McDaniel et al. (2004; see also McDaniel & Einstein, 2000) proposed that in the context of PM tasks, discrepancy might be interpreted as a signal of the significance of the stimulus. Thus, according to the discrepancy-plus-search view, having a mismatch between the actual quality and the expected quality of processing an item (e.g., a PM target) can signal discrepancy. This discrepancy is reconciled by the attribution that the item is significant. This attribution then leads to consideration of why that item is significant, which may facilitate retrieval of the PM intention associated with that item. Importantly, this process could occur even when the PM target and the nontargets both have high familiarity. Returning to the previous example, when one sees his colleagues, the cognitive system has an expectation about the coherence of processing that will be experienced. After forming the PM intention to deliver a message to a particular colleague, it could be the case that the processing of encountering that colleague diverges from the processing quality expected, possibly because one thought about that colleague when intending to deliver a message (hence changing the processing experience/quality for that colleague). This mismatch between the expected and the actual quality of processing would result in a discrepancy, leading to an attribution of significance and possible PM retrieval. Note that the discrepancy-plus-search view assumes that PM targets that are also less familiar, as compared to nontargets, can be noticed as significant as long as their actual quality of processing mismatches an expected quality of processing. Thus, a theoretical advantage of discrepancy relative to familiarity is the potentially greater diagnosticity of discrepancy than of familiarity in terms of spontaneously alerting a person to the presence of a PM target.

A few studies have reported findings consistent with the discrepancy-plus-search view. Guynn and McDaniel (2007) implemented conditions that either exposed or did not expose PM targets prior to the PM instruction. More specifically, during a recognition memory task that preceded the PM instruction, PM targets were among the studied stimuli for participants in the preexposure condition, whereas PM targets were not among the studied stimuli in the no-preexposure condition. After the recognition memory task, participants in both conditions received the same PM instruction. Guynn and McDaniel found that PM performance was greater in the preexposure condition than in the no-preexposure condition. The interpretation according to the discrepancy-plus-search view of this finding is that the quality of processing experienced when encountering the preexposed PM targets differed from that expected in the context of processing stimuli (the nontargets) that were not preexposed, thereby leading to high discrepancy for preexposed PM targets. This high discrepancy may have led to an attribution of significance to the PM targets, which in turn could stimulate subsequent retrieval of the PM intention. In the no-preexposure condition, the quality of processing for the (not preexposed) PM targets would be more comparable to that established by the nontargets, thereby minimizing discrepancy and any attribution of significance to the PM targets. This finding is not theoretically decisive, however, as the familiarity view could also provide a ready account for the results. This view would assume that the PM targets in the preexposure condition had higher familiarity than did those in the no-preexposure condition, thereby leading to better PM performance.

To better disentangle the discrepancy-plus-search and familiarity views, Breneiser and McDaniel (2006) elicited discrepancy by manipulating the preexposure of nontargets. During a recognition task preceding the PM task, participants were preexposed to the nontargets either two or five times. Then, all of the participants were exposed to the PM targets during the PM instructions. Discrepancy was assumed to be higher between the PM targets and the nontargets that were preexposed five times than between the PM targets and the nontargets preexposed twice (because the context of highly preexposed nontargets would set a standard of processing that would be relatively discrepant from the actual processing of a minimally exposed PM target). Breneiser and McDaniel found higher PM performance in the high-discrepancy condition (in which the nontargets were preexposed five times) than in the low-discrepancy condition (in which the nontargets were preexposed twice). According to the familiarity view, increasing the nontarget familiarity, as in the high-discrepancy condition, should not enhance, and perhaps would interfere with, PM performance. More importantly, the familiarity view cannot accommodate these results because the equal exposure to the PM targets (during the PM instructions) should have led to the same level of familiarity for PM targets across the two nontarget exposure conditions.

One potential problem with Breneiser and McDaniel's (2006) paradigm is the possibility that participants in the high-discrepancy condition were consciously aware of the difference between the PM targets and the nontargets. That is, perhaps the participants remembered the extensive preexposure (i.e., studying and being tested) for the nontargets during the PM task, so that the PM targets clearly stood out upon being encountered (because it would be obvious that the PM targets were items that had not been extensively preexposed). If that were the case, the higher PM performance in Breneiser and McDaniel's study may not have reflected discrepancy processes as identified by Whittlesea and Williams (1998, 2001a), since these processes are assumed to operate below the threshold of awareness.

The purpose of the present study was twofold. According to Whittlesea and Williams's (1998, 2001a) theory, discrepancy detection is not a process in which people consciously engage. Rather, the cognitive system is chronically attuned to discrepancy. To more convincingly reveal that discrepancy processes akin to those proposed by Whittlesea and Williams play a role in PM, we developed a paradigm that more closely matched the features of Whittlesea and Williams's paradigms. Specifically, we manipulated the ease of processing PM targets and nontargets in a way that was not explicit to the participants. Second, we wanted to address a limitation of previous studies that have manipulated the ease of processing for either PM targets or nontargets alone (Breneiser & McDaniel, 2006; Guynn & McDaniel, 2007). Thus, we orthogonally manipulated the processing fluency of the PM target and nontargets.

Before describing the manipulations, we will briefly present the PM paradigm. Usually in a laboratory PM paradigm, participants are told to focus on an ongoing task. Additionally, the participants are provided with PM instructions, such as "press the 1 key when a particular word (PM target) appears during the ongoing task." We used an anagram solution task with two levels of solution difficulty (easy vs. difficult) as our ongoing task for several reasons. First, it is relatively straightforward to implement different levels of anagram solution difficulty, thereby fostering processing quality differences. Second, we believed that our implementation of anagram difficulty, unlike the paradigm used by Breneiser and McDaniel (2006), was subtle enough that participants would not consciously detect this difference. Third, with anagrams we could use subliminal priming to influence the ease of solving the anagrams (see, e.g., Weldon, 1991). Using this technique to augment the difference in the quality of processing associated with the two different types of anagrams, we reasoned that we would be able to maximize discrepancy without the participants' explicit awareness. A pilot study was conducted to test the validity of the materials used in the present experiment and the validity of the priming manipulation in influencing the ease of solving anagrams without explicit awareness (details are described in the Method section).

On the basis of Whittlesea and Williams's (1998, 2001a, b) theory, we wanted the participants in the present experiment to build a certain expected quality of processing while solving the anagrams in the list. Specifically, we reasoned that when repeatedly solving anagrams with a certain level of difficulty (nontarget anagrams), participants would develop an expectation about the quality of processing for upcoming anagrams. We reasoned that in this context, a PM target with a different level of difficulty would produce a quality of processing that would be discrepant from the expectation that had been developed. For instance, when an easy PM target anagram was presented in the context of a list of easy nontarget anagrams, the actual difficulty of that PM target anagram (easy) and the expected difficulty of that item (easy) would not differ, thereby signaling little, if any, discrepancy. By contrast, if a relatively difficult PM target anagram was presented after a list of easy (nontarget) anagrams, the actual difficultly for that PM target anagram (difficult) would mismatch the expected difficulty for that PM target (easy), thereby creating discrepancy. Presumably, this discrepancy could be attributed as the significance of the PM target, which would in turn lead to a search for the source of that significance. Along the same line of reasoning, for a list of difficult nontarget anagrams, the condition with a difficult PM target should signal little discrepancy, whereas the condition with an easy PM target should signal (high) discrepancy. The discrepancy-plus-search view thus predicts an interaction such that PM performance will be higher for the difficult PM targets in the easy list and the easy PM targets in the difficult list, as compared to the difficult PM targets in the difficult list and the easy PM targets in the easy list.

In contrast, the familiarity view (McDaniel, 1995) presumes that PM retrieval is prompted by high familiarity. To the extent that ease of processing can be interpreted as high familiarity (e.g., Lindsay & Kelley, 1996), fluently processed, easy PM targets could create a sense of familiarity. We believed that differences in the ease of processing the anagrams would confer different levels of familiarity for those anagrams, on the basis of previous studies that have found increased familiarity judgments for easily processed stimuli (Lindsay & Kelley, 1996). Thus, according to the familiarity view, PM performance in the conditions with easy PM targets would be expected to be higher than that in the conditions with the difficult (less fluent) PM targets. That is, a main effect of PM target difficulty would be predicted, accompanied by no interaction with the difficulty of the nontargets.

While we designed the paradigm to tease apart two potential underlying processes of spontaneous retrieval of PM, it was still possible for participants to engage in strategic, resource-consuming monitoring processes to perform the PM task as well (McDaniel et al., 2004; Smith, 2003). Thus, *monitoring cost* was assessed in order to measure the extent to which participants engaged in monitoring (Smith, 2003). In order to compute monitoring cost, a control block of trials was needed in which the participants would perform only an ongoing task. Accordingly, in addition to the PM block, a control block was performed by all participants. Following the literature (e.g., Einstein et al., 2005; Scullin, McDaniel, Shelton, et al., 2010; Smith, 2003), we reasoned that if participants were engaging strategic, resource-consuming monitoring processes to recognize an item as a PM target, then RTs in the PM block should be significantly slower than RTs in the control block.

Note that if we were to find the interaction predicted by the discrepancy-plus-search view in the presence of monitoring, current monitoring theories could not easily provide an adequate explanation for why strategic monitoring processes would facilitate PM performance more for the discrepant PM targets. However, the multiprocess theory suggests that participants may engage in both strategic and spontaneous processes to support PM performance (Einstein & McDaniel, 2010; McDaniel & Einstein, 2007; McDaniel et al., 2004). Therefore, finding the interaction in the presence of monitoring costs would suggest that discrepancy processes stimulated retrieval on trials in which monitoring was not sustained (cf. Scullin, McDaniel, & Einstein, 2010; West & Craik, 1999).

Method

Design and participants

The experiment was based on a 2 × 2 × 2 mixed factorial design, with Anagram Solution Difficulty of the PM Targets (easy vs. difficult) and Anagram Solution Difficulty of the Nontargets (easy vs. difficult) as between-subjects factors and Block Type (PM vs. control) as a within-subjects factor. A group of 112 participants participated in exchange for partial course credit or monetary compensation, with 28 of the participants randomly assigned to each of the four experimental conditions.

Materials

A total of 82 six-lettered words drawn from the English Lexicon Project (Balota, Yap, Cortese, Hutchison, Kessler, et al., 2007) were used. The log-transformed hyperspace analogue to language (HAL) frequency of the words ranged from 5.5 to 10.48 ($M = 7.98$, $SD = 0.54$). Two words were chosen (“orange” and “lawyer”) to form PM target anagrams. The 80 words were used to form nontarget anagrams and were divided into two 40-word anagram lists. We counterbalanced which list was used during the PM block or the control block and which block was presented first. For the 82 words, two sets of anagrams, 82 easy and 82 difficult, were constructed. The easy anagrams were assembled by switching two letters adjacent to each other (e.g., “orange” to “roange”). The difficult anagrams were assembled by changing the positions of two letters that were not adjacent to each other (e.g., “orange” to “oganre”).

Priming was used to maximize the difference between the processing fluency levels for the easy and difficult anagrams. For the easy anagrams, the anagram solutions were briefly flashed (40 ms) right before the presentation of the anagram. For the difficult anagrams, words that shared the same first and last letters with the difficult anagrams were briefly flashed (40 ms). The words that preceded the difficult anagrams were not semantically associated with the solutions to the difficult anagrams.

A pilot study was conducted to validate the difficulty of both the easy and the difficult anagrams with the priming manipulation. In the pilot study, we asked 21 participants to press the “q” key if any anagram(s) stood out from a list of 54. Interspersed in the list was a subset of four anagrams that were more or less difficult than the majority of the list items. For example, some participants received a list of difficult anagrams (along with the unassociated prime) with four easy anagrams (and the solution prime), while others received a list of easy anagrams with four difficult ones. Very few keypresses were observed on anagrams from the target subsets (eight out of 61 observed keypresses). This finding suggests that the pilot participants could not easily or with much accuracy consciously identify which anagrams were more or less difficult. We used the same materials in the present experiment to discourage participants from being able to consciously identify the source of the manipulated discrepancy. Furthermore, in the pilot study we found that the participants took longer to solve the difficult anagrams (M = 6,202 ms) than the easy anagrams (M = 3,516 ms), $t(19) = –3.89$, $p = .001$. Also, upon completing each anagram, the participants were asked to rate the difficulty of the anagram solution with ratings ranging from 1 to 6 (with 1 being *easy* and 6 being *difficult*). They rated the difficult anagrams as being more difficult (M = 1.95) than the easy anagrams (M = 1.31), $t(19) = –3.89$, $p < .001$.

Procedure

The experimental participants were tested in groups of one to four. All stimuli were presented on a 17-in. Dell LCD monitor with a resolution of 1,024 × 768 pixels and a refresh rate of 60 Hz. The program was written with the E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA; Schneider, Eschman, & Zuccolotto, 2002).

Participants sat in front of the computer monitor and were provided with a keyboard for their responses. First, they were given instructions for the Raven's Advanced Progressive Matrices task (*Raven's task*; Raven, Raven, & Court, 1998) and the anagram task, each followed by a few practice trials. The Raven's task was used as a distractor task so that there would be an interval between the PM instruction and the actual PM task. The 36 problems from the Raven's task were divided into two subsets of 18 problems, one subset having the odd-numbered problems and the other having the even-numbered problems. Each subset preceded the first and the second block of anagrams (i.e., the control and PM blocks). For the Raven's task, participants were told to pick the number of the piece that best completed the pattern on the monitor and to proceed to the next trial at their own pace. For the anagram task, participants were told to solve the anagrams presented on the monitor by typing in the solution and pressing the Enter key to proceed to the next anagram. Each anagram was presented until either the Enter key was pressed or the designated 30 s was up. Then, the next anagram was presented.

After the initial instructions and the practice trials for each task, the first set of the Raven's and anagram tasks was presented to the participants. Prior to the start of the first set of tasks, participants who had the PM block first received the PM instruction on the monitor: It asked participants to press the "q" key if they saw any anagrams for "orange" or "lawyer" during the anagram task; no actual anagrams for those words were shown during the instruction or during the practice trials for the anagram task. Participants who had the control block first received this instruction after the completion of the first set of the Raven's and anagram tasks.

To ensure full understanding of the PM instruction, participants were asked to write down a summary of it, including the PM targets that were to be responded with the "q" key. After reading and summarizing the PM instruction, participants then solved the Raven's task for 5 min. Upon the completion of the Raven's task, participants solved either 42 or 40 anagrams, depending on the counterbalanced block order: 42 with the PM block first, or 40 with the control block first. The PM targets were presented on the 16th and 36th trials of the PM block. At the end of each Raven's and each anagram task, the participants were told on the monitor that the particular task was over and the next task was to be started.

For the participants who received the PM block first, immediately after the first set of the Raven's and anagram tasks was over, the participants were told that they would no longer be required to press the "q" key or look for any specific words (the PM targets). Once the first set of tasks was completed and the appropriate instructions were given, participants solved a second set of the Raven's and anagram tasks. The anagram solution difficulty level of the nontargets was the same for both the first and second anagram tasks. After the second anagram task, participants were given the posttest questionnaire to check their retrospective memory for the PM targets. Upon completion of the questionnaire, the participants were debriefed.

Results

An alpha level of .05 was set for the statistical significance of all statistical analyses, unless noted otherwise. Performance on the Raven's task, which was used as a distractor task, was not analyzed.

PM performance

The accuracy of PM performance was computed by dividing the number of correct PM responses by the number of correctly solved PM target anagrams. A correct PM response was pressing the "q" key after presentation of the PM target anagrams. A total of 11 (out of 224) PM target anagrams across conditions were not solved, and there were no PM responses for these unsolved anagrams. Consequently, these PM target anagrams were excluded from the analysis. A 2 × 2 between-subjects analysis of variance (ANOVA) was conducted on the mean PM performance, with Anagram Solution Difficulty of the PM Targets and Nontargets (easy vs. difficult) as a between-subjects factor (see Table 1 for the means). Neither the anagram solution difficulty of the PM targets ($F < 1$) nor that of the nontargets ($F < 1$) produced significant effects. However, the anagram solution difficulty of the PM targets did interact significantly with that of the nontargets, $F(1, 108) = 4.10$, $MSE = .066$. Examination of Table 1 reveals that this interaction resulted because PM performance from the discrepant conditions (in which the anagram solution difficulty of the PM targets mismatched with that of the nontargets) was greater than PM performance from the nondiscrepant conditions (in which the anagram solution difficulty of the PM targets matched with that of the nontargets). Follow-up comparisons revealed a significant advantage for difficult PM targets in the discrepant relative to the nondiscrepant condition, $F(1, 108) = 4.34$, $MSE = .066$; although the easy PM targets were nominally advantaged in the discrepant relative to the nondiscrepant condition, the difference was not significant ($F < 1$).

Given the high level of performance across conditions and the small number of PM trials, we also conducted a binary logistic regression.[1] If discrepancy indeed facilitated PM performance, one might predict more PM failures in the nondiscrepant than in the discrepant conditions. Thus, we wanted to see whether PM failure would be explained by discrepancy (or lack thereof). Furthermore, because there were only a few PM failures, we coded missing either one or two of the PM targets as nonperfect performance, while responding to both PM targets was perfect performance. PM performance was entered as the criterion variable (1 = *perfect performance*, 0 = *nonperfect performance*). The anagram difficulty of the list and of the PM target were entered as predictor variables, as well as the interaction term (of list anagram difficulty and PM target anagram difficulty). The interaction term was the only one that explained a marginally significant proportion of the variance in PM accuracy ($p = .08$).

Table 1 Mean proportions of correct prospective memory (PM) performance as a function of the PM target and nontarget difficulty

	Easy PM Target	Difficult PM Target
Easy nontarget	.89 (.05)	.98 (.05)
Difficult nontarget	.95 (.05)	.84 (.05)

Standard errors are provided in parentheses

Anagram task

Accuracy Accuracy in the anagram task was computed by taking the proportion of anagrams correctly solved for each block. PM target anagrams were excluded in this analysis. Accuracy of the anagram task was entered into a 2 × 2 × 2 × 2 mixed ANOVA, with Block Type (PM vs. control) as a within-subjects factor and Block Order (PM block first vs. control block first) and Anagram Solution Difficulty of the PM Targets and Nontargets (easy vs. difficult) as between-subjects factors. We found a significant effect of the anagram solution difficulty of the nontargets, $F(1, 104) = 66.24$, $MSE = .01$, in that participants solved more anagrams from the easy list ($M = .93$, $SD = .07$) than from the difficult list ($M = .82$, $SD = .08$). Note that the main effect of the anagram solution difficulty of the nontargets indicates that the manipulation of anagram solution difficulty was successful. A significant interaction emerged of the anagram solution difficulty of the PM targets with block order [$F(1, 104) = 5.30$, $MSE = .01$]. Follow-up *t* tests were not significant (*F*s < 1.77). Also, we found a significant block type by block order interaction [$F(1, 104) = 4.10$, $MSE = .003$]. Follow-up *t* tests showed that the overall accuracy on the anagram task was significantly higher in the control block ($M = .89$, $SD = .09$) than in the PM block ($M = .87$, $SD = .10$) if the PM block was presented first [$t(55) = -2.20$, $p = .032$]. The overall accuracy did not differ between the control and PM blocks (*M*s = .88 and .87, and *SDs* = .10 and .10, respectively) if the control block was presented first [$t(55) < 1$]. No other significant main effects or interactions appeared, including no interaction between the anagram solution difficulty of the PM targets and nontargets (*F*s < 2.13).

Reaction times (RTs) RTs to the anagrams were analyzed to see whether performing the PM task caused any slowing down of the ongoing anagram solution task. RTs to the anagrams were trimmed according to Einstein et al.'s (2005) method. Only the RTs from correctly solved anagrams were averaged for each block (PM vs. control), and RTs that were two standard deviations greater or two standard deviations smaller than the individual means were removed. The RTs were entered into a 2 × 2 × 2 × 2 mixed measures ANOVA with Block Type (PM vs. control) as a within-subjects factor and Block Order (PM block first vs. control block first) and Anagram Solution Difficulty of the PM Targets and Nontargets (easy vs. difficult) as between-subjects factors (see Table 2 for the means). A main effect of anagram solution difficulty of nontargets emerged, showing that people took longer to solve the difficult list of nontarget anagrams (4,560 ms) than to solve the easy list of nontarget anagrams (3,047 ms), $F(1, 104) = 38.38$, $MSE = 3{,}338{,}547$, again indicating that the anagram solution difficulty manipulation was successful. More importantly, we found no significant main effect of block type (PM vs. control; $F < 1$), and none of the interactions was significant (*F*s < 2.1), even with a relatively high power (power > .99)[2] to detect medium-sized effects. To examine possible monitoring costs in more detail, planned

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[1] We thank an anonymous reviewer for suggesting this analysis.

[2] Power was computed by G*Power statistical software (Faul, Erdfelder, Lang & Buchner, 2007).

Table 2 Mean reaction times for the prospective memory (PM) block and the control block as a function of the PM target and nontarget difficulty

	EListETarget	EListDTarget	DListETarget	DListDTarget
PM block	3,072 (251)	3,025 (251)	4,868 (251)	4,292 (251)
Control block	3,142 (252)	2,950 (265)	4,726 (265)	4,353 (265)

E indicates "easy" and D indicates "difficult." Standard errors are provided in parentheses

comparisons compared block types (PM vs. control) within each of the four conditions, and in the two discrepant versus nondiscrepant conditions collapsed (to increase the power even more); all of these comparisons were nonsignificant (*F*s < 1).

Functional monitoring cost In addition to monitoring costs at the block level (PM vs. control block), we computed functional monitoring costs following the procedure suggested by Scullin, McDaniel and Einstein (2010). Scullin et al. observed that monitoring costs at a block level do not necessarily reflect monitoring on all trials, and that if costs predominantly capture monitoring on trials that are not necessarily proximal to PM targets, then block-level monitoring costs will not capture the functional processes supporting PM performance. Accordingly, they suggested that the relative slowing of RTs on proximal trials that precede a PM target might be more diagnostic of the extent to which monitoring was involved in PM performance.

Thus, we analyzed the mean RTs for the five trials preceding each of the two PM targets from the PM block and the mean RTs for the comparable trials from the control block. A 2 × 2 × 2 × 2 mixed ANOVA with Block Type (PM vs. control) as a within-subjects factor and Block Order (PM block first vs. control block first) and Anagram Solution Difficulty of the PM Targets and Nontargets (easy vs. difficult) as between-subjects factors was conducted with those RTs. The results were similar to the block-level RT results. A main effect of anagram solution difficulty of the nontargets was found, $F(1, 104) = 32.28$, $MSE = 4{,}129{,}428$, such that people took longer to solve the difficult anagrams ($M = 4{,}567$ ms) than the easy anagrams ($M = 3{,}024$ ms). Planned comparisons were conducted to see whether any monitoring costs would appear for any particular condition (s). Except for the nondiscrepant condition with the difficult PM targets and the difficult nontargets [$F(1, 104) = 3.59$, $MSE = 1{,}194{,}088$, $p = .061$], none of the comparisons was significant. No other main effects or interactions were significant (*F*s < 2.62; see Table 3 for the means).

Discussion

The purpose of this experiment was to illuminate two possible spontaneous PM retrieval processes, discrepancy and familiarity. We found higher PM performance in the conditions with high discrepancy between the processing established by the nontargets and the processing required by the PM target, relative to when that discrepancy was low. No significant monitoring costs accompanied this higher performance. Countering the assumption that high familiarity, presumably associated with fluently processed PM targets, may facilitate PM retrieval, PM performance did not differ between the easy and difficult targets. Below we discuss the theoretical implications of these results.

The most theoretically important finding was that discrepancy enhanced PM performance. As we mentioned earlier, only the discrepancy-plus-search view (McDaniel et al., 2004) predicted that the mismatch between the anagram solution difficulty of the PM targets and the nontargets would enhance PM performance. When considering the factors that enhance PM performance, most of the existing theories are concerned with the nature of the PM targets (Einstein & McDaniel, 1990; McDaniel, 1995; McDaniel & Einstein, 1993; Smith, 2003; however, see Maylor, 1996; McDaniel & Einstein, 2000; Meier & Graf, 2000; Scullin, McDaniel, & Einstein, 2010; West & Craik, 2001). By contrast, the discrepancy-plus-search view anticipates that discrepancy processes that are influenced by the context in which the PM target occurs can facilitate PM retrieval, sometimes more so than by the features of the PM target itself (e.g., in this case, the processing fluency of the target).

Table 3 Mean reaction times for the five trials preceding each of two prospective memory (PM) targets in the PM block and the comparable trials in the control block as a function of the PM target and nontarget difficulty

	EListETarget	EListDTarget	DListETarget	DListDTarget
PM block	3,071 (284)	2,949 (284)	5,058 (284)	4,030 (284)
Control block	3,134 (331)	2,943 (331)	4,598 (331)	4,583 (331)

E indicates "easy" and D indicates "difficult." Standard errors are provided in parentheses

Previous work relating to the discrepancy view (e.g., Breneiser & McDaniel, 2006; Guynn & McDaniel, 2007) had provided somewhat contestable support for the involvement of discrepancy processes in PM retrieval. Guynn and McDaniel's study was ambiguous because their discrepant PM targets were also highly familiar, allowing the possibility that familiarity, instead of discrepancy, could have enhanced PM performance. The present results clearly ruled out a familiarity interpretation, because PM performance for the easy PM targets, presumed to be highly familiar because of their greater fluency of processing (stimulated by the simple nature of the anagram, the priming of the solution, or both), was not better than performance for the difficult PM targets. Instead, when the difficult PM targets were presented in a context (easy anagrams) that created discrepancy between expected processing and the actual processing, PM performance was higher than for the easy PM targets (presented in the same context).

Breneiser and McDaniel's (2006) finding was inconclusive because their paradigm might not have reflected the discrepancy attribution processes proposed by Whittlesea and Williams (2001a), particularly discrepancy detection, which operates under the threshold of awareness. In the pilot study (described in the introduction and the Method section), we found that participants were not able to identify a subset of anagrams that were more or less difficult than the rest of the anagrams, suggesting that participants were not consciously aware of the discrepancy manipulation. Consequently, we argue that participants in the present experiment were likely not consciously aware of the manipulation. Thus, our findings provide the most unambiguous support to date that discrepancy attribution contributes to spontaneous retrieval in PM.

Another interesting finding was that the higher PM performance in the discrepant conditions was not accompanied by significant monitoring costs in the RT data. This finding supports the multiprocess theory's notion that strategic monitoring is not always necessary, but instead that spontaneous retrieval can facilitate PM performance under certain circumstances (Einstein et al., 2005; McDaniel & Einstein, 2000; McDaniel et al., 2004). Still, some might suggest that the absence of monitoring costs in our RT data is inconclusive in light of the use of an anagram solution task as the ongoing activity. Several studies that have found significant monitoring costs have used a lexical decision task as the ongoing activity, which usually yields relatively fast RTs (e.g., ranging between 500 and 1,300 ms; Einstein et al., 2005; Smith, 2003). In contrast, the RTs for anagram solution responses from the present study were substantially longer (ranging between 2,000 and 5,000 ms). Thus, one might assert that monitoring processes could be engaged without apparent costs because of the relatively long time frame within which the anagram puzzles were solved (thereby allowing participants to "sneak in" monitoring; cf. Reitman, 1971). One might further suggest that the significant interaction of block type and block order in the ongoing-task accuracy data reflects that the monitoring costs did emerge for response accuracy (instead of for RTs). Accordingly, we acknowledge that it remains possible that participants could have engaged in monitoring processes.

Importantly, however, even if participants were monitoring, for a monitoring view to account for the PM patterns, that view would have to provide a reasoned explanation for why participants would engage in strategic monitoring processes more in discrepant than in nondiscrepant conditions. According to the literature, a number of factors may modulate the engagement of monitoring processes, including the nature of the PM instruction (Einstein et al., 2005) and the ongoing task demands (Marsh & Hicks, 1998). In our experiment, however, the PM instruction (e.g., "press the 'q' key when you see anagrams for 'orange' and 'lawyer' ") was the same across all conditions. Furthermore, the difficulty of the ongoing task was identical (for the nontargets) in the discrepant and nondiscrepant conditions. In short, no apparent factor would have encouraged monitoring processes more in the discrepant than in the nondiscrepant conditions, and thus we conclude that discrepancy processes represent the most plausible account of the present PM results.

We emphasize that we are not claiming that discrepancy-plus-search is the only mechanism that supports PM performance, even in the present experiment. For instance, in the nondiscrepant conditions, PM accuracy was greater than 80%, a level of performance that might be considered relatively high for conditions presumed to be low in discrepancy. According to the multiprocess theory (McDaniel & Einstein, 2000; McDaniel et al., 2004), PM is supported through various processes. Thus, it could have been the case that, on a proportion of the trials, PM performance was supported by monitoring (see Einstein & McDaniel, 2010). As well, perhaps the relatively high familiarity of the PM targets, familiarity accruing from the exposure of the target during the instruction, might have contributed to PM retrieval. These other possible mechanisms notwithstanding, it remains that the relative patterns of PM across the discrepant and nondiscrepant conditions support the view that discrepancy-plus-search processes can be involved in PM retrieval (McDaniel & Einstein, 2000; McDaniel et al., 2004).

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