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An investigation into the resource requirements of event-based prospective memory

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The multiprocess view proposes that both strategic and automatic processes can support prospective memory. In three experiments, we embedded a prospective memory task in a lexical decision task; cues were either highly associated with response words or had no relation. Analyses of RTs on ongoing task trials indicated that (1) prospective memory was more dependent on the allocation of resources immediately prior to cue presentation under conditions of low association in comparison with high association and (2) processes engaged on cue trials were more resource demanding under conditions of low association in comparison with high association. These data support the claim of the multiprocess view that prospective memory can be more resource demanding under some task conditions in comparison with others. However, the prospective memory performance data were less supportive, with declines in prospective memory due to task-importance and cue-frequency manipulations comparable across the low- and high-association conditions. Taken together, these results have implications for two prominent theories of prospective memory.

Remembering to perform previously planned actions at appropriate points in the future is referred to as prospective memory (hereafter abbreviated as PM). Event-based PM tasks require individuals to remember to perform an action when a particular event occurs in the environment (e.g., remembering to stop at the post office when driving past), and are commonly distinguished from time-based PM tasks that require actions to be performed after the passage of a certain amount of time (Einstein & McDaniel, 1990; Kvavilashvili & Ellis, 1996). In everyday, event-based PM situations, individuals are often busily engaged in other activities in the time interval between planning an action and the time that an environmental cue is encountered. In order to execute the delayed intention, individuals must interrupt these ongoing activities. Similarly, laboratory-based PM tasks typically require participants to perform a special action (e.g., press the F1 key) upon presentation of a specific cue (e.g., the word *dog*) while performing an unrelated ongoing activity (e.g., rating words; Einstein & McDaniel, 1990). The defining feature of event-based PM tasks is that, unlike retrospective memory tasks, there are no external agents (e.g., experimenter, printed instructions) directing participants to engage in a memory search. Instead, PM tasks require individuals to self-initiate the recollection of intentions in response to cues.

Theoreticians have put forward several explanatory frameworks regarding the processes that subserve PM, ranging from the view that these processes are strategic and require the allocation of cognitive resources (Burgess & Shallice, 1997; Ellis, 1996; Guynn, 2003; Shallice & Burgess, 1991; Smith, 2003; Smith & Bayen, 2004), to the view that these processes are automatic (Einstein & McDaniel, 1996; Guynn, McDaniel, & Einstein, 2001; McDaniel, 1995; McDaniel, Robinson-Riegler, & Einstein, 1998). McDaniel and Einstein (2000; see also McDaniel, Guynn, Einstein, & Breneiser, 2004) proposed the *multiprocess view*, which takes into account evidence for both strategic and automatic processes. The multiprocess view specifies the task conditions under which PM is more likely to rely on automatic processes, such as when there is a high degree of association between PM cues and intended responses.

In the present article, we focus on the multiprocess view and report a series of experiments designed to evaluate the mechanisms that this theory proposes underlie PM. In order to do this, we draw on one particular instantiation of the strategic view known as the *preparatory attentional and memory processes (PAM)* theory of PM (Smith, 2003; Smith & Bayen, 2004). The PAM theory proposes that PM requires the engagement of various cognitive processes that draw on a limited resource capacity. As a consequence, individuals have fewer resources available to perform ongoing tasks, and response costs to ongoing tasks are incurred. The multiprocess view predicts that PM can be less reliant on the resource-demanding processes specified by the PAM theory under some conditions in comparison with others. Three experiments examined the extent to which holding event-based intentions produced response costs to ongoing tasks under conditions of high and low cue–response association, and the relative extent to which these response costs were functionally related

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to PM performance at the within-subjects level. Furthermore, we manipulated factors (task importance and PM cue frequency) that were expected to influence the magnitude of these response costs. To the extent that resources are required for PM under conditions of low and high cue–response association, these variations in response costs should be indicative of PM performance.

Multiprocess View

According to the multiprocess view of PM (McDaniel & Einstein, 2000; McDaniel et al., 2004), both strategic and automatic processes play a role in PM, and the relative contribution of each depends on task conditions. More specifically, the processes underlying PM are more likely to be automatic when intended responses are simple, PM cues are distinctive, ongoing tasks encourage the focal processing of PM cues, or when cues are highly associated with responses. Under such conditions, attention to a PM cue is more likely to lead to the reflexive or obligatory retrieval of intended responses, without interference to ongoing tasks (*reflexive-associative processes*; Guynn et al., 2001; McDaniel et al., 2004; McDaniel et al., 1998). Under other task conditions, the processing of cues is less likely to lead to the automatic retrieval of intentions, and successful PM performance is dependent on the strategic processes required to notice the significance of the cue and to retrieve the intended response (*cue-focused processes*; McDaniel et al., 2004).

Recent research has provided support for the increased automaticity of PM under conditions in which ongoing tasks encourage the focal processing of PM cues (Einstein et al., 2005; Kliegel, Martin, McDaniel, & Einstein, 2004), or in which cues are highly associated with responses (Marsh, Hicks, Cook, Hansen, & Pallos, 2003; McDaniel et al., 2004). Einstein et al. (2005) and Kliegel et al. (2004) found that emphasizing the importance of an ongoing task relative to a PM task decreased PM performance in nonfocal cue conditions relative to PM performance in focal cue conditions. McDaniel et al. (2004) asked participants to remember to write down specific response words when presented with cue words during a word-rating task. In the high-association condition, cue words were highly associated with response words (e.g., *spaghetti–sauce*), whereas in the low-association condition, cue and response words were not associated (e.g., *thread–sauce*). The addition of a secondary digit-monitoring task, or preexposure of noncues (thereby making them less distinctive from cues), significantly reduced PM performance in the low-association relative to the high-association condition. This finding suggests that PM is more resource demanding under conditions of low association in comparison with high association.

An alternative method for exploring the resource requirements of PM tasks is to examine response costs to ongoing tasks and their relationship to PM performance (e.g., Marsh et al., 2003; Smith, 2003). This will be the method used in the present study. As described next, the PAM theory was used as a basis for describing the resource-demanding processes that support PM, and for describing how both the presence and functionality of these processes can be measured through ongoing task performance.

Resource Demands of Prospective Memory Tasks

It is common for theoreticians to divide PM tasks into their prospective and retrospective components (e.g., Einstein & McDaniel, 1990; Graf & Uttl, 2001). The PAM theory makes a similar distinction between preparatory attentional processes and retrospective memory processes (Smith, 2003; Smith & Bayen, 2004). According to the PAM theory, the realization of delayed intentions requires that individuals be prepared for the presentation of PM cues by engaging preparatory attentional processes. These processes serve to maintain individuals in a general state of readiness to perform PM tasks and facilitate the processing of cues. Given that preparatory attention is required before individuals know an item is a cue, these processes will be engaged on noncue trials as well as cue trials. Furthermore, the PAM theory claims that preparatory attention is functionally related to PM performance, such that the amount of preparatory attention directed toward the PM task will be positively related to PM performance. In addition to preparatory attention, the PAM theory proposes that retrospective memory processes are required on cue trials to discriminate between cues and noncues (i.e., detect cues) and to recollect intended responses.

Research has provided support for the role of preparatory attention in PM. First, findings that the addition of a demanding secondary task reduces PM performance (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh, Hancock, & Hicks, 2002; Marsh & Hicks, 1998) support the claim that PM requires cognitive resources. Second, PM tasks embedded in ongoing tasks have been shown to slow performance on noncue ongoing task trials (Brandimonte, Ferrante, Feresin, & Delbello, 2001; Guynn, 2003; Marsh, Hicks, & Cook, 2005; Marsh et al., 2003; Smith, 2003; Smith & Bayen, 2004). Third, response costs on noncue trials have been found to positively correlate with PM performance (Smith, 2003; Smith & Bayen, 2004), and response costs on trials preceding PM hits have been found to be larger than response costs on trials preceding PM misses (West, Krompinger, & Bowry, 2005). Both these effects demonstrate functional relationships between preparatory attention and PM performance.

In addition to the preparatory attention engaged on both noncue and cue trials, retrospective memory processes are required on PM cue trials to detect cues and retrieve responses. It has been demonstrated that response times (RTs) on PM cue trials, in which participants successfully remembered to perform intentions, can be 300–400 msec slower than RTs on noncue trials (Marsh, Hicks, & Watson, 2002; Marsh et al., 2003). By subtracting RTs on noncue trials control matched to cue trials, Marsh et al. (2002, 2003) eliminated response costs on cue trials that were supposedly due to preparatory attention. The interpretation of this finding (see also McDaniel et al., 1998; Smith, 2003) was that the increased response costs on cue trials were due to the influence of four processes: (1) the recognition of cues required for cue detection, (2) the verification of those cues, (3) the retrieval of responses, and

(4) the coordination of PM responses with ongoing tasks. Furthermore, the relative contribution of these processes to cue trial interference can be dissociated. For example, Marsh et al. (2003) found greater response costs on cue trials in an unrelated cue condition in comparison with a related cue condition. Given that both the PM response ("/" key) and PM coordination requirement (keypress) were held constant across conditions, these differences in cue trial interference can be attributed to variations in the resource requirements of cue-detection (i.e., recognition and verification) processes.

In summary, research has shown that both preparatory attentional and retrospective memory processes are fundamental components of PM, and that they can be estimated by examining RTs to ongoing tasks. These estimations can be used as a basis for assessing the relative automaticity of PM under low and high cue–response association conditions.

The Present Study

Three experiments are reported, which examined the relationship between ongoing task performance and PM performance under conditions of low and high cue–response association. The multiprocess view proposes that, under certain conditions, strategic processes are required for the detection of PM cues and retrieval of responses. Under these circumstances, PM should be dependent on the resource-demanding processes specified by the PAM theory. A critical assumption of the multiprocess view is that, under alternative sets of task conditions, the retrieval of intentions can be more automatic. Under such conditions, no prior identification of a cue's significance is required to prompt a memory search. Instead, mere attention to a cue brings the intended response to awareness (Moscovitch, 1994), bypassing the need to consciously detect a cue (McDaniel et al., 2004). Under these circumstances, PM should be less reliant on the resource-demanding processes specified by the PAM theory.

Despite the proposed increased automaticity of PM under conditions of high association, individuals under conditions of high association may nevertheless allocate resources to the PM task. Einstein et al. (2005) found that at least some participants demonstrated response costs to ongoing tasks under conditions that facilitated the automatic retrieval of intentions. If this is also the case here, response costs on noncue trials will be incurred under *both* low- and high-association conditions, presumably reflecting preparatory attention. Of greater relevance is that the multiprocess view predicts that the functional relationship between preparatory attention and PM performance will be stronger under conditions of low association in comparison with high association. We examined whether response costs on noncue trials were functionally related to PM performance at the within-subjects level by calculating the difference between RTs on trials preceding PM hits to RTs on trials preceding PM misses. If preparatory attention is functionally related to PM performance, RTs on trials preceding PM misses should be faster than RTs on trials preceding PM hits. This finding would indicate that a decrease in the allocation of preparatory attention had a detrimental effect on PM performance (West et al., 2005).

In addition, the multiprocess view predicts that PM processes (cue detection and/or response retrieval) engaged on cue trials should interfere less with ongoing tasks under conditions of high association in comparison with low association. More specifically, responses that are highly associated with cues (in comparison with responses that are less associated with cues) should be more automatically delivered to consciousness upon cue presentation, perhaps even bypassing the need to consciously detect cues (Einstein et al., 2005; McDaniel et al., 2004). In support of this, Marsh et al. (2003) found greater interference on cue trials under conditions of low in comparison with high association. Marsh et al. (2003) subtracted RTs on noncue trials from RTs on control-matched cue trials. We took an alternative approach, subtracting RTs on noncue trials that *directly preceded* PM cue trials from RTs on cue trials. The findings of Marsh et al. (2003) were expected to be replicated using this procedure.

In Experiments 2 and 3, we manipulated factors that were expected to decrease the extent to which preparatory attention was directed toward the PM task. These factors were the importance of the ongoing task (Experiment 2) and the frequency of cue presentation (Experiment 3). The rationale for these manipulations was twofold. First, the increased variability in RT data (and PM performance) would allow for a closer examination of the functional relationship between preparatory attention and PM performance. Second, if PM is more resource demanding under conditions of low association, PM performance under conditions of low association should be more affected by manipulations that decrease the preparatory attention directed toward PM tasks, in comparison with PM performance under conditions of high association.

EXPERIMENT 1

Experiment 1 included two PM conditions (low and high association) and a control condition. For the PM conditions, we embedded a PM task in a lexical decision task. Participants were instructed to remember to press the Enter key (and type response words) when presented with cue words during the lexical decision task. In the high-association condition, cue words were associatively related to response words. In the low-association condition, cue words were re-paired with response words so that there was no obvious associative relation. Participants in the control condition studied the same cue–response pairs and received identical instructions as did the participants in the PM conditions, but were instructed before the lexical decision task that they were no longer required to respond to cues.

Ongoing Task Response Times

We predicted that lexical decision RTs on noncue trials would be slower for the low- and high-association conditions in comparison with the control condition, reflecting the engagement of preparatory attention. The multiprocess view predicts that the functional relationship between preparatory attention and PM performance will be stronger under conditions of low association in comparison with high association. If this is the case, the difference in RTs on trials preceding PM hits in comparison with RTs on trials preceding PM misses should be larger under conditions of low association in comparison with high association. The multiprocess view also predicts that the PM cue-detection and/or response-retrieval processes engaged on cue trials will interfere more with the ongoing task under conditions of low association in comparison with high association. If this is the case, the differences between RTs on successful PM cue trials and RTs on trials that directly precede these cue trials should be larger under conditions of low association in comparison with high association.

Prospective Memory Performance

It was not clear whether PM performance would be affected by cue–response association. In full-attention conditions (i.e., no secondary task), Marsh et al. (2003) found improvements in PM performance for a high-association condition in comparison with a low-association condition. In contrast, McDaniel et al. (2004) found that cue–response association did not affect PM performance under conditions of full attention.

Method

Participants. A total of 78 students who were enrolled in undergraduate psychology classes at the University of Queensland volunteered to participate in return for course credit. There were 26 participants in each condition.

Materials. The presentation of stimuli and the collection of responses were accomplished through compatible PCs and a program written with E-Prime (Schneider, Eschman, & Zuccolotto, 2002). Sixty-six medium-frequency words were randomly chosen from the 1994 issues of *The Sydney Morning Herald* (*TSMH* word database; Dennis, 1995). Nonwords were created by removing the first syllable of each of the 66 words and placing it at the end of the letter string (Hunt & Toth, 1990). A pool of 8 critical words was selected from these 66 words, which were divided into two lists of 4 words each. For half of the participants, List 1 (*mouth*, *mature*, *reaction*, *plastic*) served as cue words, and List 2 (*actor*, *narrow*, *document*, *patient*) served as control words. For the other half of the participants, the reverse was true. Cue and control word lists were matched with respect to frequency and word length.

The 132 letter strings (66 words, 66 nonwords) were presented twice each, constituting a total presentation of 264 trials. The order of presentation of trials was random except for cues and matched control words, which occurred on fixed trials. For half of the participants, cues were presented on Trials 33, 66, 99, 132, 165, 198, 231, and 264, and control words on Trials 16, 49, 82, 115, 148, 181, 214, and 247. For the other half of the participants, the reverse was true. Cues were presented in a random order, with the exception that each cue was presented once before any cue was repeated. We repeated cues because the inclusion of small numbers of cues restricts the ability to detect effects (Maylor, 1996; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Including additional cues (>4) would have unnecessarily increased the demand on memory for recalling cue–response words. Our solution was based on the design of Smith (2003). We presented four cues twice each, while also repeating noncues to ensure that the distinctiveness of cues was not increased upon their repetition (Brandimonte & Passolunghi, 1994). Note that the presentation of cue and control words was alternated, such that any two cues were separated by 33 trials, and any two control words were separated by 33 trials.

High-association cue–response pair words were constructed by choosing the most frequent free associate to each target word using the University of South Florida word association norms (Nelson, McEvoy, & Schreiber, 1998). Half of the participants in the high-association conditions received (cue–response) *mouth–wash*, *mature–old*, *reaction–response*, and *plastic–bag* (List 1), and half received *actor–actress*, *narrow–wide*, *document–paper*, and *patient–doctor* (List 2). Low-association cue–response pairs were created by re-pairing the high-association pairs from List 1 and List 2 to create pairs without any preexisting association. Half of the participants in the low-association condition received *mouth–actress*, *mature–wide*, *reaction–paper*, and *plastic–doctor* (List 1), and half received *actor–response*, *narrow–old*, *document–wash*, and *patient–bag* (List 2).

Procedure. The experiment lasted approximately 40 min. The lexical decision task instructions informed participants that letter strings would be displayed on a computer screen and that they were required to decide as quickly and as accurately as possible whether or not each string was a word. Responses were made by pressing one of the two home keys (D = word, K = nonword). Each trial contained three displays. The first display instructed participants to press the space bar to initiate the next trial. The next display was a focus point, "+," displayed in black on a white background on the center of the screen. The duration of each focus point was randomly selected from a set of possible display times (437, 500, 562, 625, 687, 750, 822, or 886 msec) to ensure that participants could not anticipate the appearance of strings. The focus point was replaced by a string that remained on the screen until the participant made an appropriate response.

Next, participants in all of the conditions were given PM instructions. The experimenter told the participants that she was also interested in their abilities to remember to perform actions in the future. The PM instructions clearly specified that when a cue was detected, the word response to the ongoing lexical decision task should be made first and that the Enter key should be pressed (and the response word typed) during the subsequent waiting message between trials. Instructing participants to make ongoing task responses before PM responses is common practice (see, e.g., Marsh et al., 2002, 2003; McDaniel et al., 2004; Smith & Bayen, 2004). The participants were also instructed to type *X* in the text box if they detected a cue but forgot the paired response word.

After studying the cue–response words, the participants were given a memory test. In this test, the participants were given the first one or two letters of each cue word and were required to fill in the cue and response word. The participants who could not accurately recall all pairs were asked to study the list again. Next, in order to avoid ceiling effects, the participants completed a 5-min computer card task and a 5-min computer target-shooting task. After this retention interval, the lexical decision task was initiated for the PM conditions without reference to the PM task. In contrast, the control group was instructed that they were no longer required to respond to PM cues during the lexical decision task. After completion of the task, all of the participants were given a final memory test for cue–response pairs.

Results and Discussion

An alpha level of .05 was used for all statistical tests. Effect sizes for both t tests and F tests are indicated by Cohen's d (small = .20, medium = .50, and large = .80; Cohen, 1988). On the basis of sample means and variances from previous studies, power calculations for nonsignificant results were based on the detection of medium-to-large size effects (Cohen, 1988). There was no significant difference between the three conditions in the number of cue–response word pairs recalled ($M = 3.92$ of four pairs, $SD = .31$) on the posttest questionnaire [$F(1,75) = 1.6$, $MS_e = .09$].

We will now discuss several data-analytic issues that apply to all of the experiments. PM responses were scored as correct if a participant typed in *X* instead of the appropriate response word, because the critical aspect of success was fulfilling the prospective component of the task, rather than the recall of content (Dobbs & Rule, 1987). However, this type of responding occurred infrequently (Experiment 1 = 1.1% of responses; Experiment 2 = 3%; Experiment 3 = 1.9%), and did not significantly influence any of the data reported across Experiments 1–3. For the analysis of RTs on noncue trials, we excluded the first four trials, cue trials, and the four trials following each cue trial (Marsh et al., 2003). Furthermore, lexical decision responses in error (Experiment 1 = 3.7%) or 3 *SD*s above a given participant's grand mean (Experiment 1 = 1.8%) were eliminated from all RT analyses. Lexical decision accuracy was at ceiling (Experiment 1 = 96.3%), and there were no significant differences between the three conditions [$F(1,75) = 1.4$, $MS_e = .001$].

Ongoing task response times. The RT data for noncue trials are presented in Figure 1. Participants in the low-association condition were slower to respond to the lexical decision task than participants in the control condition [$t(50) = 4.51$, $d = 1.2$], and this effect was consistent for both words [$t(50) = 5.5$, $d = 1.5$] and nonwords [$t(50) = 3.2$, $d = .9$]. To further test the reliability of this effect, we analyzed RTs on control words, which were the maximum distance away possible from cue trials. Participants in the low-association condition were slower to respond to control words than control participants [$t(50) = 5$, $d = 1.4$]. Participants in the high-association condition were slower to respond to noncue trials than control participants [$t(50) = 3$, $d = .83$], and this effect was consistent for words [$t(50) = 3.3$, $d = .91$], nonwords [$t(50) = 2.4$, $d = .66$], and control words [$t(50) = 3.5$, $d = .97$]. There was no significant difference (power = .75) between the low- and high-association conditions for RTs to noncue trials ($t < 1$). Together, these findings suggest that participants under conditions of low and high association were allocating preparatory attention to the PM task.

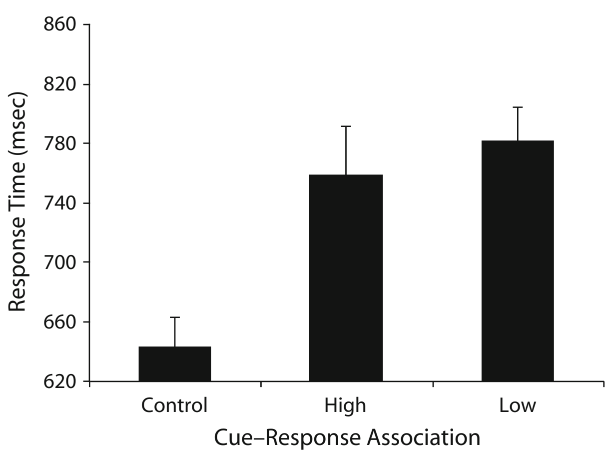

Figure 1. Effect of cue–response association on noncue-trial lexical decision response times in Experiment 1. Error bars represent standard errors.

Table 1
Average Time (in Milliseconds) to Respond to the Ongoing Task As a Function of Trial Type and Cue–Response Association in Experiments 1–3

	Precue Trials			PM Cue Trials	
	Precue Hit	Precue Miss	Precue Difference	PM Hit	Cue Difference
Experiment 1					
Low association	778	772	+6	1,708	926
High association	780	778	+2	1,264	522
Experiment 2					
Low association	812	739	+73	2,246	1,221
High association	747	777	−30	1,656	752
Experiment 3					
Low association	797	700	+97	1,792	1,004
High association	697	690	+7	1,482	707

Note—Precue difference = precue hit − precue miss (only participants with at least one precue hit and one precue miss were included); cue difference = PM hit − precue hit. RTs under the heading Precue Trials report RTs on the three trials preceding PM cue trials when the cue was successfully identified (Precue Hit), and RTs on the three trials preceding PM cue trials when the cue was missed (Precue Miss). The Precue Difference score assesses the functional relationship between response costs and PM performance by calculating the difference in RTs between the three trials preceding PM hits and the three trials preceding PM misses. RTs under the heading PM Cue Trials report RTs on successfully identified PM cue trials (PM Hit). The Cue Difference score measures the interference on cue trials by calculating the difference between RTs on successfully identified PM cue trials (PM Hit) and the three trials immediately preceding these cue trials (Precue Hit).

Additional RT data are presented in Table 1. The precue difference scores presented in Table 1 indicate that the difference in RTs on trials preceding PM hits from RTs on trials preceding PM misses was not significantly larger under conditions of low association in comparison with high association [$t(25) < 1$]. Therefore, contrary to the prediction of the multiprocess view, PM performance was not more dependent on preparatory attention under conditions of low association in comparison with high association. However, it is likely that ceiling effects in PM performance prevented the demonstration of functional relationships between precue response costs and PM performance. The differences between RTs on successfully identified PM cue trials and RTs on trials that directly precede these PM cue trials were significantly larger under conditions of low association in comparison with high association [$t(49) = 6.91$, $d = .75$].[1] These cue trial interference data support the prediction of the multiprocess view that PM cue-detection and/or response-retrieval processes engaged on cue trials should be more resource demanding under conditions of low association in comparison with high association.

Prospective memory performance. There was no significant difference between the PM performance of the low- ($M = .86$, $SD = .18$) and high- ($M = .87$, $SD = .16$) association conditions ($t < 1$). This finding is consistent with the finding of McDaniel et al. (2004), but inconsistent with the finding of Marsh et al. (2003). Marsh et al. (2003) required participants to study eight cue–response pairs, as opposed to four cue–response pairs in the present study and two cue–response pairs in the McDaniel et al. (2004) study. It is possible that inconsistencies in PM performance data across studies stem from differences in the number of cue–response pairs required to be remembered.

EXPERIMENT 2

In Experiment 2, we manipulated a factor that was expected to decrease the extent to which preparatory attention was directed toward the PM task. Several studies have demonstrated that increasing the importance of the ongoing task, relative to the PM task, decreases both response costs on ongoing tasks (as measured by faster RTs, or higher accuracy) and the likelihood of remembering to perform intended actions (e.g., Kliegel et al., 2004; Smith & Bayen, 2004). We anticipated that the increase in variability of response costs (and PM performance) resulting from the task-importance manipulation would increase the chances of finding functional relationships between precue response costs and PM performance. Therefore, in addition to manipulating cue–response association, we emphasized either the importance of the PM task (PMI condition) or the importance of the lexical decision task (LDI condition).

Ongoing Task Response Times

First, we predicted that both the low- and high-association conditions would demonstrate smaller response costs under LDI conditions in comparison with PMI conditions. The predictions of the multiprocess view regarding performance on the ongoing task are identical to those in Experiment 1. The functional relationship between preparatory attention and PM performance should be stronger under conditions of low association in comparison with high association. If this is the case, the difference in RTs on trials preceding PM hits from RTs on trials preceding PM misses should be larger under conditions of low association in comparison with high association. PM cue-detection and/or response-retrieval processes engaged on cue trials should interfere more with the ongoing task under conditions of low association in comparison with high association. If this is the case, differences between RTs on successful PM cue trials and RTs on trials that directly precede these PM cue trials should be larger under conditions of low association in comparison with high association.

Prospective Memory Performance

The multiprocess view claims that PM is more automatic when ongoing tasks encourage the focal processing of PM cues, or when cues are highly associated with responses. In support of this, previous research has demonstrated that PM performance is less resilient to task-importance manipulations under nonfocal cue conditions in comparison with focal cue conditions (Einstein et al., 2005; Kliegel et al., 2004). Similarly, the multiprocess view predicts an interaction between task importance and cue–response association, so that PM performance under conditions of low association should be more affected by manipulations of task importance than PM performance under conditions of high association.

Method

Participants, Design, Materials, and Procedure. A total of 112 students who were enrolled in undergraduate psychology classes at the University of Queensland volunteered to participate in return for course credit. The design was a 2 (cue–response association; high vs. low) × 2 (importance; PMI vs. LDI) between-subjects design. There were 26 participants in each condition. Eight participants were eliminated from the analysis because their response on a posttest questionnaire (manipulation check) did not match their assignment to task importance. Materials and procedures were identical to those used in Experiment 1, with the following exception: After the participants had correctly recalled cue–response words to criterion, the experimenter delivered the task-importance instruction. Consistent with previous research (e.g., Kliegel et al., 2004; Smith & Bayen, 2004), instructions either emphasized the relative importance of the PM task or the ongoing task.

Results and Discussion

We conducted a 2 (association: high vs. low) × 2 (importance: PMI vs. LDI) ANOVA on the number of cue–response words recalled on the posttest questionnaire, lexical decision accuracy, noncue RTs, and PM performance. The proportion of cue–response words recalled (M = 3.75, SD = .60) was not affected by importance ($F < 1$) or cue–response association ($F < 1$). Lexical decision accuracy was at ceiling (96.2%) and was not affected by importance ($F < 1$) or cue–response association ($F < 1$).

Ongoing task response times. The RT data for noncue trials are presented in Figure 2. In this experiment, 3.8% of the lexical decisions were incorrect, and an additional 2% were eliminated because of response length. An ANOVA revealed a significant main effect of task importance [$F(1,100) = 12.57$, $MS_e = 17{,}241.99$, $d = .69$], indicating that participants in the LDI condition (M = 710.8, SD = 114.82) made significantly faster lexical decisions than participants in the PMI condition (M = 802.11, SD = 146.58). The main effect for task importance was consis-

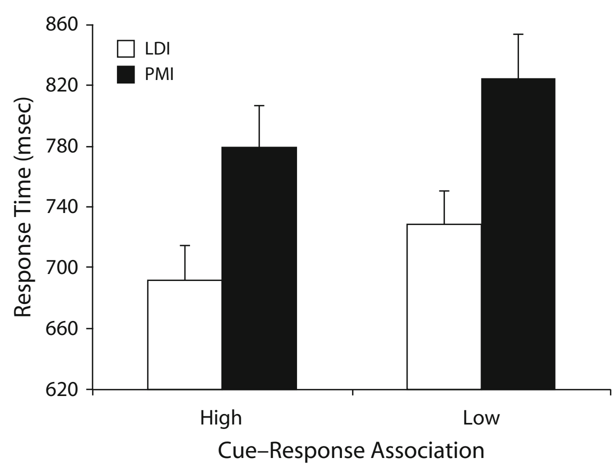

Figure 2. Effect of cue–response association and task importance on noncue-trial lexical decision response times in Experiment 2. Error bars represent standard errors. LDI, lexical decision important; PMI, prospective memory important.

tent across words [$F(1,100) = 12.34$, $MS_e = 24{,}641.24$, $d = .69$], nonwords [$F(1,100) = 9.3$, $MS_e = 16{,}029.84$, $d = .60$], and control words [$F(1,100) = 14.5$, $MS_e = 38{,}228.78$, $d = .73$]. There was no significant main effect (power = .65) for cue–response association (high, $M = 735.99$, $SD = 135.83$; low, $M = 776.91$, $SD = 140.06$) [$F(1,100) = 2.53$, $MS_e = 17{,}241.99$, $d = .30$], indicating that individuals under low- and high-association conditions were allocating similar amounts of preparatory attention toward the PM task.

The precue difference scores are presented in Table 1. The difference between RTs on trials preceding PM hits and RTs on trials preceding PM misses was significantly larger under conditions of low association in comparison with high association [$t(49) = 2.2$, $d = .62$].[2] This supports the prediction of the multiprocess view that PM performance should be more dependent on preparatory attention under conditions of low association in comparison with high association. The differences between RTs on successfully identified PM cue trials and RTs on trials that directly preceded these PM cue trials were significantly larger under conditions of low association in comparison with high association [$t(92) = 2.8$, $d = .56$]. These cue trial interference data are consistent with Experiment 1, and support the prediction of the multiprocess view that PM cue-detection and/or response-retrieval processes engaged on cue trials should be more resource demanding under conditions of low association in comparison with high association.

Prospective memory performance. The mean proportions of correct PM responses are presented in Figure 3. The ANOVA revealed a significant main effect of task importance [$F(1,100) = 15.59$, $MS_e = .06$, $d = .78$], indicating poorer PM performance for participants in the LDI condition ($M = .71$, $SD = .31$) in comparison with participants in the PMI condition ($M = .90$, $SD = .15$). There was no significant difference between the PM performance of the low- ($M = .77$, $SD = .28$) and high- ($M = .84$, $SD = .24$) association conditions [$F(1,100) = 2.10$, $MS_e = .06$, $d = .27$]. There was no significant interaction (power = .65) between cue–response association and importance ($F < 1$). Thus, contrary to the prediction of the multiprocess view, the effect of emphasizing the importance of the ongoing task on PM performance was comparable across the low- and high-association conditions.

Summary. Consistent with previous research (e.g., Smith & Bayen, 2004), individuals who perceived the ongoing task to be more important than the PM task demonstrated smaller response costs to the ongoing task and were less likely to make PM responses. Taken together, the RT data support the prediction of the multiprocess view that PM should be more reliant on the resource-demanding processes specified by the PAM theory under conditions of low association in comparison with high association. First, there was a significantly stronger functional relationship between precue response costs and PM performance under conditions of low association in comparison with high association. Second, after controlling for preparatory attention, the PM cue-detection and/or response-retrieval processes engaged on cue trials interfered more with the ongoing task under conditions of low association in comparison with high association, indicating that these processes were more resource demanding under conditions of low association. On the other hand, contrary to the prediction of the multiprocess view, PM performance was *not* less resilient to manipulations of task importance under conditions of low association in comparison with high association. In summary, responses to the ongoing task, but not PM performance, were sensitive to the manipulation of cue–response association.

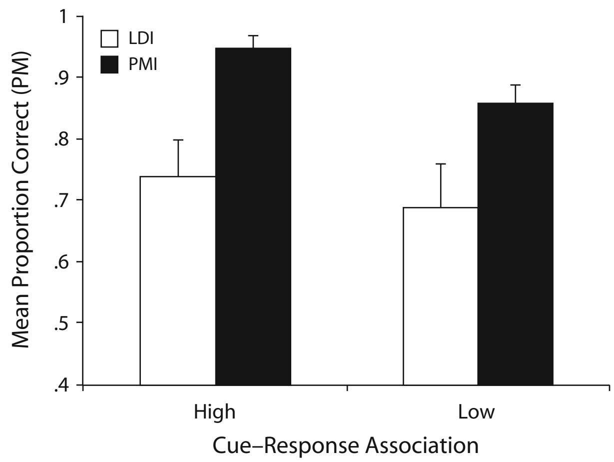

Figure 3. Effect of cue–response association and task importance on prospective memory performance in Experiment 2. Error bars represent standard errors. LDI, lexical decision important; PMI, prospective memory important.

EXPERIMENT 3

Experiment 3 examined the influence of the frequency of cue presentation on ongoing task performance and PM performance under conditions of low and high association. Graf and Uttl (2001) argued that the frequency of cue presentation should be associated with different conscious experiences. Consider the PM task of remembering to inform eight colleagues of changes in teaching arrangements the next time you see each of them. If you happen to see many of these colleagues over the course of one day, you are more likely to be reminded of the need to perform this intention than if you only converse with one (or none) of these colleagues per day during the course of the week. In Experiment 3, we included conditions in which cues were presented once every 90 trials (infrequent cue condition), and conditions identical to those in Experiment 1, in which cues were presented once every 33 trials (frequent cue condition).

Ongoing Task Response Times

First, we predicted that both the low- and high-association conditions would demonstrate smaller response costs under infrequent cue conditions in comparison with frequent cue conditions. The predictions of the multiprocess view were identical to those for the previous experiments. First, the difference between RTs on trials preceding PM hits and RTs on trials preceding PM misses should be larger under conditions of low association in comparison with high association. Second, differences between RTs on successful PM cue trials and RTs on trials that directly precede these PM cue trials should be larger under conditions of low association in comparison with high association.

Prospective Memory Performance

The multiprocess view predicts an interaction between cue frequency and cue–response association, such that PM performance under conditions of low association should be more affected by manipulations of cue frequency than PM performance under conditions of high association.

Method

Participants and Design. A total of 152 students enrolled in undergraduate psychology classes at the University of Queensland volunteered to participate in return for course credit. The design was a 3 (cue–response association: high vs. low vs. control) × 2 (cue presentation: frequent vs. infrequent) between-subjects design. There were 28 participants in each experimental condition. Two control conditions (n = 20) were also included, in which participants only performed the lexical decision task. These control conditions were matched in length (i.e., number of trials) to either the frequent (frequent control) or infrequent (infrequent control) PM conditions.

Materials and Procedure. Materials for the frequent cue condition were identical to those in Experiments 1 and 2, with the exception that cues were always presented on Trials 33, 66, 99, 132, 165, 198, 231, and 264, and control words were always presented on Trials 16, 49, 82, 115, 148, 181, 214, and 247.

The same pool of 132 letter strings (66 words, 66 nonwords) presented in the frequent PM cue conditions were also presented twice each in the infrequent PM cue conditions. For the infrequent cue conditions, an additional 114 medium-frequency words were randomly chosen (*TSMH* word database; Dennis, 1995), and nonwords were created by removing the first syllable of each of the 114 words and placing it in front of the letter string (Hunt & Toth, 1990). A total of 360 letter strings (180 words, 180 nonwords) were presented twice each, constituting a total presentation of 720 trials. The order of presentation was random except for the presentation of cues that were presented on Trials 90, 180, 270, 360, 450, 540, 630, and 720. Control words were presented on Trials 45, 135, 225, 315, 405, 495, 585, and 675. The procedures for the PM and control conditions were identical to those in Experiment 1.

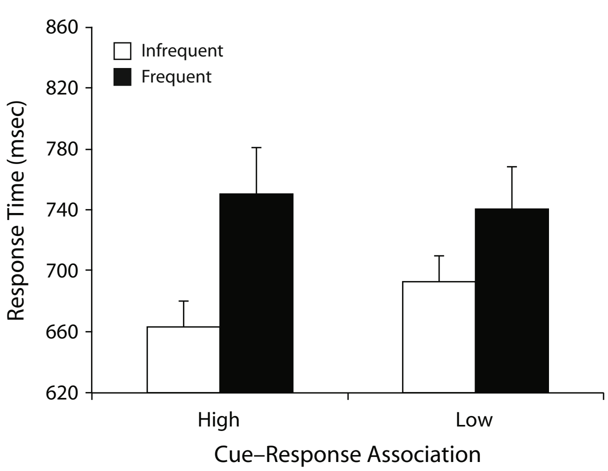

Figure 4. Effect of cue–response association and cue frequency on noncue-trial lexical decision response times in Experiment 3. Error bars represent standard errors.

Results

A 3 (association: high vs. low vs. control) × 2 (cue frequency: frequent vs. infrequent) ANOVA was conducted on the number of cue–response words recalled on the posttest questionnaire and lexical decision accuracy. The proportion of cue–response words recalled (M = 3.86, SD = .41) was not affected by cue–response association ($F < 1$) or cue frequency (F = 1.59; MS_e = .14). Lexical decision accuracy was at ceiling (96%), and was not affected by cue–response association [$F(1,108) = 1.02$, MS_e = .001] or cue frequency (F = 1.29, MS_e = .001).

Ongoing task response times. Four percent of lexical decisions were incorrect, and an additional 1.7% were outliers (>3 SDs). The two control conditions were matched in length to either the frequent PM cue or infrequent PM cue conditions in order to account for practice and/or fatigue effects. However, comparisons between the frequent (272 trials) and infrequent (720 trials) control conditions indicated no significant differences in lexical decision accuracy (frequent, M = .95, SD = .04; infrequent, M = .95, SD = .03; t = 1) or RT (frequent, M = 630.4, SD = 88.7; infrequent, M = 629.9, SD = 92.1; $t < 1$).

These data indicate that the length of the lexical decision task did not affect the speed or accuracy of response. Consequently, it was deemed unnecessary to use these control conditions to calculate difference scores for the PM conditions. Therefore, in order to test our hypotheses, we conducted a 2 (association: high vs. low) × 2 (cue frequency: frequent vs. infrequent) ANOVA on RTs.

The RT data for noncue trials are presented in Figure 4. A main effect of cue frequency was found [$F(1,108)$ = 8.04, MS_e = 16,015.64, d = .54], indicating that participants presented with cues infrequently (M = 678.08, SD = 90.94) made significantly faster lexical decisions than participants presented with cues frequently (M = 745.9, SD = 153.07). The main effect for cue frequency was consistent across words [$F(1,108)$ = 10.38, MS_e = 17,863.73, d = .62], nonwords [$F(1,108)$ = 5.03, MS_e = 16,855.47, d = .43], and control words [$F(1,108)$ = 5.36, MS_e = 26,103.91, d = .44]. There was no significant main effect for cue–response association (high, M = 707.33, SD = 137.44; low, M = 716.65, SD = 122.91; $F < 1$), indicating that individuals under low- and high-association conditions were allocating similar amounts of preparatory attention toward the PM task.

It is possible that RTs decreased for the infrequent PM cue condition relative to the frequent PM cue condition because intentions in the former condition needed to be maintained over extended periods of time. In order to address this issue, we conducted an analysis that controlled for task duration. More specifically, we compared the RTs of the infrequent PM cue condition, based on responses to the first 272 trials, with the RTs of the frequent PM cue condition, which involved a total of 272 trials. The main effect remained significant [$F(1,108)$ = 6.87, MS_e = 16,466.67, d = .50], suggesting that the decreased frequency of cue presentation contributed to the reductions in response costs for participants in the infrequent PM cue condition, over and above the possible influence of task duration.

The precue difference scores are presented in Table 1. The differences between RTs on trials preceding PM hits and RTs on trials preceding PM misses were significantly larger under conditions of low association in comparison with high association [$t(62) = 2.26$, $d = .56$].[3] This finding is consistent with Experiment 2, and supports the prediction of the multiprocess view that PM performance should be more dependent on preparatory attention under conditions of low association in comparison with high association. The difference between RTs on successfully identified PM cue trials and RTs on trials that directly preceded these PM cue trials was significantly larger under conditions of low association in comparison with high association [$t(104) = 2.29$, $d = .44$]. These cue trial interference data are consistent with data from Experiments 1 and 2, and support the prediction of the multiprocess view that PM cue-detection and/or response-retrieval processes engaged on cue trials should be more resource demanding under conditions of low association in comparison with high association.

Prospective memory performance. The mean proportions of correct PM responses are presented in Figure 5. The ANOVA revealed a significant main effect of cue frequency [$F(1,108) = 8.03$, $MS_e = .06$, $d = .57$], indicating that participants presented with cues infrequently ($M = .73$, $SD = .30$) were less likely to make PM responses than participants presented with cues frequently ($M = .87$, $SD = .18$). There was no significant main effect of cue–response association (high, $M = .82$, $SD = .24$; low, $M = .77$, $SD = .30$) [$F(1,108) = 1.05$, $MS_e = .07$]. There was no interaction (power = .68) between association and frequency ($F < 1$). Thus, contrary to the prediction of the multiprocess view, the effect of decreasing the frequency of cue presentation on PM performance was comparable across low- and high-association conditions.

In order to address the possible confound of task duration, we compared performance on the first four PM cue trials with the final four PM cue trials. Paired *t* tests revealed no significant differences, either for the frequent PM cue condition (first four, $M = .84$, $SD = .23$; second four, $M = .89$, $SD = .20$) or infrequent PM cue condition (first four, $M = .73$, $SD = .32$; second four, $M = .73$, $SD = .34$). These data indicate that it is unlikely that increased task duration contributed to the reduction in PM performance for participants in the infrequent PM cue condition.

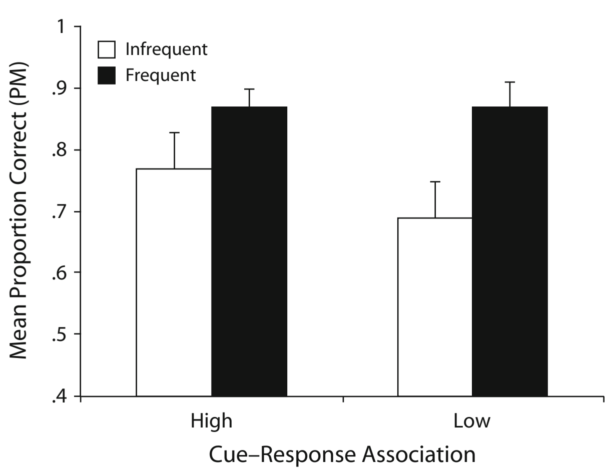

Figure 5. Effect of target–response association and cue frequency on prospective memory performance in Experiment 3. Error bars represent standard errors.

Summary. This is the first study to demonstrate that decreasing the frequency of cue presentation can reduce both response costs on an ongoing task and the likelihood that participants will remember to make a PM response. Furthermore, the RT data were consistent with the data from Experiment 2, providing additional support for the claim that PM performance is more reliant on the resource-demanding processes specified by the PAM theory under conditions of low association in comparison with high association. More specifically, the functional relationship between preparatory attention and PM performance, and the resource demands of PM processes engaged on cue trials, were both greater under conditions of low association in comparison with high association. However, consistent with Experiment 2, and contrary to the prediction of the multiprocess view, PM performance was *not* less resilient to manipulations of cue frequency under conditions of low association in comparison with high association. Several explanations are raised in the General Discussion that may account for why RTs to the ongoing task, but not PM performance, were sensitive to the manipulation of cue–response association.

GENERAL DISCUSSION

The multiprocess view claims that both strategic and automatic processes can contribute to PM, depending on task conditions. The RT data across Experiments 1–3 support this view. First, the difference between RTs on trials preceding PM hits and RTs on trials preceding PM misses were larger under conditions of low association in comparison with high association. Furthermore, after controlling for response costs on precue trials, RTs on successfully identified PM cue trials were larger under conditions of low association in comparison with high association. However, the PM performance data were less supportive. Declines in PM performance when instructions emphasized the importance of the ongoing task, or when cues were presented infrequently, were comparable across the low- and high-association conditions. The remainder of the General Discussion provides an evaluation of the theoretical implications of these findings for two prominent theories of PM.

Multiple Processes in Prospective Memory Retrieval

Across three experiments, participants demonstrated consistent response costs on noncue ongoing task trials under conditions of high association, and the magnitudes of these response costs were comparable to those of participants under conditions of low association. Response costs on noncue trials under conditions of high association would not be predicted a priori by the multiprocess view.

After all, PM processes that are automatic should not require individuals to devote resources in preparation for cues. Furthermore, there is growing evidence to suggest that individuals have good metacognitive awareness of PM situations that require the devotion of extra resources, such as when PM tasks are important (e.g., Einstein et al., 2005; Kliegel et al., 2004) or when multiple PM cues are anticipated (Marsh et al., 2003). An important conclusion to be drawn from the present research is that PM tasks can lead to significant performance costs on noncue ongoing task trials, even under conditions that presumably facilitate the more automatic retrieval of intentions.

The precue RT data support the multiprocess view. To demonstrate the functional relationship between preparatory attention and PM performance, Smith (2003; see also Smith & Bayen, 2004) correlated RTs on *all* noncue trials with PM performance. We took a different approach, examining the relationship between response costs on trials that *directly* preceded cue trials and PM performance (West et al., 2005). Under low-association conditions, there were large differences between RTs on precue hits in comparison with RTs on precue misses, reflecting the waning of preparatory attentional processes directly before PM cues were missed. In contrast, the functional relationship between precue RTs and PM performance under conditions of high association was significantly smaller. These data indicate that PM performance was more reliant on preparatory attention under conditions of low association in comparison with high association.

Response costs on cue trials (after controlling for precue RTs) were larger under conditions of low association in comparison with high association, providing further support for the multiprocess view. Marsh et al. (2003; Marsh et al., 2002; see also McDaniel et al., 1998; Smith, 2003) argue that cue trial interference is due to the influence of four processes: (1) the recognition of cues required for cue detection, (2) the verification of those cues, (3) the retrieval of responses, and (4) the coordination of PM responses with ongoing tasks. As discussed in the introduction, there is substantial evidence that these hypothetical subcomponents of PM can be dissociated. The cue trial interference effects found across Experiments 1–3 raise some interesting questions about how the relative automaticity of different subcomponents of PM vary as a function of cue–response association. According to Marsh et al. (2003), differences in cue trial interference between low- and high-association conditions purely reflect the relative ease of response retrieval once PM cues have been recognized and verified (i.e., detected). On one level, we agree with this view. After all, both the specific words used as PM cues and the response coordination requirements of the PM task (press Enter key) were identical across the cue–response conditions, leaving the relative difficulty of retrieving response words as the prime candidate for the observed differences in cue trial interference.

However, the multiprocess view states that responses that are highly associated to cues are automatically delivered to consciousness, *bypassing the need to consciously detect cues* (Einstein et al., 2005; McDaniel & Einstein, 2000; McDaniel et al., 2004). In other words, when reflexive-associative processes dominate PM, cue-detection and response-retrieval processes are more likely to operate in parallel. In contrast, when cue-focused processes dominate, cue detection is a prerequisite for response retrieval. On this basis, the smaller interference observed on cue trials under conditions of high association may partially reflect the fact that cue detection and response retrieval operated in parallel, as opposed to serially. Admittedly, these claims need to be substantiated with some version of a psychological refractory period analysis of component task performance (e.g., Pashler, 1998). Nonetheless, at a minimum, we have demonstrated that PM processes engaged on cue trials were more resource demanding under conditions of low association in comparison with high association. Future research is required to determine whether these resource demands purely reflect response retrieval, or both cue detection and response retrieval.

As discussed above, the RT data indicate that the cue-detection and/or response-retrieval processes engaged on *successful* PM cue trials were less resource demanding under conditions of high association in comparison with low association. However, the comparable declines in PM performance across low- and high-association conditions due to task-importance and cue-frequency manipulations are not consistent with this view. Furthermore, the declines in PM performance under conditions of high association challenge the stronger (albeit more controversial) claim of the multiprocess view that PM responses are more likely to be retrieved automatically (i.e., be totally resource free) when cues and responses are highly associated (Einstein et al., 2005; McDaniel et al., 2004). PM processes that do not require cognitive resources should not have been influenced by changes in the importance of the PM task or the frequency of cue presentation.

This notwithstanding, there are alternative explanations for the PM performance data that are less incompatible with the multiprocess view. For example, individuals who perceived the lexical decision task to be more important (or who were presented with cues infrequently) may have only processed cues to the informational level required for lexical decisions (i.e., to come to the decision that letter strings were words), rather than to the informational level required to initiate the reflexive retrieval of responses (Maylor, 1998; Moscovitch, 1994). Second, the manipulations may have influenced the processes involved in the coordination of the execution of PM responses (Einstein et al., 1997; Marsh et al., 2003). For example, participants may have been less inclined to interrupt the ongoing task and schedule the intended action when they perceived the ongoing task to be more important. In both these circumstances, the advantage of having highly associated cue–response words would be lost.[4]

We only manipulated one of the factors specified by the multiprocess view that promotes the automaticity of PM. Whereas the RT data were sensitive to our manipulation of cue–response association, PM performance was not. In contrast, Einstein et al. (2005) and Kliegel et al. (2004) found that PM performance was sensitive to their manipulations of the focal processing of PM cues. Future research is required to determine exactly which of the factors specified by the multiprocess view influences the automaticity of PM, how these factors interact, and via which dependent variable(s) effects are likely to be observed (e.g., precue trial RT, cue trial RT, PM performance). For example, the automaticity of PM may be more likely to be reflected in PM performance data (in addition to RT data) under conditions in which the saliency of cues (e.g., presented in uppercase font; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000), or the distinctiveness of cues from background context (e.g., presenting low-meaningful words as cues; Einstein & McDaniel, 1990), are manipulated concurrently with cue–response association.

Support and Implications for the PAM Theory

According to the PAM theory, preparatory attention and retrospective memory processes interact to determine the success of PM. The role of these processes has been well supported by empirical data (e.g., Guynn, 2003; Marsh et al., 2003; Smith, 2003; Smith & Bayen, 2004; West et al., 2005), and are not in dispute here. In fact, the present findings provide further support for the PAM theory. First, response costs were observed on noncue trials, reflecting the engagement of preparatory attention. Second, participants in conditions that demonstrated smaller response costs to the ongoing task were also less likely to make PM responses. Third, the cue trial interference data are consistent with the notion that resource-demanding retrospective memory processes are engaged on cue trials to detect cues and retrieve responses.

However, the present findings have implications for the PAM theory and the Smith and Bayen (2004) multinomial model of PM. First, despite the fact that both low- and high-association conditions allocated preparatory attention, we found a stronger relationship between precue response cost and PM performance under conditions of low association in comparison with high association. To account for these data, the multinomial model would need to be extended so that preparatory attention can serve different functions under different task conditions, with some of these functions being weighted as more influential for PM performance than others. For example, Guynn (2003) found evidence for two "strategic" processes: a checking mechanism that explicitly checks the environment for cues and can be turned on and off fairly easily, and a retrieval mode (general readiness to treat stimuli as cues), which cannot be turned on and off easily. Response costs under conditions of high association may predominantly reflect the instantiation of general retrieval modes, as opposed to explicit checking for cues. Second, decreasing the frequency of cue presentation reduced both preparatory attention and PM performance. It would be useful if the multinomial model was extended to make predictions regarding response costs on ongoing activities under conditions such as when single intentions need to be maintained over long periods of ongoing task time, as is often the case in everyday life (e.g., drop the car off at the mechanic's after work).

Conclusions

Recent interest in PM has resulted in the development of a number of theoretical frameworks that postulate the processes underlying PM. This article was not intended to contrast the multiprocess view with the PAM theory. These two theories are compatible on many levels, especially if the multiprocess view's "largely automatic" tasks refer to cases in which PM requires at least minimal resources. Instead, we focused on demonstrating that PM can be more resource demanding under some task conditions in comparison with others, providing some support for the claim of the multiprocess view that multiple processes are involved in PM.

AUTHOR NOTE

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NOTES

1. We also presented control-matched words in Experiments 1–3. We recalculated cue difference scores using the Marsh et al. (2003) method and found that it did not significantly affect any of the cue difference scores reported across Experiments 1–3.

2. Only RTs for participants with at least one precue hit and one precue miss were included in this within-subjects analysis. Twenty-eight out of 52 participants in the low-association conditions were represented, in comparison with 23 out of 52 participants in the high-association conditions. The majority of excluded participants were excluded on the grounds that they had perfect hit rates on the PM task. However, the inclusion of these RTs to average precue hit RTs had little effect—for either the low-association ($M = 810$, $n = 47$; in comparison with $M = 812$, $n = 28$) or the high-association ($M = 752$, $n = 50$; in comparison with $M = 747$, $n = 23$) conditions.

3. Thirty-one out of 56 participants in the low-association conditions were represented, in comparison with 33 out of 56 participants in the high-association conditions. As in Experiment 2, the majority of excluded participants were excluded on the grounds that they had perfect hit rates on the PM task. However, the inclusion of these RTs to average precue hit RTs had little effect—for either the low-association ($M = 770$, $n = 53$; in comparison with $M = 797$, $n = 31$) or high-association ($M = 709$, $n = 54$; in comparison with $M = 697$, $n = 33$) conditions.

4. It was suggested by one reviewer that some participants may have made associations between PM cues and the intention of *typing* in a response word (hit Enter key), rather than associations between cue and response words.

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