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Investigating the Cost to Ongoing Tasks Not Associated with Prospective Memory Task Requirements

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Abstract

The purpose of the current study was to investigate the relationship between prospective memory (PM) and consciousness by examining cost to ongoing activities, with cost assumed to reflect a direction of conscious resources away from the ongoing task in service of the PM task. Ongoing task blocks in which the PM task was relevant or irrelevant were alternated to achieve three aims: determine if cost would persist in irrelevant blocks when relevant and irrelevant blocks were clearly demarcated and irrelevant stimuli were incompatible with the PM task; investigate if costs would be greatest at the start of irrelevant blocks; and determine whether costs would occur when the irrelevant block preceded any relevant blocks. Costs were found in irrelevant blocks and greater cost at the start of the irrelevant blocks suggest the cost may be due in part to participants making decisions about the engagement of conscious resources at transition points.

Keywords

prospective memory; cost; irrelevant context; preparatory attentional processing; attentional allocation policy; strategic monitoring

1. Introduction

Prospective memory (PM), or remembering to perform intentions in the future, is an important memory function in our daily lives. The goal of the current study is to build upon prior research investigating the relationship between PM and consciousness. Specifically, the current study examines the efficiency with which participants can limit the allocation of conscious resources to the PM task to times when these conscious resources can support PM performance. The allocation of conscious resources to the PM task is measured in PM

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paradigms by examining performance on ongoing activities. Performance of PM tasks outside of the laboratory often involves interrupting some ongoing activity in order to carry out the intended action. For instance, I may need to remember to give a message to a colleague. If this colleague walks by when I am conversing with another colleague, I have to interrupt the conversation to deliver the message. To capture this aspect of real world PM tasks, laboratory PM tasks are typically embedded in an ongoing task. For example, participants might be asked to remember to make the PM response of pressing the F1 key if they see the target word "dog" during on ongoing lexical decision task. In addition to providing a reasonable analog to real world PM tasks, the ongoing task can serve as a way to measure the extent to the PM task involves conscious resources (Smith, 2003).

A decline in ongoing task performance in a group of participants who are given PM instructions relative to a control group that does not do the PM task is often called the cost to the ongoing task. Cost to the ongoing task is generally thought to reflect the extent to which the PM task involves processing that draws on our limited span of consciousness. Although costs to the ongoing task may not be found for all PM tasks (Einstein & McDaniel, 2010)[1], costs are consistently found when the properties of the target associated with the intention are not the focus of ongoing task processing (i.e., *non-focal targets*; Einstein et al., 2005), and the extent of the cost can be positively related to non-focal PM performance (e.g., Loft & Humphreys, 2012; Smith & Bayen, 2004), thus, in some circumstances the conscious resources that produce a cost are beneficial.

At the same time, it would not be beneficial to draw on our limited span of consciousness unnecessarily, such as during intervals when it is not possible to perform the PM task. However, prior research suggests that participants do in some cases engage these conscious resources during contexts in which the PM task is not relevant. The current study provides a replication of earlier work by Marsh, Cook, and Hicks (2006) and Lourenço and Maylor (in press), and goes beyond this prior research by examining whether participants continue to devote conscious resources to the PM task in irrelevant contexts when the irrelevant blocks of trials are clearly demarcated from blocks of trials relevant to the PM task (all three experiments), and when the stimuli in irrelevant blocks are incompatible with making a PM response (Experiments 2 and 3). Experiment 3 also investigates whether the cost in irrelevant blocks is dependent upon having previously performed the PM task, and whether the magnitude of this cost varies across trials within irrelevant blocks.

1.1 Allocation of Conscious Resources in Irrelevant Contexts

We are aware of six prior studies that have focused specifically on whether a cost is found in contexts in which the PM task is not relevant versus when the PM task is relevant. Key

[1]The multiprocess view (MPV) of PM makes a distinction between focal and non-focal PM tasks. In focal PM tasks the characteristics that define the PM target event are processed as part of the ongoing task requirements. The MPV further proposes that PM tasks may sometimes be accomplished through spontaneous retrieval of the delayed intention (e.g., Einstein et al., 2005). Specifically, if the PM task is a focal task, with a simple action combined with instructions that do not emphasize the PM task, participants are less likely to engage strategic monitoring processes and will instead rely on spontaneous retrieval. This in turn should eliminate the cost to the ongoing task (Harrison & Einstein, 2011). In the case of non-focal tasks the MPV would expect that strategic monitoring would be involved and a cost to the ongoing task would be demonstrated. A non-focal task was selected for the current experiments because we were specifically interested in whether a cost, when found, can be isolated to the relevant trials only. The MPV does not make a specific prediction about factors that would influence demonstration of a cost during irrelevant blocks of the ongoing task.

details of the methods used in each study can be found in Table 1. In two studies the cost has been eliminated in the irrelevant context (Marsh, Hicks, & Cook, 2006; Cook, Marsh, Clark-Foos, & Meeks, 2007). In both of these studies the relevant context was clearly demarcated and temporally rather distant from the irrelevant context. In contrast, other studies have presented less differentiated relevant and irrelevant contexts and have found that the cost persists in the irrelevant context. Marsh, Cook et al. (2006; Experiment 1B) and Lourenço and Maylor (in press) both found a reduction, but not an elimination, in cost for irrelevant compared to relevant trials. Marsh, Cook et al. also found reduced costs on irrelevant trials when participants were cued regarding the nature of each upcoming randomly presented trial (Experiment 2 and 3), but not when relevant and irrelevant stimuli were presented at random without cueing (Experiment 1A). However, three more recent studies have found variations in cost on non-cued randomly alternating relevant and irrelevant trials (Cohen, Jaudas, Hirschhorn, Sobin, & Gollwitzer, 2012; Lourenço & Maylor, in press; Lourenço, White, & Maylor, 2013). Overall, a fairly consistent picture has emerged showing that the cost, while sometimes reduced on irrelevant trials, is not eliminated on irrelevant trials when the switch between relevant and irrelevant trials occurs randomly or over relatively short blocks. In other words, the PM task is absorbing some of our limited conscious capacity during times when this would not necessarily be the most efficient use of our conscious resources.

1.2 Why Would Conscious Resources be Allocated to the PM Task in Irrelevant Contexts?

A number of theoretical explanations have been proposed regarding the allocation of conscious resources to the PM task in ongoing task contexts that are relevant to PM tasks (for review see Hicks, Marsh & Cook, 2005; Loft & Humphreys, 2012) and several of these explanations also address the mechanisms behind the allocation of conscious resources to the PM task during blocks of PM irrelevant trials. One way in which conscious resources can be involved is through strategic monitoring. Guynn's (2003) two process model of strategic monitoring (activation/retrieval mode + checking) proposes that the first stage of monitoring is a retrieval mode in which the intention is maintained in an active state. This first stage can be followed by the second level of monitoring in the form of checking for targets. Guynn predicted that participants would engage both levels of monitoring on experimental (relevant) trials regardless of whether blocked or alternating randomly, but that when the trials were blocked, neither type of monitoring should be engaged for the control (irrelevant) trials. The findings from the Marsh, Cook, et al. (2006) Experiment 1 B contradicts the two process model given that a cost was found on their irrelevant trials despite the blocking of relevant and irrelevant trials. However, Guynn used blocks of 24 trials compared to the use of ten trials in Marsh, Cook, et al., and Guynn did not specify how many trials must occur in a block to see elimination of cost to the ongoing task. We return to this issue in the general discussion in Section 5.2.

Marsh, Cook et al. (2006; Hicks et al., 2005) suggested that metacognitive beliefs, formed at the time of intention encoding, will influence how participants allocate conscious resources between the PM and the ongoing task, referred to as 'attentional allocation policies'. Marsh, Cook et al. propose that these policies can be altered during the experiment according to participants' expectations regarding the predicted relevance of upcoming stimuli to PM tasks. For instance, the policy could be affected by unconscious activation of the intention when a stimulus is relevant to the PM task, producing a greater cost in the relevant context. They also suggest that "…greater interference on intention-related material could reflect a conscious strategy of processing the material more carefully…" (p. 1642). According to this view costs will be greater in blocks that are more relevant to the PM tasks, consistent with the findings of greater cost on relevant versus irrelevant blocks of trials (Lourenço et al., in press; Marsh, Cook et al., 2006, Experiment 1B).

Another explanation arises from comparing the length of the relevant and irrelevant blocks, as shown in Table 1, in Marsh, Cook et al. (2006; see also Lourenço and Maylor (in press) and Marsh, Hicks et al. (2006). Marsh, Cook et al. suggested that when blocks are relatively short, "the intention could need to be executed imminently, so it would be of some value to keep it slightly activated or available" (p. 1642). Marsh Cook et al. proposed that the elimination of cost in the longer blocks in the Marsh, Hicks et al. (2006) study, indicates that in the Marsh, Hicks et al. study "knowledge that the relevant context was temporally distal meant that keeping the intention activated was of no fundamental use until that context was encountered" (p. 1642). Thus, when shorter blocks are used (Lourenço & Maylor; Marsh, Cook et al) participants may continue to intentionally allocate some conscious resources to the PM task in irrelevant blocks if the relevant block is deemed temporally imminent enough to warrant that.

Further explanation for the cost in the irrelevant context can be found in the preparatory attentional and memory processes (PAM) theory (Smith, 2003, 2008, 2010). The PAM theory proposes that successful PM performance involves preparatory attentional processes that include a process of making decisions about the appropriate responses for a given stimulus or situation. Preparatory attentional processes are resource demanding in that they draw on our limited span of consciousness, but a distinction is made here between consciousness and focal awareness. Preparatory attentional process can occur as the focus of attention in the form of explicit monitoring for the target events, but more often the processes will take place on the periphery of attention. "Those processes may not be the focus of attention, but they do consume conscious resources." (Smith Hunt, McVay, & McConnell, 2007, p 742) Preparatory attentional processes allow the individual to be prepared to recognize an opportunity to carry out the intention, with the recognition of target events involving processes similar to those involved in retrospective memory tasks. Retrospective memory is also required for recalling the intended action. With respect to the cost in the irrelevant context, PAM theory proposes that "preparatory attentional processing is likely to be initiated at points of transition" in our activities (Smith et al., 2007, p.742; see also Smith, 2008). That is, when transitioning between relevant blocks and irrelevant blocks participants need to determine whether preparatory attentional processing is required for that block. There is evidence from the task switching literature that such switching of task response sets is resource demanding and costs performance (Gopher, Armony, & Greenshpan, 2000; Rogers & Monsell, 1995). Thus, in the irrelevant blocks, even if an individual decides that preparatory attentional processing is not necessary for that particular block, there may be conscious resource demands (costs) associated with making this decision. In a similar vein, Marsh, Cook et al.'s (2006; Hicks et al., 2005) attentional allocation view would assume that participants may need to make conscious strategic decisions regarding adjustments to their attentional allocation policy. However, costs should decrease across trials in irrelevant blocks, once the decision not to engage preparatory attentional processing, or to adjust attention allocation policies, has been made. This latter point is investigated in Experiment 3.

While the aforementioned explanations of the differences between studies that have reported costs in irrelevant blocks (Lourenço & Maylor, in press; Marsh, Cook et al, 2006) and studies that have not reported costs in irrelevant blocks (Cook et al. 2007; Marsh, Hicks et al., 2006) are quite reasonable, methodological differences between these two sets of studies point to an alternative explanation. In the Marsh, Cook et al. and Lourenço and Maylor studies participants were not explicitly told that the PM targets would not appear on the irrelevant blocks. Thus, participants may have been unsure about the relevance of the PM task on irrelevant blocks in the Marsh, Cook et al. and Lourenço and Maylor experiments, leading to a cost on the trials not associated with the intention. In contrast, Cook et al. (2007) told participants that the irrelevant block was in fact irrelevant and Marsh, Hicks et al. (2006) told participants that the target words would not appear in the irrelevant block.

Therefore, there was no clear demarcation between irrelevant and relevant PM blocks in the Marsh, Cook et al. studies or in the Lourenço and Maylor study. In our Experiment 1 relevant and irrelevant PM blocks were clearly demarcated by (a) explicitly instructing participants that the PM target words would only appear on one type of trial, (b) informing participants prior to the start of each block which type of stimuli would appear in that block, and (c) having participants self-initiate the start of each block. These design changes may discourage the allocation of resources to the PM task in irrelevant contexts, and thus Experiment 1 serves as an important replication and extension of the Marsh, Cook et al. and Lourenço and Maylor studies.

2. Experiment 1

In our first experiment we embedded a non-focal PM task requirement in an ongoing color-matching task, because this task combination has produced robust costs to ongoing tasks during relevant PM contexts in prior studies (Boywitt & Rummel, 2012; Horn, Bayen, Smith, & Boywitt, 2011; Smith & Bayen, 2004, 2006; Smith, Bayen, & Martin, 2010; Smith, Horn, & Bayen, 2012; Smith et al., 2007). We used short blocks that either included the relevant trial type (blocks in which participants in the PM group were to perform the PM task) or included the irrelevant trial type (blocks in which neither the PM group nor control group was to perform the PM task). We explicitly told participants that the PM target words would only appear on one type of trial. In addition we queried subjects to be sure that they could identify which trial type was relevant to the PM task following the PM instructions and again during a post-test questionnaire. Furthermore, participants were informed prior to the start of each block which type of stimuli would appear in that block, and participants initiated the start of each block. The temporal proximity explanation predicts that we should continue to see the cost during the irrelevant blocks, replicating Marsh, Cook et al. (2006) and Lourenço and Maylor (in press). The PAM theory also predicts a cost in these short irrelevant blocks because of the need to make decisions in each block about the relevance of the block to the PM task and any related need to engage preparatory attentional processing. Alternatively, if methodological differences underlie the different patterns seen in previous studies then our more clearly demarcated irrelevant and relevant PM contexts could eliminate the cost on irrelevant blocks.

2.1 Method

2.1.1 Participants and design—Introductory psychology students volunteered for this and the subsequent experiments in exchange for credit towards a course requirement. The 113 participants in the first experiment, who were native English speakers, were randomly assigned to either a control condition (n = 58) or a PM condition (n = 55). The design included the within-subject manipulation of block type, as detailed below in Section 2.1.2.

2.1.2 Materials and procedures—After completing a consent form, participants read instructions for the ongoing color-matching task. On each trial of the color-matching task, participants saw four rectangles presented one at a time for 500 ms followed by a 250 ms blank screen. The 83 by 60 pixel rectangles were presented in the center of a black screen. Each rectangle was shown in a different color (blue, green, yellow, red, or white). Following the fourth color rectangle a word was displayed on the screen. The color in which the word was displayed either matched one of the four colors on that trial (a match trial) or the word color did not match (non-match trial). This manipulation comprised the within-subject variable of trial type.

Participants were instructed to press the Y key for "yes" if the color of the word matched one of the four colors shown on that trial and to press the N key for "no" if the color of the word did not match any of the colors shown on that trial. Following their response, a message was displayed asking the participants to press the space-bar to start the next trial. Following two practice trials, participants were invited to ask questions before starting the color-matching trials. The words for the ongoing task were medium frequency words used in Smith (2003).

During the session the participants completed a total of nine blocks of color-matching trials (see Figure 1a). The first block of 36 color-matching trials established a baseline for performance on the color-matching task prior to the instructional manipulation. The subsequent blocks each included eight trials for a total of 100 trials across the experiment. Half of the trials were match trials and half were non-match trials. For the match baseline and filler trials, the word color matched the first, second, third, or fourth color rectangle shown on that trial, with each of these possibilities occurring equally often. Two of the PM target trials were non-match trials and two were match trials. On the match PM target trials the color of the word matched the color of the second or third color rectangle. The order of match and non-match trials and the position of the matching color were randomly determined for each participant. The order of filler and target words was also random. In the PM condition, the target words appeared on the fourth or fifth trial in Blocks 2, 4, 6, and 8, as shown in Figure 1a.

Following the first block of the color-matching task participants were instructed that for the remaining color-matching trials each block of trials would appear in all uppercase or all lowercase. The word "UPPERCASE" or the word "lowercase" was presented prior to starting each block to indicate which would occur in that block. For participants in the control condition the uppercase and lowercase designations had no significance. Control participants were then told that they would study six words for three minutes, and that they would be asked to recall these words at the end of the experiment.

For participants in the PM condition either the upper or the lower case designation was associated with a PM intention in the following way. Participants in the PM condition were instructed that they would learn six words and that they should try to remember to press the "F1" key if these words appeared during the ongoing color-matching task. Participants were told to make their PM response after making the response for the ongoing task. Furthermore, participants were instructed that the PM target words would only appear in uppercase block (or lowercase blocks for the other half of the participants) and therefore they did not need to remember to perform this task during the lowercase (or uppercase) blocks. As a manipulation check, participants responded to a multiple choice question in which they were asked to indicate which type of trials (upper or lowercase) were relevant for the PM task. If participants answered incorrectly, the computer program would return to the PM instructions for review and retesting.

Participants were given the opportunity to ask questions before learning the six target words. All participants learned the target words in order to equate the groups on this dimension and on the need to remember the words during the course of the experiment. Participants in both conditions were shown six target words simultaneously on the computer screen for three minutes. After learning the target words, participants worked on a number puzzle for five minutes before starting the second block of color-matching trials.

All participants completed Blocks 3 to 9 without additional instructions, save for the designation of "UPPERCASE" or "lowercase" preceding each block. In both conditions, the blocks alternated between lower and uppercase. Half of the participants received uppercase letters in Block 1 and half received lowercase letters in Block 1. In the former counterbalancing condition (illustrated in Figure 1a), words in the second block were presented in uppercase and the PM intention was associated with the uppercase context. In the latter counterbalancing condition, the words in the second block appeared in lowercase and the PM intention was associated with the lowercase context. For each participant in the PM condition, four of the six possible PM targets were randomly selected to appear once each on Blocks 2, 4, 6, and 8 (thus four targets were presented during the experiment in total). The same counterbalancing of uppercase and lowercase was used for the control condition.

Following completion of the final block of color-matching trials, participants in the PM condition were asked to indicate which context (upper or lowercase) was relevant for the PM task. One participant who responded incorrectly was excluded and replaced. Participants in both the PM and control condition completed a recognition test for the target words, in which they were shown the six target words and six non-target words in a random order and responded Yes or No to indicate if the word was in the target list.

2.2 Results and Discussion

2.2.1 PM performance and target recognition—Participants in the PM group correctly responded to 76% of PM targets (*SE* = 4%). Although only the PM group was given PM instructions, both groups learned the target words and then were given a post-task recognition test for those words. The PM and control groups did not differ with respect to the corrected hit rate on the post-task target recognition test, $F < 1$, p =.405, (M = .92, SE = .02).

2.2.2 Ongoing task performance—The analysis of ongoing task performance for the test phase excluded PM target trials and the two trials that followed the target trials in order to avoid finding a cost associated with carrying out intentions or with post-output PM monitoring processes. We collapsed over Blocks 2, 4, 6, and 8 to evaluate performance during relevant blocks (i.e., blocks in which the PM group was to perform the PM task) and collapsed over Blocks 3, 5, 7, and 9 to examine performance during irrelevant blocks (i.e., blocks in which neither group was to perform the PM task).

2.2.2.1 Accuracy: Adopting an approached used previously by Horn et al., (2011) and Smith et al. (2012), we examined participants' ability to correctly discriminate between match and non-match trials in the ongoing color-matching task using corrected hit rates. The corrected hit rate in baseline Block 1 (M = .84, SE = .01) was not affected by group, $F < 1$, p = .924. Corrected hit rates for the test blocks were analyzed using a 2 (group: PM or control) X 2 (block type: relevant or irrelevant) mixed ANOVA which produced no main effects or interaction, all *F*s < 1, *p*s > .62, (M = .81, SE = .02). Consistent with prior work using the color-matching ongoing task (e.g., Smith et al. 2007), a cost was not demonstrated on accuracy.

2.2.2.2 Response times: In all experiments, trials with response times (RTs) of less than 200 ms or more than 3 standard deviations from an individual's mean RT were excluded, with the mean and standard deviation calculated separately for each trial type (match and non-match) and for the baseline block, blocks with PM targets (relevant blocks), and blocks without PM targets (irrelevant blocks). This resulted in the exclusion of 1% of trials. Only trials with accurate responses were included in analyses of RT. Response times in relevant and irrelevant blocks as a function of condition are presented in Table 2.

Baseline RTs did not differ as a function of group, $F(1,111) = 1.73$, $p = .192$, (M = 1329 ms, SE = 32). In the analysis of RTs in the experimental blocks, shown in Table 2, a 2 (group) X 2 (block type) mixed ANOVA with RTs as the dependent variable, produced main effects of group, $F(1,111) = 56.37$, $MSE = 282772$, $p < .001$, $\eta_p^2 = .34$, and block type, $F(1,111) = 145.73$, $MSE = 79896$, $p < .001$, $\eta_p^2 = .57$, which were qualified by a significant interaction, $F(1,111) = 62.12$, $MSE = 79896$, $p < .001$, $\eta_p^2 = .36$. The interaction was investigated with separate ANOVAs for each block type. The RTs in the relevant blocks were larger for the PM group than for the control group, $F(1,111) = 88.06$, $MSE = 219694$, $p < .001$, $\eta_p^2 = .44$. Although the effect size was smaller, the PM group was also slower than the control group to respond in the irrelevant blocks, $F(1,111) = 10.89$, $MSE = 142974$, $p = .001$, $\eta_p^2 = .09$.

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The demonstration of a cost to the ongoing task during blocks that are associated with an intention is consistent with previous studies which used similar PM and ongoing tasks (e.g. Smith et al, 2007, 2012; Smith & Hunt, in press). The demonstration of a cost for the PM group relative to the control group during the blocks that are not associated with an intention (irrelevant blocks) replicates the findings of Marsh, Cook et al. (2006) and Lourenço and Maylor (in press). Furthermore, the current results indicate that the findings reported in Marsh, Cook et al. and Lourenço and Maylor were not due to the fact that irrelevant and relevant PM contexts were not clearly demarcated. It is more likely that costs persisted in irrelevant blocks in the Marsh, Cook et al. and Lourenço and Maylor studies and in Experiment 1 because participants needed to frequently make decisions about the relevance of the PM task for the upcoming block or because the temporal proximity of alternating PM task contexts was relatively short.

3. Experiment 2

In the first experiment words served as the PM targets. Words also served as stimuli for the ongoing task in the irrelevant blocks and therefore the stimuli in the irrelevant blocks were bivalent in that they could afford the PM response as well as the ongoing task response. In Experiment 2, materials were changed so that irrelevant blocks did not include words and therefore stimuli in the irrelevant blocks were univalent and would not afford a PM response.

Research in the task switching domain has consistently found greater task switch costs for bivalent than for univalent stimuli (Rubin & Merian, 2005; Ruthruff, Remington, & Johnston, 2001). Making decisions related to preparatory attentional processing or attentional allocation policies may be less resource demanding when stimuli in irrelevant blocks are univalent and only afford a response from the ongoing task set, as opposed to when stimuli in irrelevant blocks are bivalent and afford responses from both the ongoing and PM task sets. Thus, using univalent stimuli in irrelevant blocks that are incompatible with the PM task could lead to less pervasive cost or potentially an elimination of cost during irrelevant blocks. However, it is also possible that at least part of the cost in irrelevant blocks occurs because the intention is maintained due to the imminent nature of the PM task in subsequent blocks. In Experiment 2, the imminent presentation of the bivalent stimuli in relevant blocks at the time participants are dealing with irrelevant blocks remains the same as in Experiment 1. The aim of Experiment 2 was to extend Marsh, Cook, et al. (2006) and Lourenço and Maylor (in press) by examining whether costs can be found in irrelevant blocks for stimuli that were incompatible with making a PM response.

3.1 Method

3.1.1 Participants—The 201 participants were randomly assigned to either a control group (n=103) or PM (n=98) group.

3.1.2 Materials and procedures—Materials and procedures matched those of Experiment 1 with the following exceptions. The words presented in PM relevant blocks as probes in the color-matching task were always in lower case. For the irrelevant blocks the probe stimuli for the color-matching task were strings of lowercase x (xxxxxx), as shown in

Figure 1b. Participants were informed that some blocks of trials will include x-strings, that no words will occur during these blocks, and that the PM task did not have to be performed during these blocks. Blocks alternated between word and x-string stimuli as shown in the lower part of Figure 1b. The word "words" or the letter string "xxxxx" was presented prior to starting each block to indicate which type of stimulus would occur in that block. As in Experiment 1, participants completed a multiple choice question to test their comprehension of the context instructions prior to starting the task and following completion of the last block of trials. Three participants who failed to respond correctly on the post-task question were excluded and replaced.

3.2 Results and Discussion

3.2.1 PM performance and target recognition—Participants in the PM group correctly responded to 47% of the PM targets, *SEM* = 4%. Although there was a trend towards a higher corrected hit rate for post-task recognition of the target words for the control group (*M* = .95, *SE* = .01) relative to the PM group (*M* = .92, *SE* = .01), $F(1,199) = 2.94$, $MSE = .02$, $p = .088$, $\eta_p^2 = .02$, target recognition in the PM group is still very high and does not predict level of PM performance, $r = .13$, $p = .213$.[2]

3.2.2 Ongoing task performance—As in the analysis of Experiment 1, target trials and the two trials following each target were excluded in the analysis of ongoing task performance.

3.2.2.1 Accuracy: Baseline corrected hit rate (*M* = .87, *SE* = .01) was not affected by group, $F < 1$, $p = .81$. Accuracy in the experimental blocks was affected by block type, $F(1,199) = 36.06$, $MSE = .03$, $p < .001$, $\eta_p^2 = .15$, with more accurate responding in the irrelevant blocks (*M* = .83, *SE* = .01), than in the relevant blocks (*M* = .72, *SE* = .03). Recall that the relevant blocks in this experiment used words as the ongoing task stimuli, while the irrelevant blocks included x-strings (see Figure 1). The decrease in accuracy in the relevant blocks compared to the irrelevant blocks for both groups (block type did not interact with group $F(1,199) = 2.52$, $p = .114$), may indicate that automatic word reading interferes with ongoing task performance, consistent with the Stroop effect (MacLeod, 1991). Also in contrast to Experiment 1, the second experiment produced evidence for a cost to ongoing task accuracy as there was a significant main effect of group, $F(1,199) = 4.14$, $MSE = .08$, $p = .043$, $\eta_p^2 = .02$, with more accurate responding in the control group (*M* = .82 , *SE* = .01) than in the PM group (*M* = .78, *SE* = .02).

3.2.2.2 Response times: The same RT trimming criteria were used in this experiment as in Experiment 1, resulting in the exclusion of less than 1% of trials. Response times in relevant and irrelevant blocks as a function of condition are presented in Table 2.

[2]PM performance was reduced in Experiment 2 relative to Experiment 1. This could be due to the switch to the use of x-strings in the irrelevant blocks. It is possible that when words are present in the irrelevant blocks, as in Experiment 1, the words can serve as reminders of the PM task when the PM targets are words. Alternatively, participants in the PM condition of Experiment 1 showed a robust cost during irrelevant blocks and by devoting resources to the PM task during the irrelevant blocks this may serve to facilitate PM performance during the relevant blocks. On the other hand, differences across experiment could simply be a function of the particular samples of participants in each experiment.

Baseline RTs did not differ between the PM and control groups, $F < 1$, $p = .437$, ($M = 1269$, $SE = 24$). As in Experiment 1, we analyzed RTs in a 2 (group: control or PM) x 2 (block type: relevant or irrelevant) mixed ANOVA that produced main effects of group, $F(1,199) = 46.83$, $MSE = 411729$, $p < .001$, $\eta_p^2 = .19$, and block type, $F(1,199) = 415.07$, $MSE = 124643$, $p < .001$, $\eta_p^2 = .68$, which were qualified by a significant interaction, $F(1,199) = 110.25$, $MSE = 124643$, $p < .001$, $\eta_p^2 = .36$.As can be seen in Table 2, a significant cost was found in the PM relevant blocks, with slower RTs for the PM group than for the control group, $F(1,199) = 79.20$, $MSE = 414004$, $p < .001$, $\eta_p^2 = .29$.

In contrast to Experiment 1, in which the stimuli in the irrelevant blocks were words and therefore could potentially afford a PM response, our initial group comparison (Table 2 PM condition with all participants) for irrelevant blocks in Experiment 2 was not significant, $F(1,199) = 1.91$, $p = .168$, suggesting that a cost was eliminated for univalent stimuli in the irrelevant blocks. However, PM performance was also noticeably lower in this experiment relative to performance in the first experiment (47% versus 76%) and the effect size for the cost to response times in PM relevant blocks was also smaller in this experiment ($\eta_p^2 = .29$ versus .44). The motivating issue in this study is whether participants can effectively allocate resources to the ongoing task rather than to the PM task during the irrelevant blocks. One obvious way to reduce cost in the irrelevant blocks is to not allocate resources to the PM task in any blocks, either relevant or irrelevant. While reducing allocation of resources overall will also result in a reduction or elimination of cost during irrelevant blocks, this comes at a cost to PM performance, and this seems to have happened in the second experiment. The real question of interest is whether participants can maintain PM performance while also reducing or eliminating cost in the irrelevant blocks. Thus, we conducted an analysis of response times including only participants in the PM group who responded correctly to at least one of the four presented PM target events.

In order to be sure that this subset of the PM group (n= 59) continues to be well matched to the control group, we began with a reanalysis of baseline response times, which did not differ as a function of group, $F(1,160) = 1.23$, $p = .268$. The reanalysis of relevant and irrelevant blocks as a function of group produced a main effect of group, $F(1,160) = 66.71$, $MSE = 348058$, $p <.001$, $\eta_p^2 = .29$, and a main effect of block type, $F(1,160) = 440.05$, $MSE = 105240$, $p < .001$, $\eta_p^2 = .73$, as well as a significant interaction, $F(1,160) = 136.67$, $MSE = 105240$, $p < .001$, $\eta_p^2 = .46$. Participants in the PM group who made at least one correct PM response had slower response times than did participants in the control group for the relevant blocks, $F(1,160) = 107.80$, $MSE = 343915$, $p < .001$, $\eta_p^2 = .40$, and also for the irrelevant blocks, $F(1,160) = 4.81$, $MSE = 109383$, $p =.030$, $\eta_p^2 = .03$. Overall, the results of Experiment 2 confirm the findings from Experiment 1, and that of Marsh, Cook et al. (2006) and Lourenço and Maylor (in press), indicating that participants are not completely effective at redirecting resources to the ongoing task when the PM task is irrelevant. Experiment 2 also provides new information in that this pattern was found during irrelevant blocks in which the stimuli were univalent and thus could not afford a PM response.

4. Experiment 3

The primary goal of the third experiment was to replicate the costs to univalent stimuli found in Experiment 2, and to more explicitly investigate the cognitive mechanisms underlying cost in the irrelevant blocks. The irrelevant blocks in Experiments 1 and 2 always followed PM relevant blocks, and there is evidence from the task switching literature that previously implemented task response sets can interfere proactively with the establishment of new task response sets (Allport, Styles, & Hsieh, 1994). Thus, it is possible that the cost seen in the irrelevant blocks in the first two experiments was due in part to the fact that the irrelevant blocks always came after the relevant blocks. Experiment 3 was designed to investigate whether a history of having performed blocks of trials with PM task requirements (relevant blocks) is required to observe a cost in irrelevant blocks. That is, we tested whether a cost would be found in an irrelevant block that is not preceded by a PM relevant block. If a history of having performed the PM task is required to find a cost in the irrelevant block, then we should not find a cost in the irrelevant block that is not preceded by a PM relevant block. To investigate this issue, Experiment 3 included an irrelevant block after the PM instructions, but prior to the PM relevant block. In Figure 2, the key block is Block 3. By comparing performance in this block in the PM and control groups, we were able to examine the effects of expecting to have to perform the PM task later in the experiment, in the absence of having just performed the PM task.

The third experiment included additional trials in each block to investigate another key question. In addition to the possible effect of the temporal proximity of relevant contexts, we have argued that costs in irrelevant blocks at least partly reflect that participants need to make decisions about engaging preparatory attentional processing or adjustments to attention allocation policies, at points of transition between relevant blocks and irrelevant blocks. If at least some of the cost in irrelevant blocks is attributable to this decision process, then with additional irrelevant trials the cost is likely to be reduced. In this case, the PM group should show greater cost earlier in irrelevant blocks.

4.1 Methods

4.1.1 Participants—The 131 participants were randomly assigned to either a PM condition (N = 82) or a control condition (N = 49).[3]

4.1.2 Materials and procedures—Materials and procedures (Figure 2) matched those of Experiment 2 with the following exceptions (see Figure 2). Participants completed two baseline blocks, each with 24 trials: Block 1 with x-strings followed by Block 2 with words. The number of test blocks was reduced to three and the number of trials in each block was increased to 26 to allow for more observations across each test block. In Block 4, PM targets

[3]The original design of Experiment 3 included an additional manipulation of expectation in Block 5. Following completion of Block 4, half of participants in each group were told that there would be two more blocks, one block of x-strings followed by a another block with words. The other half of the participants were told that the next block of x-strings would be the final block of trials. In fact, the fifth block was the final block for all participants. The manipulation of expectation in Block 5 did not affect ongoing task accuracy or response times and did not interact with group in any of the five blocks, all *p*s > .15. Expectation did not affect PM performance or post-task target recognition, *p*s > .36. For the sake of conciseness, we do not discuss the manipulation in the text and we collapsed over the expectation variable in the reported analyses.

appeared on trials 13 and 24, one a non-match trial and the other a match trial. As in Experiments 1 and 2, participants completed a multiple choice question to test their comprehension of the context instructions prior to starting the task and following completion of the last block of trials. Six participants who responded incorrectly on the post-task question about which context (words versus xxxx) was associated with the PM task were excluded and replaced.

4.2 Results and discussion

4.2.1 PM performance and target recognition—Participants in the PM group responded correctly to 78% of target events (*SE* = .04). Corrected hit rates for post-task target recognition (*M* = .94, *SE* = .01) did not differ as a function of group, $F < 1$, $p = .942$.

4.2.2 Ongoing task performance—As in the earlier experiments, the analysis of ongoing task performance excluded the PM target trials and two trials following each target trial.

4.2.2.1 Accuracy: Performance in the two baseline blocks was analyzed in a 2 (block: 1 and 2) X 2 (group) ANOVA. Ongoing task corrected hit rates were significant higher in Block 2 (*M* = .91, *SE* = .01) than in Block 1 (*M* = .86, *SE* = .01), $F(1,129) = 15.19$, *MSE* = .01, $p < .001$, $\eta_p^2 = .11$. This pattern could be due to a practice effect benefitting the second block in which the word stimuli were used, or a speed-accuracy trade-off as noted below in Section 4.2.2.2. However, the essential baseline performance finding is that the main effect of group was not significant, $F(1,129) = 2.42$, $p = .123$, and the variables did not interact, $F < 1$, $p = .900$, indicating that the two groups were well matched with respect to baseline ongoing task accuracy.

As in the previous two experiments, the block in which the PM task was not performed, in this case Blocks 3 and 5, were combined as irrelevant blocks in a 2 (group) X 2 (block type: relevant versus irrelevant) ANOVA. Although neither the main effect of group, $F < 1$, $p = .415$, nor the main effect of block type reached significance $F(1,129) = 1.83$, $p = .178$, the two variable did interact with one another, $F(1,129) = 5.70$, *MSE* = .01, $p = .018$, $\eta_p^2 = .04$. There was evidence of a cost to ongoing task accuracy in the PM relevant Block 4, in the form of a trend toward better accuracy for the control group (*M* = .85, *SE* = .02) relative to the PM group (*M* = .80, *SE* = .02), $F(1,129) = 2.92$, *MSE* = .03, $p = .090$, $\eta_p^2 = .02$. The two groups did not differ with respect to accuracy in the irrelevant blocks (*M* = .85, *SE* = .01), $F < 1$, $p = .629$.

4.2.2.2 Response times: Prior to analysis, RT data were trimmed in the same manner as in the previous experiments with less than 1% of trials excluded. Response times in relevant and irrelevant blocks as a function of condition are presented in Table 2.

Baseline RTs varied as a function of block with longer RTs for words in Block 2 (*M* = 1399, *SEM* = 42) than with x-strings in Block 1 (*M* = 1311, *SEM* = 27), $F(1,129) = 7.71$, *MSE* = 49909, $p = .006$, $\eta_p^2 = .06$. The longer RTs in Block 2 with words could indicate interference from the word stimuli in performing the ongoing color-matching task. However, as noted above in Section 4.2.2.1, accuracy was also better in this block and the combined pattern may indicate a speed accuracy trade-off. The role of word versus non-word stimuli in the color-matching task is not a primary focus of this study, more importantly, neither the main effect of group, $F(1,129) = 2.11$, $p = .149$, nor the interaction of group and stimulus type, $F(1,129) = 1.38$, $p = .242$, reached significance. Thus the two groups were well matched with respect to baseline performance.

In a 2 (group) X 2 (block type: relevant and irrelevant) mixed ANOVA, the main effects of group, $F(1,129) = 82.20$, $MSE = 332075$, $p < .001$, $\eta_p^2 = .39$, and block, $F(1,129) = 174.86$, $MSE = 112263$, $p < .001$, $\eta_p^2 = .58$, were qualified by a significant interaction, $F(1,129) = 132.49$, $MSE = 112263$, $p < .001$, $\eta_p^2 = .51$. The interaction was investigated with separate analyses for each block type. As expected for this PM task, a cost was found in the PM relevant Block 4 with longer RTs in the PM group ($M = 2341$, $SE = 79$) than in the control group ($M = 1181$, $SE = 44$), $F(1,129) = 116.21$, $MSE = 354819$, $p < .001$, $\eta_p^2 = .47$. The cost in Block 4, replicates numerous studies showing a cost in this task on PM relevant blocks (e.g. Horn et al., 2011; Smith & Bayen, 2004, 2006; Smith et al., 2007, 2012). As in the first two experiments, the PM group ($M = 1283$, $SE = 36$) also responded more slowly than did the control group ($M = 1108$, $SE = 35$) in the irrelevant blocks, $F(1,129) = 10.45$, $MSE = 89518$, $p = .002$, $\eta_p^2 = .08$. This cost to the ongoing task in the irrelevant blocks occurred even though the stimuli in those blocks were univalent and thus inconsistent with the defining characteristics of the PM targets, replicating the findings from Experiment 2.

As noted in Section 4 we were also interested in whether the cost would be demonstrated in an irrelevant block that precedes any PM relevant blocks, therefore we compared the two groups in separate analyses of Block 3 and Block 5 RTs. The PM group had slower response times in both Block 3 ($M = 1296$, $SE = 39$) and Block 5 ($M = 1267$, $SE = 38$) relative to the control group ($M = 1123$, $SE = 35$, and $M = 1090$, $SE = 41$, respectively), both $F(1,129)$s > 9.25, ps = .003, η_p^2s = .07. The cost in Block 3 demonstrates that the expectation of having to complete the PM task in a subsequent block of the experiment can result in a cost to the ongoing task in an irrelevant block even without having performed an ongoing task block with a PM task requirement prior to that particular irrelevant block.

Finally, we conducted a finer grained analysis to determine the pattern of cost in the irrelevant blocks. Specifically, if costs in irrelevant blocks partly reflect that participants need to make decisions about engaging preparatory attentional processing at points of transition between relevant blocks and irrelevant blocks, the PM group will show variations in cost within blocks, with greater cost at the start of the irrelevant block.[4] The trials within the irrelevant Blocks 3 and 5 were subdivided into three subsets: Trials 1 to 8, Trials 9 to 18, and Trials 19 to 26. These data, shown in Table 3, were analysed in a 2 (group) x 2 (block) x 3 (subset) mixed ANOVA in which the main effect of subset, $F(1.76, 226.75) = 30.14$, $MSE = 65402$, $p < .001$, $\eta_p^2 = .19$, was qualified by significant interactions of subset and group,

[4]While it is the case that the PAM theory would predict that participants will also make decisions about whether to engage preparatory attentional processes at the start of the PM relevant blocks, the predictions for resulting patterns of RTs is less clear for the PM relevant blocks. While the decision on whether to engage preparatory attentional processes may slow RTs on the first few trials, the engagement of preparatory attentional processes and any retrospective recognition processes may slow RTs to a similar extent on subsequent trials. Because RTs provide only an indirect measure of the underlying processes (Smith, 2010) and because the relative resource demands of these different processes is not known, predictions concerning the cost across trials in the PM blocks are not clear.

$F(1.76, 226.75) = 3.90$, $MSE = 65402$, $p = .026$, $\eta_p^2 = .03$, and subset and block, $F(1.90, 244.81) = 3.16$, $MSE = 60581$, $p = .047$, η_p^2s = .02, using Greenhouse-Geisser correction. No other main effects or interactions reached significance, *p*s > .13. The interactions were investigated with separate 2 (group) x 2 (block) ANOVAs for each of the three subsets.

In the case of the first subset (Trials 1 to 8), both block, $F(1,129) = 8.70$, $MSE = 58292$, $p = .004$, $\eta_p^2 = .06$, and group, $F(1,129) = 4.82$, $MSE = 227840$, $p = .030$, $\eta_p^2 = .04$, produced significant main effects. The two variables did not interaction, $F < 1$, $p = .676$. Participants showed a practice effect, with faster response times in the first subset of Block 5 ($M = 1266$, $SE = 35$) relative to the first subset of trials in Block 3 ($M = 1360$, $SE = 32$). A cost was demonstrated for the first subset of trials in these irrelevant blocks, with slower response times for the PM group ($M = 1381$, $SE = 40$) relative to the control group ($M = 1156$, $SE = 39$).

The practice effect was not evident in the either the second subset (Trials 9 to 18) or third subset (Trials 19 to 26) as in both cases the main effect of block was not significant, *F*s < 1, *p*s > .63. The main effect of group also failed to reach significance in either the second subset, $F < 1$, $p = .837$, or the third subset, $F(1, 129) = 1.73$, $p = .191$. Block and group did not interact in either the second or third subsets of trials, *F*s < 1, *p*s > .43. Thus the cost in the irrelevant trials seen in the overall analyses was driven primarily by differences between the two groups at the start of the irrelevant blocks.

5. General Discussion

In three experiments, participants who were given PM instructions showed a cost in the form of slower ongoing task responses relative to a control group who performed the ongoing task without the PM task. The cost suggests that participants directed conscious resources away from the ongoing task to engage in processes related to the PM task. The cost was evident during blocks of the ongoing task that were relevant to the PM task, i.e. blocks in which the PM task was to be performed, consistent with a number of previous studies using similar tasks (e.g. Boywitt & Rummel, 2012; Smith & Bayen, 2004; Smith et al., 2007). However, a cost was also found in blocks that were not relevant to the PM task, i.e., blocks in which participants did not need to perform the PM task. Our findings replicate the results reported in earlier studies and build upon the earlier work in four ways. First, our results show that a cost can be found in irrelevant blocks even when relevant and irrelevant PM contexts are clearly demarcated; that is, when participants (a) are explicitly instructed that the PM target words can only appear on one type of trial, (b) are informed prior to the start of each block which type of stimuli will appear, and (c) self-initiate the start of each block. Second, our results show that the cost can be found in the irrelevant blocks even when the stimuli in the irrelevant blocks are univalent and thus incompatible with the PM task response (Experiments 2 and 3). Third, our results show that the cost in the irrelevant blocks is not dependent upon a history of having a PM task requirement in a preceding block (Experiment 3). Fourth, by conducting finer grained analysis of response times across the irrelevant blocks, we demonstrated that costs were eliminated on later trials within relatively short irrelevant blocks (Experiment 3).

The finding of a significant cost only at the start of the irrelevant blocks in Experiment 3 supports the theoretical claim that there are conscious resource demands associated with making decisions about preparatory attentional processing that are more likely to occur at points of transition. This is in line with findings in the task switching literature that switching task response sets is resource demanding and costs performance (Gopher et al. 2000; Rogers & Monsell, 1995). The results are also consistent with Marsh, Cook et al. (2006)'s attentional allocation policy view. From the perspective of Marsh, Cook et al., the current findings of greater cost at the start of the irrelevant blocks in Experiment 3 suggests that, at least in the current task, participants may have engaged in conscious strategic choices regarding adjustments in their attentional allocation policy. In contrast if the temporal proximity of relevant PM blocks was solely responsible for costs in irrelevant block, then we would not have found a change in costs across trials within irrelevant blocks. To our knowledge the current results provide the first comparison of the temporal proximity explanation with the attentional allocation policy view and the PAM theory.

While Marsh, Cook et al. (2006) allowed for the possibility that the change in attentional allocation policy could occur unconsciously, as noted in the previous paragraph, they also allowed for the possibility that the change could be made through conscious strategy decisions. Thus, the current results are consistent with both the attention allocation policy view and the PAM theory. However, Marsh, Cook et al. (2006) argued that their finding of a reduced cost in the irrelevant blocks relative to the PM blocks was inconsistent with the PAM theory. The apparent discrepancy can be explained as follows. Marsh, Cook et al's argument rests upon the assumption that once a PM intention was formed, the preparatory attentional processes would be engaged in a consistent fashion until the PM task could be performed (in their words, they assumed that the PAM theory viewed these processes as "monolithic"). This is incorrect. Quoting Smith et al. (2007, p. 742) "One need not be constantly engaged in preparatory attentional processing once an intent is formed." In fact, Smith's (2003) original demonstration of a cost compared two groups of participants, both of whom were given the same PM task, except that in one case this task was delayed during the criterion ongoing task. In other words, the control condition in the Smith (2003) study was equivalent to the irrelevant blocks in these experiments and in Marsh, Cook et al. and Marsh, Hicks, et al. (2006). The PAM theory does not propose that the preparatory attentional processes must be continuously maintained, only that they need to be engaged at the point when the PM task can be performed, thus the fact that the cost is reduced in the irrelevant blocks relative to the relevant blocks is consistent with the PAM theory, particularly, as discussed, the fact that the cost was more prominent in the start of the irrelevant blocks.

One aspect of the findings could be seen as inconsistent with prior research. The finding of a cost in Block 3 of Experiment 3 demonstrates that a cost can be found in an irrelevant block that precedes any block in which the PM task is relevant (i.e., no history of having performed the PM task). At first glance this would appear to conflict with the findings of Marsh, Hicks et al. (2006) in which a cost was not found in an irrelevant block that preceded the PM relevant block. However, as discussed in the introduction, the temporal proximity explanation would propose that because the PM relevant block in the Marsh, Hicks et al. study did not immediately follow the irrelevant block (i.e., in the relevant block the PM task was not temporally imminent) participants need not maintain the intention in an active state in the irrelevant block in the Marsh, Hicks et al. experiment. In addition, in Experiment 3 we found that costs decreased over time within irrelevant blocks, as predicted by PAM theory and the attention allocation policy view. In contrast to the blocks of 26 trials used in our Experiment 3, Marsh, Hicks et al. had 105 trials and all non-target trials were included in their analysis, potentially masking any costs that might have occurred on just a small subset of the trials at the beginning of irrelevant blocks.

5.1 Alternative Theoretical Account

As noted in Section 1.2, Guynn's (2003) two process model of strategic monitoring addresses the issue of cost during irrelevant trials. However, two findings from the current study appear problematic for Guynn's model: 1) the demonstration of a reduced cost in the irrelevant blocks relative to the PM blocks and 2) the fact that the cost was found only at the beginning of the irrelevant blocks in Experiment 3.

In Guynn's view the first stage of monitoring is a retrieval mode in which the intention is maintained in an active state, which can be followed by the second level of monitoring in the form of checking for targets. In her experiment, Guynn compared performance on control trials (i.e., trials not relevant to the PM task) and experimental trials (i.e., trials relevant to the PM task) as a function of whether the control trials and experimental trials were alternated or blocked. Guynn predicted that participants would engage both levels of monitoring on experimental (relevant) trials regardless of whether blocked or alternating, but that when the trials were blocked, neither type of monitoring should be engaged for the control (irrelevant) trials. A block in Guynn's experiment case consisted of 24 trials, similar to the 26 trials used in our third experiment. Thus, following the logic specified in predictions for her own experiment, it appears that Guynn's view would predict that neither level of monitoring would be engaged on the irrelevant trials in our Experiment 3, and therefore the two process model would not predict a cost to the ongoing task in the irrelevant blocks of Experiment 3. Thus, the current results, and least the results of Experiment 3, seem incompatible with Guynn's two process model.

In addition, Guynn (2003) predicted that the first level of monitoring (retrieval mode) would be engaged on control (irrelevant) trials that alternated with the experimental (relevant) trials, however, it is not clear how rapidly an alternation would have to occur for Guynn to predict that the first level of monitoring is engaged during control trials and therefore, it is also not clear what prediction she would make for the shorter blocks of 8 trials used in our Experiments 1 and 2. A post hoc explanation would perhaps suggest that the fact that the cost was lower in the irrelevant blocks than in the relevant blocks indicates that the first level of monitoring is engaged during the irrelevant trials of Experiment 1, while the second level of checking is not. On the whole, it appears that a more parsimonious explanation of the current findings can be found in the attentional allocation policy explanation and by PAM theory than by the Guynn (2003) two process model of strategic monitoring.

5.2 Conclusion

The focus of the current study on costs in both PM relevant and irrelevant contexts captures an important aspect of many PM tasks in workplace and everyday settings. The work of pilots, surgeons, and air traffic controllers, for example, can require operators to frequently switch been different ongoing task contexts that have varying degrees of relevance to deferred intended actions (Dismukes, 2012; Loft, Smith & Bhaskara, 2011; Loft, Smith, & Remington, 2013; Wickens & McCarley, 2008). Understanding when and why individuals devote conscious resources to the PM task at the expense of ongoing activities will increase understanding of PM performance and may lead to ways to improve PM (Smith, 2010). Specifically, by determining how to encourage individuals to devote conscious resources to the PM task during appropriate intervals (i.e., during times when the PM task can be performed) and not at other times, we may be able to maintain good PM performance during relevant PM contexts while minimizing the disruption of other activities during irrelevant PM contexts. Future research should also examine whether training individuals to build in transition points into their activities and to use these transition points to evaluate the relevant intentions, can improve PM performance.

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References

Allport, A.; Styles, EA.; Hsieh, S. Shifting intentional set: Exploring the dynamic control of tasks. In: Umilta, C.; Moscovitch, M., editors. Consciousness and nonconscious information processing: Attention and Performance. Vol. XV. Cambridge, MA: MIT Press; 1994. p. 421-452.

Boywitt CD, Rummel J. A diffusion model analysis of task interference effects in prospective memory. Memory & Cognition. 2012; 40:70–82. [PubMed: 21755410]

Cohen AL, Jaudas A, Hirschhorn E, Sobin E, Gollwitzer PM. The specificity of prospective memory costs. Memory. 2012; 20:848–864. [PubMed: 22900905]

Cook GI, Marsh RL, Clark-Foos A, Meeks JT. Learning is impaired by activated intentions. Psychonomic Bulletin & Review. 2007; 14:101–106. [PubMed: 17546738]

Dismukes RK. Prospective memory in workplace and everyday situations. Current Directions in Psychological Science. 2012; 21:215–220.

Einstein GO, McDaniel MA. Prospective memory and what costs do not reveal about retrieval processes: a commentary on Smith, et al. (2007). Journal of Experimental Psychology: Learning, Memory and Cognition. 2010; 36:1082–1088.

Einstein GO, McDaniel MA, Thomas R, Mayfield S, Shank H, Morrisette N, et al. Multiple processes in prospective memory retrieval: Factors determining monitoring versus spontaneous retrieval. Journal of Experimental Psychology: General. 2005; 134:327–342. [PubMed: 16131267]

Gopher D, Armony L, Greenshpan Y. Switching tasks and attention policies. Journal of Experimental Psychology: General. 2000; 129:308–329. [PubMed: 11006903]

Guynn MJ. A two-process model of strategic monitoring in event-based prospective memory: Activation/retrieval mode and checking. International Journal of Psychology. 2003; 38:245–256.

Harrison TL, Einstein GO. Prospective memory: Are preparatory attentional processes necessary for a single focal cue? Memory & Cognition. 2010; 38:860–861.10.3758/MC.38.7.860 [PubMed: 20921099]

Hicks JL, Marsh RL, Cook GI. Task interference in time-based, eventbased, and dual intention prospective memory conditions. Journal of Memory and Language. 2005; 53:430–444.

Horn SS, Bayen UJ, Smith RE, Boywitt CD. The multinomial model of prospective memory: Validity of ongoing-task parameters. Experimental Psychology. 2011; 58:247–255. [PubMed: 21106476]

Loft S, Humphreys MS. Enhanced recognition of words previously presented in a task with non-focal prospective memory requirements. Psychonomic Bulletin and Review. 2012; 19:1142–1147. [PubMed: 22847597]

Loft S, Smith RE, Bhaskara A. Prospective memory in an air traffic control simulation: External aids that signal when to act. Journal of Experimental Psychology: Applied. 2011; 17:60–70. [PubMed: 21443381]

Loft S, Smith RE, Remington RW. Minimizing the disruptive effects of prospective memory in simulated air traffic control. Journal of Experimental Psychology: Applied. 2013; 19:254–265. [PubMed: 24059825]

Lourenço JS, Maylor EA. Is it relevant? Influence of trial manipulations of prospective memory context on task interference. The Quarterly Journal of Experimental Psychology. in press.

Lourenço JS, White K, Maylor EA. Target context specification can reduce costs in nonfocal prospective memory. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2013; 39:1757–1764.

MacLeod, Colin M. Half a century of research on the Stroop effect: An integrative review. Psychological Bulletin. 1991; 109:163–203. [PubMed: 2034749]

Marsh RL, Cook GI, Hicks JL. Task interference from event-based intentions can be material specific. Memory & Cognition. 2006; 34:1636–1643. [PubMed: 17489290]

Marsh RL, Hicks JL, Cook GI. Task interference from prospective memories covaries with contextual associations of fulfilling them. Memory & Cognition. 2006; 34:1037–1045. [PubMed: 17128602]

Rogers RD, Monsell S. Costs of a predictable task switch between simple cognitive tasks. Journal of Experimental Psychology: General. 1995; 124:207–231.

Rubin O, Meiran N. On the origins of the task mixing cost in the cueing task-switching paradigm. Journal of Experimental Psychology: Learning, Memory and Cognition. 2005; 31:1477–1491.

Ruthruff E, Remington RW, Johnston JC. Switching between simple cognitive tasks: The interaction of top-down and bottom-up factors. Journal of Experimental Psychology: Human Perception and Performance. 2001; 27:1404–1419. [PubMed: 11766933]

Smith RE. 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. 2003; 29:347–361.

Smith, RE. Connecting the past and the future: Attention, memory, and delayed intentions. In: Kliegel, M.; McDaniel, MA.; Einstein, GO., editors. Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives. Mahwah, NJ: Erlbaum; 2008. p. 27-50.

Smith RE. What costs do reveal and moving beyond the cost debate: Reply to Einstein and McDaniel (2010). Journal of Experimental Psychology: Learning, Memory, and Cognition. 2010; 36:1089–1095.

Smith RE, Bayen UJ. A multinomial model of event-based prospective memory. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2004; 30:756–777.

Smith RE, Bayen UJ. The source of age differences in event-based prospective memory: A multinomial modeling approach. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2006; 32:623–635.

Smith RE, Bayen UJ, Martin C. The cognitive processes underlying event-based prospective memory in school age children and young adults: A formal model-based study. Developmental Psychology. 2010; 46:230–244. [PubMed: 20053020]

Smith RE, Horn SS, Bayen UJ. Prospective memory in young and older adults: The effects of ongoing task load. Aging, Neuropsychology, and Cognition. 2012; 19:495–514.

Smith RE, Hunt RR. Prospective memory in young and older adults: The effects of task importance and ongoing task load. Aging, Neuropsychology, and Cognition. in press.

Smith RE, Hunt RR, McVay JC, McConnell MD. The cost of event-based prospective memory: Salient target events. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2007; 33:734–746.

Wickens, CD.; McCarley, JS. Applied attention theory. Boca Raton, FL: Taylor & Francis; 2008.

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HIGHLIGHTS

- Costs to ongoing tasks in contexts irrelevant to prospective memory task.
- Costs to univalent stimuli that could not afford prospective memory response.
- Costs not dependent upon a history of having performed the prospective memory task.
- Costs greatest at the start of irrelevant contexts.

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A. Experiment 1

Group	Block 1				Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Block 8	Block 9
PM	lower	Instructions (PM or Control)	Study targets	Filler Task 5 min	UPPER *PM Targets*	lower	UPPER *PM Targets*	lower	UPPER *PM Targets*	lower	UPPER *PM Targets*	lower
Control	lower				UPPER	lower	UPPER	lower	UPPER	lower	UPPER	lower

B. Experiment 2

Group	Block 1				Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Block 8	Block 9
PM	xxxxxx	Instructions (PM or Control)	Study targets	Filler Task 5 min	words *PM Targets*	xxxxxx	words *PM Targets*	xxxxxx	words *PM Targets*	xxxxxx	words *PM Targets*	xxxxxx
Control	xxxxxx				words	xxxxxx	words	xxxxxx	words	xxxxxx	words	xxxxxx

Figure 1.

Diagram of the procedure for Experiment 1 (shown in A) for the counterbalancing condition in which the PM intention is associated with blocks with words in uppercase and the procedure for Experiment 2 (shown in B). In both experiments, Block 1 provided baseline measures. Blocks 2, 4, 6, and 8 served as the relevant blocks in which the PM task was to be performed for PM group. Blocks 3, 5, 7, and 9 served as the irrelevant blocks in which the PM task was not relevant. PM = prospective memory.

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Group	**Block 1**	**Block 2**	Instructions (PM or control)	Study Target Words	Filler Task 5 min	**Block 3**	**Block 4**	**Block 5**
PM	xxxx	words				xxxx	words *PM targets*	xxxx
Control	xxxx	words				xxxx	words	xxxx

Figure 2.
Diagram of the procedure for Experiment 3. Blocks 1 and 2 provided baseline measures. Block 4 served as the relevant block in which the PM task was to be performed for PM group. Blocks 3 and 5 served as the irrelevant blocks in which the PM task was not relevant. PM = prospective memory.

Table 1

Prior investigations of cost on irrelevant ongoing task trials using event-based PM tasks.

	Ongoing Task	Block Length	Designation of irrelevant trials	Notes
Cohen, Jaudas, Hirschhorn, Sobin, & Gollwitzer (2012)	Lexical Decision	Baseline and PM block, each with 252 trials.	PM targets were either words or non-words.	
Cook, Marsh, Clark-Foos, & Meeks (2007)	Intentional study task	List of 40 words.	Participants told that the PM target would not appear during the first study list, but that the PM targets could appear during the second study list.	Only the first study list was presented.
Lourenço & Maylor (in press)	Locate uppercase letter	Baseline block and PM block, each with 256 trials.	Ongoing task stimuli appeared in yellow or in white on black background and PM task was associated with one or the other color.	Trials alternated between colors either randomly or in blocks of 8 trials.
Lourenço, White, & Maylor (2013)	Lexical decision	Baseline and PM blocks, each with 256 trials	PM task was to respond to target syllable, which appeared only on word trials.	Participants told syllable would appear in words only or in both words and non-words. Words and non-words alternated randomly.
Marsh, Cook, & Hicks (2006)	Picture and word naming	Baseline Block 1 (before PM instructions): 40 pictures and 50 words. Block 2: 50 pictures and 40 words.	Participants told to make PM response only for pictures of furniture or only for furniture words. In Exp. 3, intention was associated with color of letter string (red or green).	Exp. 1A and 2: pictures and words alternated randomly. Exp. 2 only: the cue *picture* or *word* shown just before each trial. Exp. 1B: alternated in sets of ten (10 pictures, 10 words, etc.) Exp. 3: asterisk preceding each string indicated color of string.
Marsh, Hicks, & Cook (2006) Experiment 1	Lexical decision	Phase 1 and Phase 2 each included a block of 105 ongoing task trials.	Participants were told that there would be three distinct phases and "that the animal words would appear during the third and final stage, and not during Phases 1 or 2."	Phase 2 was a questionnaire. Participants interacted with experimenter during Phase 2.

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Table 2

Means and standard errors for ongoing task response times as a function of condition and block type. PM = participants who were given prospective memory instructions. Control = participants not given prospective memory instructions. Relevant blocks = blocks in which the PM condition was to perform the PM task. Irrelevant blocks = blocks in which the PM task did not have to be performed.

		Block Type			
		Relevant		Irrelevant	
Experiment	**Condition**	***M***	***SE***	***M***	***SE***
1	PM	2246	74	1498	57
	Control	1421	50	1263	44
2	PM (all participants)	2353	83	1265	39
	PM (one or more PM responses)	2539	107	1315	46
	Control	1545	39	1197	31
3	PM	2341	79	1283	36
	Control	1181	44	1108	35

Table 3

Experiment 3: Ongoing task response times (in ms) for subsets of the irrelevant blocks of the color-matching task. PM = participants who were given prospective memory instructions that were relevant in Blocks 4. Control = participants not given prospective memory instructions.

	Block 3 Trials						**Block 5 Trials**					
	1 to 8		**9 to 18**		**19 to 26**		**1 to 8**		**9 to 18**		**19 to 26**	
	M	***SE***	***M***	***SE***	***M***	***SE***	***M***	***SE***	***M***	***SE***	***M***	***SE***
PM	1414	43	1186	42	1189	46	1311	45	1193	47	1151	39
Control	1268	42	1165	49	1088	41	1190	53	1187	60	1098	50