Differential Benefits of Prospective Memory Reminders Depending on Cognitive Load

Phil Peper¹, Durna Alakbarova¹, and Hunter Ball¹

¹University of Texas at Arlington

Author Notes

Address correspondence to Hunter Ball, Department of Psychology, University of Texas at Arlington, Arlington, TX 76019. Email: Hunter.Ball@uta.edu

Phil Peper, Durna Alakbarova, and B. Hunter Ball, Department of Psychology, University of Texas at Arlington, 501 Nedderman Drive, Arlington TX, 76109.

Portions of the data were presented at the Virtual Psychonomics 2020 Annual Meeting and the 2020 Armadillo Conference.

All data is currently publicly available: <https://osf.io/z59ru/>

Abstract

Prospective memory (PM) refers to the ability to remember to complete a task at the appropriate moment in the future. Past research has found reminders can improve PM performance in both laboratory and naturalistic settings, but few projects have examined the circumstances when reminders are most beneficial. Three experiments in the present study tested the effect of reminders in an event-based PM task under different cognitive loads. In Experiments 1 (specific targets) and 2 (nonspecific targets), load was manipulated by having participants respond to a single (low load) or multiple (high load) targets. In Experiment 3, the association between pairs was manipulated by presenting strongly associated pairs (low load) or weakly associated pairs (high load). Half of the participants in each experiment received reminders whereby PM target information was placed at the top of the computer screen. Across all three experiments, it was found that the benefit of reminders was greater under high load than low load conditions. Importantly, the improvements in PM from reminders generally occurred without any additional cost to ongoing task performance and without any reduction of retrospective memory for the targets at the end of the experiment. Together these results suggest that reminders can be beneficial for reducing PM failures, particularly under high load, without the potential downside of increased effort expenditure.

Keywords: prospective memory; offloading; reminders; cognitive load

Word count: 9616

Differential Benefits of Prospective Memory Reminders Depending on Cognitive Load

Event-based prospective memory (PM) refers to our ability to remember to complete deferred intentions in response to environmental cues, often while busily engaged in various ongoing activities. For example, encountering a medicine bottle while doing chores may serve as an event-based cue to take a medication. While a single intention may be relatively easy to manage, oftentimes people have multiple concurrent intentions, various cues to respond to, and/or different actions to perform. One potentially efficacious way to deal with difficulty of maintaining multiple intentions is to offload demands onto the environment (Risko & Gilbert, 2016). Using reminders, such as smartphone alerts for taking a medication or writing to-do lists for groceries, reduces cognitive load and can mitigate capacity limitations that can be potentially reached as intentions mount. Although reminders have been shown to be beneficial in both laboratory (e.g., Gilbert, 2015a; Guynn et al., 1998; Vortac et al., 1995) and naturalistic (Ball et al., 2021; Ihle et al., 2012; Schnitzspahn et al., 2020) settings, reminders can be effortful to set up and increase the risk of forgetting should the reminder fail (Kelly & Risko, 2019). In order to maximize efficiency, it would therefore be optimal to rely on reminders for more demanding tasks and one's own memory for easier tasks. The present study aims to explore the efficacy of reminders in an event-based PM task under varied cognitive load.

In the laboratory, event-based PM is typically examined by instructing participants to fulfill an intention embedded within an ongoing task. For example, participants may be instructed to perform an ongoing syllable judgement task in which they decide whether a word on the screen has two or three syllables as quickly and accurately as possible. Prior to performing the task participants form the intention to respond to a certain target word (e.g., the word “apple”) or target category (e.g., any *fruit*) with a unique key response (e.g., press “7”) whenever

they are encountered during the ongoing task. The primary outcome variable is PM performance, which refers to the proportion of PM targets that receive a successful PM response. A secondary measure often assessed is the speed and accuracy of ongoing task responding on non-target trials during the PM block. Participants are often slower and/or less accurate when possessing an intention compared to when the same task is performed without an intention (Smith, 2003), which is referred to as ongoing task *cost*. This cost to ongoing task performance is typically thought to reflect the diverting of attention away from the ongoing task and towards PM processing (but see Heathcote et al., 2015).

Importantly, not all PM intentions incur costs to ongoing task performance. The Multiprocess Framework of PM states that different processes (i.e., controlled and automatic) can be used to notice targets (Einstein et al., 2005; Shelton et al., 2019). The specificity, or focality, of the event-based target in part determines which process is used. Focality refers to the degree to which the ongoing task focuses attention on relevant features of the PM target. Highly specific, or focal targets, are encoded explicitly (e.g., *apple*) and can be noticed relatively automatically, because feature-driven processes (e.g., discrepancy) can trigger spontaneous retrieval of the PM intention. This idea is supported by the finding that specific targets are often detected at high rates with minimal cost to ongoing task performance (Scullin et al., 2010). In contrast, controlled processes are typically required for nonspecific, or nonfocal, targets (e.g., exemplars from the category *fruits*), as they necessitate preparatory attention to actively monitor for a PM target. This idea is supported by the finding that nonspecific PM performance is comparatively low and can produce considerable cost to ongoing task performance (Einstein et al., 2005; Marsh et al., 2003). As preparatory monitoring places demands on working memory

(Brewer et al., 2010), this suggests that nonspecific targets produce greater cognitive load than specific targets.

Other studies have shown that manipulations that increase working memory load influence PM performance (Marsh & Hicks, 1998). For example, Marsh et al. (2003) found that increasing targets from 4 to 8 reduced PM performance, whereas Cohen et al. (2008) found that increasing the number of targets increased the ongoing task cost. Similarly, Wesslein et al. (2014) found that reducing PM target specificity and increasing the number of targets reduced overall PM performance. Wesslein et al. also applied a multinomial model to the data, which produces two different parameter values. The first parameter measures preparatory attention and is associated with working memory capacity (Smith & Bayen, 2005), whereas the second parameter reflects retrospective memory processes associated with memory retrieval (Smith & Bayen, 2004). They found that reducing specificity affected the attention parameter, whereas increasing the number of targets affected both the attention and memory parameters. Thus, specificity and the number of targets may increase both attention and memory loads.

Another way to increase the cognitive load of a PM task is manipulating the association of the PM target and the target action. For example, participants may learn a series of paired associates (e.g., *salt – pepper*) with the intention that, any time they see the target (e.g., *salt*) during the ongoing task, they should type out the action word that was paired with it (e.g., *pepper*). Several studies have found that manipulating the degree of association between the target-action pairs impacts PM performance (e.g., Cook et al., 2014; McDaniel et al., 2004). For example, PM performance is much higher with strongly associated pairs (e.g., *salt – pepper*) than weakly associated pairs (e.g., *candle – elbow*). Better PM performance for strong associations occurs because participants can reflexively recall the associated pair upon noticing the target

(Einstein & McDaniel, 2010). In contrast, retrieval of a weak pair requires a controlled search process. Thus, like increasing the number of targets, weakening the association between PM targets and actions can increase memory demands.

One way to reduce the cognitive load of a task is to offload goal-related contents onto the environment (Risko & Gilbert, 2016). For example, people can create to-do lists, update online calendars with future appointments, or set a gym bag next to their front door to not forget it before leaving for work. Previous studies on the effect of PM reminders in the laboratory have sought to examine the temporal characteristics of reminders (Vortac et al., 1995), the type of effective reminders (Guynn et al., 1998), and the effectiveness of reminders under varied ongoing task loads (Chen et al., 2017). Vortac et al. (1995) compared the effectiveness of reminders available at different time periods during an air traffic control PM task. Specifically, they compared reminders available before the PM target occurred (but not during), throughout the PM task, and selectively available in a small window around the PM trial. They found a benefit of reminders when they are available throughout the entire PM task and selectively around (and during) the PM trial. That is, PM target reminders are effective as long as they are available during the PM trial (but see Loft et al., 2011 for evidence of habituation to always-available reminders). Consistent with Vortac et al. (1995), Guynn et al. (1998) found that brief reminders of the target alone or target action alone presented approximately one-minute before the PM trial provided no benefit to PM performance. However, reminders of the target *and* target action combined improved PM performance. Finally, Chen et al. (2017) manipulated ongoing task load by having participants do a 1-back or a 2-back task and found that reminders improved PM performance regardless of task load. Interestingly, although ongoing task load did not influence PM performance, reminders did result in better ongoing task performance during the

high task load condition. Importantly, however, while these studies have been critical in demonstrating when reminders are effective, none of these studies manipulated the load of the PM task.

To our knowledge, the only studies examining the effectiveness of reminders under varied PM load used an intention offloading task. In the task, participants are instructed to drag centrally located circles to the bottom of the screen (Gilbert, 2015a; Gilbert et al., 2020). Each circle is either numbered or alphabetized, and the circles are dragged sequentially. A random circle is periodically flashed a certain color (e.g., blue). When the flashed circle's turn comes, it must be dragged to a different side of the screen (e.g., left) that matches the flashed color (e.g., blue). Participants can set reminders by dragging the target circle next to its destination as soon as it flashed, reminding participants of the unique response required. Otherwise, the intention must be remembered internally (i.e., without setting a reminder). The primary finding in this paradigm is that performance is considerably higher when participants set reminders (Cherkaoui & Gilbert, 2017; Gilbert, 2015a, 2015b; Gilbert et al., 2020). Critically, reminders are used more often and show a greater benefit when the number of target circles within a trial block is high (i.e., with increased cognitive load). Participants also had lower performance without reminders and chose to set reminders more when the task was nonfocal compared to focal (Gilbert, 2015a). Gilbert et al. (2020) additionally found that participants relied on reminders even when they could otherwise successfully use their internal ability alone, suggesting people use reminders suboptimally. Thus, when the cognitive load is high, reminders are set more often and provide a greater benefit. However, reminders can also be overused even when it is costly to do so.

Although the findings from the intention offloading task are important, there is some debate over whether the task truly reflects PM proper or instead reflects a type of short-term

memory task (e.g., Gilbert, 2015a). Typically, lengthy delays occur between intention formation and retrieval to ensure that the intention is not in conscious awareness and treated as a vigilance task (Graf & Uttl, 2001). In contrast, the delay intervals during the intention offloading task occur over the course of 10 to 20 seconds. The prospective intention can thus be created and occupy working memory until the appropriate moment for execution appears. Furthermore, because the ongoing task simply involves dragging circles to the bottom of the screen, it is difficult to assess whether PM demands influence ongoing task performance and whether this can be affected by reminders. It is therefore important to extend the findings of Gilbert and colleagues using a more typical event-based PM task and with different types of cognitive load.

Current Study

The present study directly assessed the effectiveness of reminders for PM as a function of PM load across three experiments. In Experiments 1 (specific targets) and 2 (nonspecific targets), load was manipulated by having participants respond to a single (low load) or multiple (high load) targets. In Experiment 3, the association between pairs was manipulated by presenting strongly associated pairs (low load) or weakly associated pairs (high load). Target (Experiment 1 and 2) and target-action pair (Experiment 3) reminders were listed at the top of the screen in the reminder conditions across all experiments (see Figure 1). The primary

Figure 1*Task Appearance in Each Condition for all Three Experiments*

Note. Squares on the right represent the appearance of the PM task for the reminder conditions. In Experiments 1 and 2, the bottom squares represent task appearance for the high load conditions. Load was manipulated within subjects in Experiment 3.

hypothesis was that reminders would have a larger benefit to PM performance under high load than under low load. Of additional theoretical importance was the influence of reminders on ongoing task performance. Reminders could be used to reduce attentional demands associated with monitoring and reduce ongoing task costs (Chen et al., 2017). Alternatively, reminder checking could detract from ongoing task performance. This additional cost may be deemed worthwhile in order to improve memory under high loads. However, if ongoing task performance is worse in the low load condition with reminders, this would suggest that participants may unnecessarily use costly resources to use reminders when the contents of the PM could instead be relatively easily maintained internally (Gilbert et al., 2020).

Preregistration statement

All research reported herein was conducted using appropriate ethical guidelines and was approved by the Institutional Review Board at the University of Texas at Arlington. We report how we determined our sample size, all data exclusions, and all manipulations¹. Data for all three experiments can be found at <https://osf.io/z59ru/>.

Experiment 1

Experiment 1 tested the effect of target reminders and varied cognitive load in an event-based PM task using specific targets. Specific targets were chosen based on a wealth of research assessing PM performance with a single (e.g., focal) target (Chen et al., 2017; Einstein et al.,

¹ It should be noted that we initially conducted three other experiments that are not included in the current manuscript (<https://osf.io/z59ru/> OSF – PMReminder.docx). In these studies, load was manipulated by comparing performance for 4 (low load) versus 8 (high load) specific targets for the first two (collected through SONA and then MTurk) and 5 (low load) versus 10 (high load) specific targets for the third (collected on MTurk). The MTurk studies were not preregistered due to an oversight on the first author's part while research was shifted online amid the early stages of Covid-19-related precautions. While reminders tended to improve PM performance, there was not the anticipated interaction between load and reminders. In hindsight, and as will become apparent in the current set of studies, we realized that four targets may actually be considered *high* load, thereby reducing the effectiveness of the load manipulation. Following this realization, we changed our load manipulation (i.e., 1 versus 4) and report those experiments in the paper. All data will be made available on request.

2005; Gilbert, 2015a; Marsh et al., 2003). The generally high PM performance and low ongoing task costs with a single specific target suggests that it places relatively little demands on working memory (Brewer et al., 2010). Cognitive load was manipulated by having participants learn either one (low load) or four (high load) specific targets. Previous research has shown that ongoing task costs can increase as the number of specific targets go from one to four (Cohen et al., 2008), suggesting that four targets place higher demands on working memory. To examine the influence of reminders, participants in the reminder conditions were informed that the single target (low load) or all four targets (high load) would be presented at the top of the screen throughout the duration of the PM task (see Figure 1). Those in the no reminder conditions were not given these instructions and had to rely on their own memory to notice the targets. We predicted that reminders would show a larger improvement to PM performance under high load compared to low load conditions. We did not have any specific predictions for ongoing task performance across conditions, as several different outcomes were theoretically plausible. An improvement of ongoing task performance by reminders would suggest reminders reduce load such that attention could be reoriented to the ongoing task. Worse ongoing task performance would suggest that having reminders impairs ongoing task performance, perhaps due to reminder checking. Finally, some combination of the two could produce a null effect on the influence of reminders. Experiment 1 preregistration information can be found at <https://osf.io/v9wm7>.

Method

Participants

An a priori power analysis based on a medium effect size ($n_p^2 = .06$) recommended a sample size of 175 for an alpha of .05 and power of .80. We set the final sample size to 200 with anticipation that some participants will be removed for meeting exclusionary criteria.

Participants (aged 18 – 37; $M = 19.12$, $SD = 2.45$) were undergraduates at the University of Texas at Arlington recruited through SONA systems for class credit. Of the total 200 participants collected, 7 were excluded for meeting exclusionary criteria detailed below, for a final sample size of 193. Participants were randomly assigned to one of four conditions, including the no reminder low load ($N = 48$), no reminder high load ($N = 50$), reminder low load ($N = 46$), and reminder high load ($N = 49$).

Design

A (load: low vs. high) x 2 (reminder: reminder vs. no reminder) between-subjects design was employed, such that participants either learned one (low load) or four (high load) PM targets with (reminder condition) or without (no reminder condition) the use of reminders.

Materials

Ongoing task stimuli were selected from the English Lexicon Project (Balota et al., 2007). These consisted of 252 words that were 7-10 letters in length, half of which had two syllables and half of which had three syllables. There was an equal number of two- and three-syllable words of each letter count. An additional four words were selected as PM targets. Two of the PM targets were two-syllable words (*insight* and *backlash*) and two were three-syllable words (*fallacy* and *disservice*). The stimuli were presented in uppercase white font at the center of the screen on a dark gray background. Participants in the reminder conditions had the target(s) listed at the top of the screen in yellow font.

All data collection was completed online. Experimental procedures were developed on and presented with PsychoPy3 software. QuestionPro survey software obtained participant consent and randomly assigned participants to each condition. The PsychoPy3 experiment was hosted on Pavlovia.com.

Procedure

The experiment involved participants performing a syllable judgement ongoing task with PM targets embedded. Participants completed demographics questions, practiced the ongoing task, received the intention instructions (and were quizzed), learned a set of targets (and were quizzed), performed the actual task, and completed a post-experimental questionnaire. For the ongoing syllable judgment task, participants were required to make two versus three syllable judgements about English words presented on a computer. Participants pressed the “F” key for two-syllable words (e.g., *boredom*) and the “J” key for three-syllable words (e.g., *cynical*). After each judgement, a brief (500ms) fixation cross appeared before another word stimulus was presented.

Practice Block Phase. After reading instructions for the ongoing task, participants completed a 20-trial practice block and received accuracy feedback after each trial. Participants were only allowed to proceed after achieving 75% accuracy or greater on the practice. Afterward, participants performed another practice block (40 trials) without feedback.

Attention Check Phase. Participants provided gender information after the practice block phase along with a filler question. There was then an attention check that instructed the participant to “Press the 2-key to indicate you are paying attention.” Attention check failures resulted in immediate exiting of the experiment and participants not receiving credit.

Intention Instruction Phase. Upon completing the practice phase, participants received instructions for the upcoming PM task. Participants were instructed that they were going to learn a single word or list of words that were to later appear during the syllable judgment task. The PM intention was to make a special response (press the “7” key) whenever they encountered the PM target(s). They were to press the “7” key *instead* of making their ongoing task response.

However, participants were told that the primary objective was still to perform the ongoing task as quickly but as accurately as possible. A brief instructions quiz was then presented to each participant with two questions. The first question asked about the goal of the intention (i.e., look for specific words). The second question asked for the PM response (i.e., press the “7” key). Participants had to get every question correct before proceeding. If they answered a question wrong, they had to reread the instructions to ensure proper encoding of the PM task.

Target Learning Phase. Participants then studied one (low load condition) or four (high load condition) PM targets for five seconds each. Their memory for the targets was then quizzed using a two-alternative forced choice test. A PM target and a control-matched word (i.e., matched in letter and syllable length) were presented on the left and right side of the screen. Half of the time the correct answer appeared on the left side of the screen and half of the time it appeared on the right. Participants pressed either the left or right arrow key to indicate which word they studied previously. Participants had to achieve 100% accuracy before proceeding. If there was an incorrect answer, at the end of the recognition quiz they were required to restudy all the targets and take the quiz again.

Reminder Phase. After achieving 100% accuracy, the PM instructions were reiterated for all participants. The no reminder conditions then began the distractor task. The reminder condition was additionally instructed, “To help you remember the studied words, they will be listed in the upper part of your screen in yellow during the next syllable judgement task.”. The reminder conditions then began the distractor task.

Distractor Phase. Participants completed arithmetic problems involving multi-digit addition and subtraction for two-minutes before the PM block.

PM Block Phase. Before beginning the PM block, participants received instructions that reiterated only the ongoing task instructions. The ongoing task consisted of 200 trials with word type (two vs. three syllable) randomly presented. Every 25 trials a PM target was presented. In the low load conditions, one of the four PM targets was randomly selected and then presented eight times. In the high load conditions, the four cues were randomly presented two times each, once in the first half and once in the second half of the PM block.

For the no reminder conditions, the task appearance mirrored the second ongoing task practice block. In contrast, for the reminder conditions, participants additionally had the single learned PM target (low load) or all four PM targets (high load) listed in yellow font at the top of the screen (see Figure 1). The target reminders remained on the screen for the entire duration of the PM block.

Post-experimental Questionnaire Phase. After the PM block, participants completed post-experimental questions assessing their retrospective memory for the PM task. They were first asked to freely recall the intention. They were then given a multiple-choice test to identify the PM intention (i.e., “look for specific words”) and the response (i.e., “press 7”). Participants then answered two 5-point Likert scale questions, one on the perceived importance of the ongoing task and the other on the perceived importance of the PM task (1 = *Not at all important*, 5 = *Very important*). An attention check followed the importance questions instructing the participant to “Press the 3-key to indicate you are paying attention.” The reminder conditions were then asked a 5-point Likert scale question about how frequently they checked the reminder (1 = *Not at all*, 5 = *All the time*). Recognition memory for the PM targets was assessed using the same two-alternative forced choice test as in the target learning phase. Lastly, participants were asked

whether they wrote down the PM targets. Participants were informed that reporting cheating would not influence their credit compensation.

Exclusionary Criteria

Exclusionary criteria were preregistered. Attention check failures resulted in immediate termination of the study. Participants who failed the attention checks had incomplete data and were not counted toward the sample total. Participants were excluded for the following: a) zero scores on PM performance *and* failing to recognize the PM response key on the post-experimental questionnaire ($n = 1$); b) reporting cheating (writing down PM targets; $n = 4$); c) performing below 50% on the math distractor ($n = 1$); d) achieving less than 50% ongoing task accuracy for either two- or three-syllable words in both the control and PM block ($n = 1$). Participants meeting first exclusionary criterion (forgetting the PM task instructions) represented a failure in retrospective memory rather than an PM error.

Results

Separate 2 (load: low vs. high) x 2 (reminder: reminder vs. no reminder) between-subjects ANOVAS were conducted for PM performance, ongoing task performance, and recognition memory. A successful PM response involved pressing the “7” on target trials in lieu of making ongoing task response. Late responses were not counted as correct. PM performance was calculated as a proportion of successful PM responses out of eight PM trials. Ongoing task performance during the PM block included accuracy and mean response times. The first three ongoing task trials and the three ongoing task trials following a PM trial were excluded from analyses (Ball & Bugg, 2018). Ongoing task reaction times were calculated for correct responses only. Trials falling below -3.0 and above 3.0 standard deviations away from an individual’s mean response time mean were excluded from analyses. Recognition memory refers to the

proportion of correctly identified PM targets on the recognition test at the end of the experiment. The aforementioned data analyses were preregistered. Exploratory analyses were also conducted for perceived PM task importance and frequency of reminder checking.

PM Performance

The analysis for PM performance revealed that PM was higher with reminders [*Reminder*: $F(1, 186) = 31.17, p < .001, \eta_p^2 = .142$], and with low cognitive load [*Load*: $F(1, 186) = 41.77, p < .001, \eta_p^2 = .181$]. There was also an interaction between the two [*Reminder x Load*: $F(1, 186) = 5.99, p = .015, \eta_p^2 = .031$]. This interaction reflects that while reminders improved PM in both the low load [$F(1, 92) = 5.89, p = .017, \eta_p^2 = .060$] and high load [$F(1, 97) = 28.15, p < .001, \eta_p^2 = .225$] conditions, the improvements from reminders was greater under high load.

Figure 2

PM Performance in Experiment 1 as a Function of Reminder and Cognitive Load

Note. This figure shows the PM performance results in each condition. PM performance refers to the proportion of PM targets detected by the total targets that appeared (eight).

Ongoing Task Performance

Accuracy. For ongoing task accuracy, there was no effect of reminder [*Reminder*: $F < 1$] or load [*Load*: $F < 1$], and there was no interaction between the two [*Reminder* $\times$ *Load*: $F(1, 189) = 1.60, p = .208, \eta_p^2 = .008$].

Table 1*Means and standard errors for non-PM performance outcome variables*

Group	OGT Accuracy		OGT RTs (ms)		Recognition Memory	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Experiment 1						
Low - No Reminder	.94	.01	1671	100	1.00	.00
High - No Reminder	.93	.01	1559	65	.98	.01
Low - Reminder	.92	.02	1462	76	1.00	.00
High - Reminder	.94	.01	1747	97	1.00	.00
Experiment 2						
Low - No Reminder	.94	.01	1489	77	1.00	.00
High - No Reminder	.95	.01	1621	72	1.00	.00
Low - Reminder	.93	.01	1553	99	1.00	.00
High - Reminder	.92	.01	1845	94	.99	.01
Experiment 3						
No Reminder	.94	.01	1685	58	.99	.01
Reminder	.95	.01	1537	66	.99	.01

Note. OGT = ongoing task; RT = response time.

Response Time. For response times, there was no effect of reminder ($F < 1$) or load ($F < 1$). There was, however, an interaction between the two [*Reminder $\times$ Load*: $F(1, 189) = 5.21, p = .024, \eta_p^2 = .027$]. This interaction reflects that response times were nominally, but not significantly, faster with reminders than without reminders under low load [$F(1, 92) = 2.36, p = .128, \eta_p^2 = .025$], and response times were nominally, but not significantly, slower with reminders than without reminders under high load [$F(1, 97) = 2.88, p = .093, \eta_p^2 = .029$].

Recognition Memory

The analysis of recognition memory found no significant effect of reminder [*Reminder*: $F(1, 189) = 2.91, p = .090, \eta_p^2 = .015$], no effect of cognitive load [*Load*: $F(1, 189) = 2.91, p =$

.090, $\eta_p^2 = .015$], and there was no interaction between the two [*Reminder x Load*: $F(1, 189) = 2.91, p = .090, \eta_p^2 = .015$].

Exploratory Analyses

PM Importance. For the analysis of perceived importance of the PM task, there was no effect of reminder [*Reminder*: $F < 1$] or cognitive load [*Load*: $F < 1$] on PM task importance, and there was no interaction between the two [*Reminder x Load*: $F < 1$].

Reminder Checking. The analysis of reminder checking frequency was conducted only on the two reminder conditions. Participants reported checking the reminder more frequently in the high load condition than in the low load condition [$F(1, 93) = 39.12, p < .001, \eta_p^2 = .346$].

Discussion

Experiment 1 tested the effect of reminders on PM as a function of cognitive load using specific targets. As predicted, reminders improved PM performance, particularly under high load. This is consistent with previous research showing that reminders provide greater benefit when the number of targets is high compared to a single target (Gilbert, 2015a). Of note, the benefit of reminders was not due to improved recognition memory or to reminders inflating the perceived importance of PM task. However, it is possible that the greater reminder benefit under high load could be partially driven by the increase in reminder checking frequency. Unlike Chen et al. (2017) that found benefits to ongoing task performance with reminders, there was no clear effect of reminders or load on ongoing task performance. While there was a significant load by reminder interaction on response times, reminders did not significantly influence response times within each load condition. It is possible that any reduction in attentional load by having reminders was washed out by reminder checking. Chen et al. used a single focal cue (i.e., a certain letter in an n-back task) that may not have required frequent checking. In the present

study, no difference in ongoing task performance between the reminder and no reminder conditions in the low condition suggests that participants did not rely on reminders unnecessarily when the intention could easily be remembered internally.

It should be noted that performance was very high in the low load condition. Previous research using single specific (or focal) targets have reported similar results (Einstein et al., 2005; Hicks et al., 2017; Marsh et al., 2003). It is therefore possible that the benefits with reminders in the low load condition were limited by ceiling effects. Experiment 2 was designed as a conceptual replication using nonspecific targets in order to remove ceiling effects.

Experiment 2

The purpose of Experiment 2 was to conceptually replicate Experiment 1 using nonspecific (i.e., categorical) PM targets. Past research showed nonspecific targets can reduce PM performance and increase ongoing task costs, suggesting nonspecific targets require greater attention to notice (i.e., preparatory monitoring; e.g., Smith, 2003; Smith & Bayen, 2004, 2005). If ceiling effects obscured any important findings in Experiment 1, this should be remedied in the current experiment as we anticipate performance to be considerably lower (also see Gilbert, 2015a). Load was manipulated in a similar manner as Experiment 1 with one (low load) or four (high load) nonspecific targets. That is, participants learned a single category (e.g., *birds*; low load) or four categories (e.g., *birds, furniture, sports, and vegetables*; high load) and were instructed to make a PM response to any exemplars from a learned category (e.g., *parakeet*). Those in the reminder conditions had the nonspecific target(s) (i.e., category words) listed at the top of their screen. As with Experiment 1, we predicted that reminders would improve PM performance, particularly under high cognitive load. We did not have any specific predictions for

ongoing task performance, because as described in Experiment 1, there are multiple possible theoretical outcomes. Preregistration for Experiment 2 can be found at <https://osf.io/7cxvs>.

Method

Participants

An a priori power analysis based on the effect size from pilot data recommended 120 participants across the four conditions. Due to experimenter error, 160 participants were collected. All participants (*aged* 18 – 40; $M = 19.64$, $SD = 3.53$) were undergraduate students at the University of Texas at Arlington that received class credit for participation. Of the 160 participants collected, nine participants were excluded for meeting exclusionary criteria detailed below, leaving the final sample size at 151. Participants were randomly assigned to one of four conditions, including the no reminder low load ($N = 37$), no reminder high load ($N = 36$), reminder low load ($N = 39$), and reminder high load ($N = 39$).

Design and Materials

A 2 (load: low vs. high) x 2 (reminder: reminder vs. no reminder) between-subjects design was employed, such that participants either learned one (low load) or four (high load) PM targets with (reminder condition) or without (no reminder condition) the use of reminders. Ongoing task stimuli were the same as Experiment 1. Nonspecific category targets were chosen from category norms (Van Overschelde et al., 2004). The four categories were *birds*, *vegetables*, *furniture*, and *sports*. The three most common exemplars from each category. There was a total of 36 category exemplars. The bird exemplars were *bluejay*, *cardinal*, *flamingo*, *sparrow*, *seagull*, *parakeet*, *penguin*, and *woodpecker*. The vegetable exemplars were *broccoli*, *spinach*, *potato*, *zucchini*, *pepper*, *cucumber*, *cabbage*, and *lettuce*. The furniture exemplars were *loveseat*,

dresser, nightstand, ottoman, recliner, armoire, bookshelf, and cabinet. The sports exemplars were *baseball, running, swimming, volleyball, bowling, badminton, wrestling, and lacrosse.*

QuestionPro survey software was used to obtain consent and randomly assign participants to each condition. The experiment was developed with PsychoPy3 and hosted on Pavlovia.com in the same manner as Experiment 1.

Procedure

The overall procedure in Experiment 2 matched that of Experiment 1, except the PM targets were nonspecific (i.e., categorical) instead of specific words. Participants learned a single (low load) or four (high load) category words. They were instructed to make a PM response (press the “7” key) whenever they saw an exemplar (e.g., *parakeet*) from a learned category (e.g., *birds*) in the subsequent syllable rating task. Eight PM targets appeared in the PM block, with one occurring every 25th trial. In the low load condition, one of the four categories was randomly selected as the PM target for each participant and each of the eight exemplars was randomly presented during the ongoing task once. In the high load conditions, all four of the categories were selected as PM targets. Two exemplars were randomly selected from each category and presented during the PM block. One exemplar from each of the four categories was randomly selected to appear among the first four PM targets. Then the second exemplar from each category appeared as one of the last four PM targets. The category order and the exemplar from each category was randomized, meaning that across all participants in the high load conditions, each of the exemplars had an equal chance of appearing in the PM block. The reminder conditions had the single category (low load) or all four category (high load) names (e.g., *birds*) listed at the top of the screen in yellow font (see Figure 1).

Exclusionary Criteria

Participants were excluded for the following: a) failing to have any PM hits *and* failing to recall the PM response key during the post-experimental questionnaire ($n = 4$); b) reporting cheating (writing down PM targets; $n = 1$); c) performing below 50% on the math distractor ($n = 0$); d) achieving less than 50% in ongoing task accuracy for either two- or three-syllable words in both the control and PM block ($n = 4$).

Results

The data analytic approach was identical to Experiment 1. As with Experiment 1, PM performance, PM block ongoing task performance (accuracy and response times), PM target recognition memory were separately submitted to a 2 (load: low vs. high) x 2 (reminder: reminder vs. no reminder) ANOVA. Exploratory analyses for perceived PM task importance [2 (Load) x 2 (Reminder) ANOVA] and reminder checking frequency (one-way ANOVA) were also conducted.

PM Performance

The analysis for PM performance revealed that PM was higher with reminders [*Reminder*: $F(1, 147) = 15.89, p < .001, \eta_p^2 = .098$], and with low cognitive load [*Load*: $F(1, 147) = 19.94, p < .001, \eta_p^2 = .119$]. There was also an interaction between the two [*Reminder x Load*: $F(1, 147) = 6.02, p = .015, \eta_p^2 = .039$]. This interaction reflects that reminders did not improve PM in the low load condition [$F < 1$], but they did in the high load condition [$F(1, 73) = 26.15, p < .001, \eta_p^2 = .264$].

Figure 3*PM Performance as a Function of Reminder and Cognitive Load*

Note. This figure shows the PM performance results in each condition. PM performance refers to the proportion of PM targets detected by the total targets that appeared (eight).

Ongoing Task Performance

Accuracy. For ongoing task accuracy, reminders reduced performance [*Reminder*: $F(1, 147) = 4.70, p = .032, \eta_p^2 = .031$]. However, there was no effect of load [$F < 1$] and no interaction between the two [$F < 1$].

Response Time. For response times, there was no effect of reminder [*Reminder*: $F < 1$]. However, increasing cognitive load slowed response times [*Load*: $F(1, 147) = 5.92, p = .016, \eta_p^2 = .039$]. There was no interaction between the two, [*Reminder* $\times$ *Load*: $F < 1$].

Recognition Memory

For recognition memory, there was no significant effect of reminder [*Reminder*: $F < 1$] or cognitive load [*Load*: $F < 1$], and there was no interaction between the two [*Reminder* $\times$ *Load*: $F < 1$].

Exploratory Analyses

PM Importance. For the analysis of perceived importance of the PM task, there was no effect of reminder [*Reminder*: $F(1, 147) = 1.58, p = .211, \eta_p^2 = .011$] or cognitive load [*Load*: $F(1, 147) = 3.72, p = .056, \eta_p^2 = .025$], and there was no interaction between the two [*Reminder x Load*: $F(1, 147) = 3.20, p = .076, \eta_p^2 = .021$].

Reminder Checking. The analysis of reminder checking frequency was conducted only on the two reminder conditions. Participants reported checking the reminder more frequently in the high load condition than in the low load condition [$F(1, 76) = 27.25, p < .001, \eta_p^2 = .264$].

Discussion

Experiment 2 replicated the PM performance benefit of reminders under high cognitive load observed in Experiment 1, but with lower overall performance. The benefit to PM performance did not come at a cost to recognition memory and it was not due to increased perceived importance of the PM task. As in Experiment 1, the improved PM performance could be in part explained by the increased reminder checking in the high load reminder condition. Contrary to Experiment 1, there was an overall cost of reminders to ongoing task accuracy and slower response times under high load. The finding that reminder benefits came at small cost to ongoing task performance for nonspecific targets, but not specific targets, is generally consistent with Gilbert (2015a) who found that participants rely on reminders to a greater extent when the targets are nonfocal than when they are focal. Notably, there was no influence on response times, which is typically a more sensitive indicator of PM monitoring.

Experiments 1 and 2 manipulated cognitive load by increasing the number of PM targets. Increasing the number of targets can increase demands on both prospective (attention) and

retrospective (memory) components of PM (Wesslein et al., 2014). Experiment 3 aimed to look at the effects of reminders specifically on memory load.

Experiment 3

While the first two experiments manipulated the attention and memory loads by increasing the number of PM targets, Experiment 3 focused on whether reminders provided differential benefit under strictly varied memory load. An event-based PM task that uses target-action paired associates requires participants to respond by typing in the action word when a specific target appears in the ongoing task. Paired associates with strong associations (e.g., *salt – pepper*) have a low cognitive load, whereas paired associates with weak associations (e.g., *candle – elbow*) have a high cognitive load (Cook et al., 2014; McDaniel et al., 2004). Cognitive load in Experiment 3 was manipulated within-subjects by having participants learn two strongly associated pairs and two weakly associated pairs. The reminder condition had all four paired associates listed at the top of the screen. As with previous experiments, we anticipated that reminders would produce a greater benefit to PM performance under high load than low load. We did not have any specific hypothesis for ongoing task performance. The preregistration for Experiment 3 can be found in the supplemental file at <https://osf.io/d46f3>.

Method

Participants

A power analysis for a 2x2 mixed methods ANOVA based on the interaction effect size from Experiment 2 recommended 80 participants. A conservative sample of 100 participants was chosen (reminder $n = 50$; no reminder $n = 50$) to account for potential exclusionary data. The entire sample consisted of undergraduate students at the University of Texas at Arlington (*aged* 18 – 28, $M = 18.81$, $SD = 1.77$) who received class credit for participation. Of the total 100

participants collected, thirteen participants were excluded for meeting exclusionary criteria detailed below, for a final sample of 87. Participants were randomly assigned to either the reminder condition ($N = 44$) or the no reminder condition ($N = 43$).

Design

A 2 (load: low vs. high; *within*) x 2 (reminder: reminder vs. no reminder; *between*) mixed-method design was employed. Load was manipulated within-subjects by varying the association between the target-action paired associates. All participants experienced both high (low-load) and low-association (high-load) target-action paired associates.

Materials

Ongoing task stimuli were the same as Experiment 1. For the PM target-action pairs, paired associates were chosen using the Florida Association Norms (Nelson et al., 2004). High association paired associates (low load) had forward and backward associations both above .5 (e.g., *positive – negative* and *forward – backward*). Low association (high load) paired associates had no forward or backward association (e.g., *renounce – sculpture* and *conference – intimate*).

Procedure

The procedure was similar to those used in Experiment 1 and 2. It included and ongoing task practice with feedback (20 trials), ongoing task practice with feedback (40 trials), PM task instructions, PM task instructions quiz, PM task practice, PM target-action pair study, PM target-action pair quiz, distractor, PM block (200 trials), and post experimental questions.

There were a few changes to accommodate the difference in the PM response (i.e., typing the target word). The first change was to the ongoing task more generally. Rather than the ongoing task response resulting in the onset of the next trial, a “+” symbol appeared indicating that they were to press the spacebar to continue to the next trial (Cook et al., 2014). After

practicing the ongoing task, participants received instructions for the PM task. Participants were instructed that they would learn four target-action paired associates and should type in the second word of the pair if they encountered the first word during the syllable judgment task.

Specifically, participants were instructed to type in the second word during the “+” message that followed the ongoing task response. For example, when *positive* was presented, participants should have first pressed the “J” key to indicate it was a three-syllable word, then typed in the word “*negative*” when the “+” message appeared, and then pressed the spacebar to move onto the next trial. Participants were instructed to type “*idk*” if they noticed the PM target but forgot what the action word associate was.

Because this task is slightly more complicated than the previous procedures, a practice PM task was inserted after the PM task instructions quiz (but prior to the PM target-action pair learning phase) to ensure the participants fully understood the instructions. Participants studied a practice target-action pair (*flower* – *sunlight*) and then completed a brief (5-trial) version of a PM block. Participants completed four syllable judgement trials before being presented with the PM cue (*flower*). Participants had to correctly type in the practice target word (*sunlight*) during the “+” message after making their ongoing task response to “*flower*” to continue to the next part of the study. If they did not do it correctly, they were brought back to the PM instructions screen and then redid the practice PM block. Upon successful completion of the practice, participants then studied the four target-action pairs for five seconds each. They were then quizzed on target-action pair using a two-alternative choice test as in Experiments 1 and 2. In the reminder condition, participants were instructed that the target-action pairs would be presented at the top of the screen (see Figure 1). Participants then completed the distractor task, PM block, and post-experimental questionnaires similar to Experiments 1 and 2.

Analysis and Exclusionary Criteria

Participants were excluded for meeting the following preregistered criteria: a) failing to have any PM hits *and* failing to recall the PM response key during the post-experimental questionnaire ($n = 4$); b) reporting cheating (writing down PM cues; $n = 3$); d) performing below 50% on the math distractor ($n = 2$); c) achieving less than 50% in ongoing task accuracy for either two- or three-syllable words in both the control and PM block ($n = 2$); e) falling outside three standard deviations of the sample mean in ongoing task response times ($n = 2$). This last exclusionary criterion was added to the preregistration to capture participants not putting in a good faith effort into the task.

Results

In Experiment 3, PM performance was submitted to a 2 (load: low vs. high; *within*) x 2 (reminder: reminder vs. no reminder; *between*) mixed method ANOVA. PM performance refers to targets (e.g., *positive*) correctly responded to with the action word (e.g., *negative*). PM block ongoing task performance (accuracy and response times) and PM target recognition memory were separately submitted and one-way ANOVAs. An exploratory analysis for perceived PM task importance also applied a one-way ANOVA.

PM Performance

The analysis for PM performance revealed that PM was higher with reminders [*Reminder*: $F(1, 85) = 21.90, p < .001, \eta_p^2 = .205$], and with low cognitive load [*Load*: $F(1, 85) = 38.43, p < .001, \eta_p^2 = .31$]. There was also an interaction between the two [*Reminder x Load*: $F(1, 85) = 9.16, p = .003, \eta_p^2 = .097$]. This interaction reflects that although reminders improved

PM under the low load [$F(1, 85) = 7.36, p = .008, \eta_p^2 = .080$], reminders improved PM to a greater extent under high load [$F(1, 85) = 32.56, p < .001, \eta_p^2 = .277$]².

Figure 4

PM Performance as a Function of Reminder and Cognitive Load

Note. This figure shows the PM performance results in each condition. PM performance refers to the proportion of PM targets correctly responded to out of the total targets that appeared (eight). All participants had two low load and two high load paired associates that each appeared twice.

² Participants were instructed to type in “idk” if they recognized the target but forgot what action word to type in. We therefore also calculated the proportion of targets where they typed in any response (correct response, incorrect response, or “idk”) to serve as a measure of “target noticing”. The preregistration document listed the 2 (Load; within) x 2 (Reminder; between) mixed method ANOVA for target noticing as a supplementary analysis. The analysis for target noticing revealed that targets were noticed more often with reminders [$Reminder: F(1, 85) = 21.36, p < .001, \eta_p^2 = .201$], and with low cognitive load [$Load: F(1, 85) = 31.18, p < .001, \eta_p^2 = .268$]. There was also an interaction between the two [$Reminder \times Load: F(1, 85) = 5.73, p = .019, \eta_p^2 = .063$]. This interaction reflects that although reminders improved target noticing under the low load [$F(1, 85) = 9.59, p = .003, \eta_p^2 = .101$], reminders improved target noticing to a greater extent under high load [$F(1, 85) = 27.57, p < .001, \eta_p^2 = .245$]. As the pattern of target noticing mirrors that of PM performance, it will not be discussed further.

Ongoing Task Performance

Accuracy. For ongoing task accuracy, reminders had no effect on performance

[*Reminder*: $F(1, 85) = 1.32, p = .253, \eta_p^2 = .015$].

Response Time. For response times, there was no effect of reminder [*Reminder*: $F(1, 85) = 2.81, p = .097, \eta_p^2 = .032$].

Recognition Memory

For recognition memory, there was no significant effect of reminder [*Reminder*: $F < 1$].

Exploratory Analyses

PM Importance. For perceived importance of the PM task, there was no effect of reminder [*Reminder*: $F < 1$].

Discussion

Consistent with previous research, PM performance was significantly better under low than under high load (Cook et al., 2014; McDaniel et al., 2004). Critically, however, Experiment 3 replicated the results from Experiments 1 and 2 in that reminders provided a greater benefit to PM performance under high load. Additionally, the reminder benefit did not occur due to improved recognition memory for the PM target-action pairs or to increased perceived PM task importance. Finally, there was no influence of reminders on ongoing task performance. These findings provide clear evidence that reminders are particularly beneficial when memory load is high.

General Discussion

The present study aimed to test the effect of reminders on PM performance as a function of PM load. Across all three experiments, it was found that the benefit of reminders was greater under high load than low load conditions. Importantly, the improvements in PM from reminders

generally occurred without any additional cost to ongoing task performance and without any reduction of retrospective memory for the targets at the end of the experiment. Together these results suggest that reminders can be beneficial for reducing PM failures, particularly under high load, without the potential downside of increased effort expenditure. Below we discuss the theoretical and applied ramifications of such findings.

Previous research has shown that increased cognitive load – whether that be manipulated through target specificity, the number of targets, or retrieval demands – can negatively impact PM performance (Cook et al., 2014; Einstein et al., 2005; Marsh et al., 2003; McDaniel et al., 2004; Wesslein et al., 2014). This pattern was replicated across all three experiments of the current study. That is, without the use of reminders, PM performance was better for single target compared to multi-target intentions in Experiments 1 and 2 and for strongly associated relative to weakly associated pairs in Experiment 3. These results are consistent with predictions from the Multiprocess Framework (Einstein et al., 2005) that posits that task parameters determine the extent to which effortful and attention-demanding processes are used to retrieve PM intentions. Given the difficulty of intention fulfilment under high load, it is important to examine whether compensatory strategies can be used to improve performance.

One strategy that has been shown to be beneficial for improving PM is offloading. Across various laboratory tasks – including standard event-based tasks, aviation tasks, virtual week tasks, and intention offloading tasks – the ability to use reminders to offload PM demands onto the environment has been found to increase intention fulfilment (Chen et al., 2017; Cherkaoui & Gilbert, 2017; Gilbert, 2015a, 2015b; Gilbert et al., 2020; Guynn et al., 1998; Henry et al., 2012; Loft et al., 2011; Vortac et al., 1995). The current study replicated this finding, demonstrating that reminders benefitted PM across all three experiments. Critically, only one prior experiment

(using the intention offloading task) has examined how reminders may be beneficial under different PM task loads (Gilbert, 2015a). Our results showed that the largest benefits could be seen when demands were the greatest. It should be noted, however, in both Experiments 1 and 3, there was still an improvement from offloading even under low load. One possibility is that even with specific cues participants engaged in preparatory monitoring. The Preparatory Attention and Memory Process theory argues that some degree of attention is required to successfully complete even the simplest of event-based PM tasks and that no PM task is fully automatic (Smith, 2003). However, if this were the case, it is not entirely clear why this same effect was not found in Experiment 2 using nonspecific cues. Perhaps having a reminder present throughout the task increases the fluency of target processing even under low load, making it more likely for spontaneous retrieval to occur following discrepant processing (Morita, 2006). In contrast, a nonspecific (i.e., categorical) reminder would not necessarily increase discrepancy, as the reminder is not target-specific. Regardless of the exact reasons, the fact that there was still some benefit to PM even under low load provides further support for the utility of reminders. Corroborating and extending previous findings, however, reminder benefits are clearly greatest under high load (Gilbert, 2015a; Gilbert et al., 2020).

The results of the current study help better understand the mechanisms underlying PM offloading. Multinomial modelling applied to PM tasks has shown that different demands can influence the prospective (attention) and retrospective (memory) components of PM (Smith & Bayen, 2004, 2005). For example, Wesslein et al. (2014) showed reducing target specificity increased demands on attention, whereas increasing the number of targets increased both the demands on attention and memory processes. The fact that reminders (independent of load) benefitted both specific (Experiments 1 and 3) and nonspecific (Experiment 2) targets in the

current study suggests that reminders may reduce demands on attention. This is further supported by the small benefit of reminders for specific targets even under low load when memory demands should be negligible. Additionally, Ball et al. (2021) found that individuals with low working memory benefited from reminders more than high working memory individuals in the intention offloading task. In addition to attention, reminders likely lessened demands on the retrospective component of PM in Experiments 1 and 2, as the benefit of reminders became much stronger as the number of targets increased. Furthermore, the direct manipulation of memory demands in Experiment 3 adds clearer support for the idea that reminders improved the memory component of PM. Borrowing terminology from the episodic memory literature (Tulving & Pearlstone, 1966), it is possible that reminders reduce demands on attention by increasing the *availability* of the intention, whereas they reduce demands on memory by increasing *accessibility* of the intention. Increased availability may in part stem from reductions in lapses of intention (West & Craik, 1999).

In addition to improvements to PM performance, the current study investigated whether reminders influenced ongoing task processing. Past research has considered ongoing task cost to reflect devoting attention to the PM task instead of the ongoing task (e.g., Smith, 2003). Task characteristics leading to higher PM demands, such as nonspecific cues and a higher number of targets, have been shown to reduce ongoing task performance (Cohen et al., 2008; Einstein et al., 2005; Marsh et al., 2003; but see Wesslein et al., 2014 for no additional ongoing task cost). Assuming reminders reduce attentional demands, presumably this should result in more attention being devoted to the ongoing task that results in improved ongoing task performance (e.g., Chen et al., 2017). However, another possibility is that reminder checking periodically diverts attention away from the ongoing task by orienting gaze to the target list in order to refresh the PM target

representation. In the current study, only in Experiment 2 was there a reduction in ongoing task accuracy with reminders. Notably, there was no influence on response times, which is typically a more sensitive indicator of PM processing demands. This suggests a third possibility. In general, reminders may be used to reduce demands on attentional resources that could be redirected to improve ongoing task processing. However, periodic checking of reminders may reduce the ongoing task performance on the subset of trials where attention is diverted to the reminders. These opposing processes could lead to the mostly null results observed in the present study. Future studies could examine objective reminder use by requiring a button press to access the reminders similar to clock checking in time-based PM tasks (Oksanen et al., 2014).

Examining ongoing task performance also provided a means to examine whether participants unnecessarily relied on reminders. The “minimal memory” view asserts that people will use reminders whenever possible in order to minimize internal processing load (Ballard et al., 1997). Consistent with this idea, Gilbert et al. (2020) found participants chose to set reminders despite being able to perform the task using their own memory – even when it was costly to use reminders. Critically, in the present study, no difference in ongoing task performance with and without reminders when the PM target could easily be remembered (i.e., low load) suggests reminders were not used unnecessarily.

Finally, the current study explored whether having reminders influenced later memory of the targets during a post-experimental recognition test. Prior research in the retrospective memory domain has examined the influence of expected reminders on memory recall. For example, (Kelly & Risko, 2019) had participants engage in multiple study-test opportunities with reminders. On the final test, the reminder was unexpectedly taken away. Those who expected a reminder had worse memory than those in a condition in which they always had to rely on their

own memory (and thus did not expect a reminder). In the present study, participants had a reminder for the PM task, but did not have a reminder when their recognition memory was tested at the end of the procedure. However, this did not appear to influence memory, as recognition was quite high in both conditions. It is possible that the difference in findings compared to previous research is that the greater exposure to the PM targets during the PM task could have provided further opportunities for rehearsing and encoding the targets. Alternatively, these findings may simply reflect that performance was (perhaps unsurprisingly) near ceiling given so few targets in both low and high load conditions.

Conclusions

Three experiments demonstrated PM is improved by reminders, especially when the PM load is high. In everyday life, effective PM ability is essential to navigating a complex world and critical for maintaining independence with increased age (Woods et al., 2012). Remembering and executing the multitudes of daily intentions (e.g., appointments, medications, grocery lists, etc.) and various spontaneous tasks that arise from moment to moment (e.g., replying to emails, getting gas, filling a pet's water bowl, etc.) can be difficult. Given the current findings, reminders provide a promising tool for supporting populations with low PM abilities (e.g., schizophrenia) or general cognitive decline (e.g., older adults). The finding that there was no apparent cost of reminders to ongoing task performance or a no reduction in retrospective memory representations further highlights the utility of externally supporting PM.

References

- Ball, B. H., & Bugg, J. M. (2018). Context cue focality influences strategic prospective memory monitoring. *Psychonomic bulletin & review*.
- Ball, B. H., Peper, P., Alakbarova, D., Gilbert, S. J., & Brewer, G. (2021). Individual Differences in Prospective Memory Offloading in Laboratory and Naturalistic Settings.
- Ballard, D. H., Hayhoe, M. M., Pook, P. K., & Rao, R. P. (1997). Deictic codes for the embodiment of cognition. *BEHAVIORAL AND BRAIN SCIENCES*, 20, 723-767.
- Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., Neely, J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). The English Lexicon Project. *Behav Res Methods*, 39(3), 445-459. <https://doi.org/10.3758/bf03193014>
- Brewer, G. A., Knight, J. B., Marsh, R. L., & Unsworth, N. (2010). Individual differences in event-based prospective memory: Evidence for multiple processes supporting cue detection. *Memory & cognition*, 38(3), 304-311.
- Chen, Y., Lian, R., Yang, L., Liu, J., & Meng, Y. (2017). Working memory load and reminder effect on event-based prospective memory of high-and low-achieving students in math. *Journal of Learning Disabilities*, 50(5), 602-608.
- Cherkaoui, M., & Gilbert, S. J. (2017). Strategic use of reminders in an ‘intention offloading’ task: Do individuals with autism spectrum conditions compensate for memory difficulties? *Neuropsychologia*, 97, 140-151.

- Cohen, A. L., Jaudas, A., & Gollwitzer, P. M. (2008). Number of cues influences the cost of remembering to remember. *Mem Cognit*, 36(1), 149-156.
<https://doi.org/10.3758/mc.36.1.149>
- Cook, C., Ball, B. H., & Brewer, G. A. (2014). No effects of executive control depletion on prospective memory retrieval processes. *Conscious Cogn*, 27, 121-128.
<https://doi.org/10.1016/j.concog.2014.04.006>
- Einstein, G. O., & McDaniel, M. A. (2010). Prospective memory and what costs do not reveal about retrieval processes: A commentary on Smith, Hunt, McVay, and McConnell (2007). *J Exp Psychol Learn Mem Cogn*, 36(4), 1082-1088; discussion 1089-1095.
<https://doi.org/10.1037/a0019184>
- Einstein, G. O., McDaniel, M. A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N., & Breneiser, J. (2005). Multiple processes in prospective memory retrieval: factors determining monitoring versus spontaneous retrieval. *J Exp Psychol Gen*, 134(3), 327-342. <https://doi.org/10.1037/0096-3445.134.3.327>
- Gilbert, S. J. (2015a). Strategic offloading of delayed intentions into the external environment. *Quarterly Journal of Experimental Psychology*, 68(5), 971-992.
<https://doi.org/10.1080/17470218.2014.972963>
- Gilbert, S. J. (2015b). Strategic use of reminders: Influence of both domain-general and task-specific metacognitive confidence, independent of objective memory ability. *Consciousness and Cognition*, 33, 245-260. <https://doi.org/10.1016/j.concog.2015.01.006>

- Gilbert, S. J., Bird, A., Carpenter, J. M., Fleming, S. M., Sachdeva, C., & Tsai, P.-C. (2020). Optimal use of reminders: Metacognition, effort, and cognitive offloading. *Journal of Experimental Psychology: General*, 149(3), 501.
- Graf, P., & Utzl, B. (2001). Prospective memory: a new focus for research. *Conscious Cogn*, 10(4), 437-450. <https://doi.org/10.1006/ccog.2001.0504>
- Gynn, M. J., McDaniel, M. a., & Einstein, G. O. (1998). Prospective memory: when reminders fail. *Memory & cognition*, 26(2), 287-298.
<http://www.ncbi.nlm.nih.gov/pubmed/9584436>
- Heathcote, A., Loft, S., & Remington, R. W. (2015). Slow down and remember to remember! A delay theory of prospective memory costs. *Psychol Rev*, 122(2), 376-410.
<https://doi.org/10.1037/a0038952>
- Henry, J. D., Rendell, P. G., Phillips, L. H., Dunlop, L., & Kliegel, M. (2012). Prospective memory reminders: a laboratory investigation of initiation source and age effects. *Q J Exp Psychol (Hove)*, 65(7), 1274-1287. <https://doi.org/10.1080/17470218.2011.651091>
- Hicks, J. L., Franks, B. A., & Spitler, S. N. (2017). Prior task experience and comparable stimulus exposure nullify focal and nonfocal prospective memory retrieval differences. *Quarterly Journal of Experimental Psychology*, 70(10), 1997-2006.
- Ihle, A., Schnitzspahn, K., Rendell, P. G., Luong, C., & Kliegel, M. (2012). Age benefits in everyday prospective memory: the influence of personal task importance, use of reminders and everyday stress. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*, 19(1-2), 84-101. <https://doi.org/10.1080/13825585.2011.629288>

Kelly, M. O., & Risko, E. F. (2019). Offloading memory: Serial position effects. *Psychonomic bulletin & review*, 26(4), 1347-1353.

Loft, S., Smith, R. E., & Bhaskara, A. (2011). Prospective memory in an air traffic control simulation: External aids that signal when to act. *Journal of Experimental Psychology: Applied*, 17(1), 60-70. <https://doi.org/10.1037/a0022845>

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *J Exp Psychol Learn Mem Cogn*, 24(2), 336-349.
<https://doi.org/10.1037//0278-7393.24.2.336>

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29(5), 861.

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *J Exp Psychol Learn Mem Cogn*, 30(3), 605-614. <https://doi.org/10.1037/0278-7393.30.3.605>

Morita, T. (2006). Reminders supporting spontaneous remembering in prospective memory tasks
1. *Japanese Psychological Research*, 48(1), 34-39.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (2004). The University of South Florida free association, rhyme, and word fragment norms. *Behavior Research Methods, Instruments, & Computers*, 36(3), 402-407.

- Oksanen, K. M., Waldum, E. R., McDaniel, M. A., & Braver, T. S. (2014). Neural mechanisms of time-based prospective memory: evidence for transient monitoring. *PLoS One*, 9(3), e92123. <https://doi.org/10.1371/journal.pone.0092123>
- Risko, E. F., & Gilbert, S. J. (2016). Cognitive Offloading. *Trends in Cognitive Sciences*, 20(9), 676-688. <https://doi.org/10.1016/j.tics.2016.07.002>
- Schnitzspahn, K. M., Kvavilashvili, L., & Altgassen, M. (2020). Redefining the pattern of age-prospective memory-paradox: new insights on age effects in lab-based, naturalistic, and self-assigned tasks. *Psychol Res*, 84(5), 1370-1386. <https://doi.org/10.1007/s00426-018-1140-2>
- Scullin, M. K., McDaniel, M. A., Shelton, J. T., & Lee, J. H. (2010). Focal/nonfocal cue effects in prospective memory: Monitoring difficulty or different retrieval processes? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36(3), 736.
- Shelton, J. T., Scullin, M. K., & Hacker, J. Y. (2019). The multiprocess framework: Historical context and the “dynamic” extension. In J. Rummel & M. A. McDaniel (Eds.), *Prospective Memory* (pp. 10-26). Routledge.
- Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29(3), 347.
- Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30(4), 756.

- Smith, R. E., & Bayen, U. J. (2005). The effects of working memory resource availability on prospective memory: A formal modeling approach. *Experimental Psychology*, 52(4), 243-256.
- Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. *Journal Of Verbal Learning And Verbal Behavior*, 5(4), 381-391.
- Van Overschelde, J. P., Rawson, K. A., & Dunlosky, J. (2004). Category norms: An updated and expanded version of the norms. *Journal of Memory and Language*, 50(3), 289-335.
- Vortac, O. U., Edwards, M. B., & Manning, C. A. (1995). Functions of external cues in prospective memory. *Memory*, 3(2), 201-219.
- Wesslein, A.-K., Rummel, J., & Boywitt, C. D. (2014). Differential effects of cue specificity and list length on the prospective and retrospective prospective-memory components. *Journal of Cognitive Psychology*, 26(2), 135-146.
- West, R., & Craik, F. I. (1999). Age-related decline in prospective memory: the roles of cue accessibility and cue sensitivity. *Psychol Aging*, 14(2), 264-272.
<https://doi.org/10.1037//0882-7974.14.2.264>
- Woods, S. P., Weinborn, M., Velnoweth, A., Rooney, A., & Bucks, R. S. (2012). Memory for intentions is uniquely associated with instrumental activities of daily living in healthy older adults. *J Int Neuropsychol Soc*, 18(1), 134-138.
<https://doi.org/10.1017/S1355617711001263>