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The role of task-appropriate processing, context, and attention allocation in prospective memory: a multinomial modeling approach

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THE ROLE OF TASK-APPROPRIATE PROCESSING, CONTEXT, AND ATTENTION ALLOCATION IN PROSPECTIVE MEMORY: A MULTINOMIAL MODELING APPROACH

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ABSTRACT

This study investigated the influences of attention and retrospective memory processes on prospective memory. In Experiment 1, participants who processed prospective memory cues under conditions that did not coincide with the processes required for making judgments in an ongoing task showed greater levels of performance at the expense of the attentional resources needed to complete the ongoing task. This differed compared to participants who processed cues under conditions that required the same processes needed to performance the ongoing task. In Experiment 2, the reinstatement of contextual features associated with prospective memory cues from the time of intention formation, or encoding, to the opportunity for retrieval resulted in greater levels of performance compared to a lack of contextual reinstatement of the cues. This difference in performance did not affect the attentional resources needed to perform the ongoing task between the two conditions. The data from both experiments were fit to a formal model as a means to address the contributions of attention and memory processes in performance, as well as to address the validity of the model in investigations of prospective memory. Finally, participants were administered a questionnaire meant to assess overall task impressions, and to address participants' attention allocation policies given the requirements of the experiment.

INTRODUCTION

The type of memory that aids in the completion of delayed intentions is termed prospective memory (PM). Examples of PM as it occurs in real-world settings include remembering to give a colleague a message or remembering to take a medication. In typical laboratory paradigms, participants engage in an ongoing task meant to simulate a real-world activity while holding an intention to make a special response to an item embedded within the ongoing task (i.e., a PM cue; Einstein & McDaniel, 1990). An important feature of PM is that its function is partly determined by the interaction between attentional processes and processes involved in retrospective memory. Once formed, an intention is stored in memory until the appropriate time arrives to initiate the intended action. For example, on a weekday morning you form an intention to stop by the grocery store on the way home from work. The intention may come to mind at certain points during the day, but for the majority of your time the intention does not enter into conscious thought. When the appropriate time arrives, such as when you are driving home from work, the intention may become activated and you initiate the plan to stop off at the grocery store.

The example above demonstrates how certain aspects of attention as well as characteristics of the PM cues can affect the ability to carry out an intention. For instance, the grocery store (i.e., a primary characteristic of the PM cue) may not be on the typical route you take on the way home from work. This may result in unsuccessful completion of the intention if you do not remember to alter your normal route on the way home from work. Additionally, you may be talking on your cell phone while driving home from work, which could result in your attention being focused on the conversation, and you may forget to stop at the grocery store as a result (i.e., a characteristic of the attention component). Laboratory studies of PM attempt to systematically investigate such aspects of attention and characteristics of the PM cues, and how they may interact with retrospective memory processes, to examine how they affect the ability to carry out intentions and how holding intentions in memory may affect other ongoing activities.

Research has shown that manipulations of the ongoing task, or manipulations of the characteristics of the PM cues, can affect performance to the ongoing task as well as performance to successfully carrying out the intention. Manipulations of the ongoing task that can adversely affect PM performance include dividing attention (e.g., Marsh & Hicks, 1998; McDaniel, Robinson-Riegler, & Einstein, 1998; McDaniel, Guynn, Einstein, & Breneiser, 2004), placing greater emphasis on the performance to the ongoing task over the performance on responding to the PM cues (e.g., Loft & Yeo, 2007; Loft, Kearney, & Remington, 2008; Smith & Bayen, 2004), or increasing the demands of the ongoing task (e.g., Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003; Marsh, Hancock, & Hicks, 2002). Manipulations of the PM cues that have been shown to affect PM performance as well as ongoing task performance (termed task interference) include characteristics of the instructions for the intention (e.g., Hicks, Marsh, & Cook, 2005), the number of PM cues presented during the ongoing task (e.g., Cohen, Jaudas, & Gollwitzer, 2008), the salience of the PM cues (e.g., Hicks, Cook, & Marsh, 2005), and how the processing required to successfully respond to the PM cues matches the processing needed to complete the ongoing task (e.g., McDaniel et al., 1998). Thus, there are several ways attentional processes and characteristics of the PM cues contribute to the successful completion of intentions and to the successful completion of the ongoing task. A primary goal of this study was to examine this interaction of attention and memory processes, and how this allows for the successful completion of intentions. Additionally, this study examined the validity and usefulness of a formal model that has been used to account for the contribution of attention and memory in laboratory investigations of PM.

Two theories receiving much attention recently, and that are frequently debated in the PM literature, attempt to account for these aspects of attention and memory in PM. The theories make similar arguments for how the characteristics of the PM cues influence performance, but have differing explanations as to the role of attention in the retrieval of PM cues. The preparatory attention and memory processes theory (PAM; Smith, 2003) argues that some form of attentional processes, or strategic monitoring processes, will always be required to successfully retrieve PM cues. The PAM theory proposes that this occurs through preparatory attentional processes that are engaged when an intention is formed. These processes require a certain amount of attentional capacity needed to retrieve PM cues as well as to perform the ongoing task. The PAM theory argues that the completion of intentions cannot occur if these preparatory attention processes are not engaged. These processes may not always be conscious in nature, but Smith and her colleagues have demonstrated that intentions consistently require preparatory attention processes in a variety of conditions, including conditions that should lead to relatively effortless retrieval of PM cues (Smith, Hunt, McVay, & McConnell, 2007). The PAM theory has also been supported by a formal model constructed to account for how these attentional processes are manifested in certain situations (Smith & Bayen, 2004, 2005, 2006).

A competing theory of PM argues that it would be maladaptive for attentional processes to be constantly engaged given the presence of an intention being held in memory. The multiprocess framework (McDaniel & Einstein, 2000) proposes that the retrieval of PM cues can occur in two ways – through a more automatic or spontaneous fashion, or via an effortful, attentionally demanding monitoring process. The manner in which PM cues can be retrieved from memory depends on how the PM cues are processed in relation to the characteristics of the ongoing task. Focal processing of PM cues, as defined by McDaniel and Einstein, is determined by how closely the processing needed to retrieve PM cues from memory matches that of the processing needed to complete the ongoing task. An example of how focal processing might occur in the laboratory is when participants have to make lexical decisions to items in the ongoing task while the retrieval of a PM cue requires a special response to be made to a specific word (e.g., *dormitory*). Both the retrieval of the PM cue and the characteristics of the ongoing task require semantic processing, with deciding whether an item is a word or not while having to make a special response to a specific word. An example of nonfocal processing would be having participants make lexical decisions in the ongoing task while the retrieval of a PM cue requires having to make a special response to a specific syllable, or a set of two letters (e.g., *or*). A real-world example of this focal versus nonfocal processing distinction can be found in the everyday activity of holding an intention to purchase a book of stamps. This intention may easily be retrieved while mailing a letter at the post office, while this intention may fail to be retrieved if you are at the drug store to fill a prescription. The notion of the drug store may not easily bring to mind the idea that stamps can be purchased there, while the notion of the post office is highly associated with the intention to purchase a book of stamps. McDaniel and Einstein argue that spontaneous retrieval of PM cues can occur if the cues are processed focally in relation to the processes required by the ongoing task. Monitoring processes would be required for PM retrieval when the PM cues must be processed nonfocally in relation to the processing requirements of the ongoing task.

Focal or nonfocal processing of PM cues can also affect performance on the ongoing task in which the cues are embedded. Interference to the ongoing task, or task interference, is used as an index of the occurrence of monitoring. Task interference is typically measured by reaction times and performance on the ongoing task, such as in making correct lexical decisions. According to the multiprocess framework, under nonfocal processing conditions, retrieval of PM cues depends on strategic monitoring processes in order to successfully detect the cues, with greater levels of task interference resulting in higher rates of PM performance. When PM cues are processed focally, allowing for spontaneous retrieval, task interference is reduced or eliminated.

Although these two theories may differ in their explanations of how attentional processes are utilized in the retrieval of PM cues, they generally agree on how retrospective memory processes may affect the retrieval of PM cues from memory. A similarity that exists for these theories is that the match between the features of the intention and the processing requirements for successful retrieval of the intention facilitates PM performance. This could be explained in what McDaniel and Einstein (2000) would consider as focal processing of the PM cue. Smith and Bayen (2004) would argue that this type of processing would increase retrieval of a PM cue by resulting in a change to a parameter of their formal model assumed to account for retrospective memory processes needed to successfully retrieve PM cues. Research investigating this aspect of PM has some similarities to research in certain areas of traditional retrospective memory.

A prominent example of a type of retrospective memory approach to PM can be found in investigations of the similarity between the type of processing needed to perform the ongoing task and the type of processing needed for the retrieval PM cues (e.g., Marsh et al., 2000; Meier & Graf, 2000; Meiser & Schult, 2008). This line of research was based on the idea of transfer-appropriate processing from the retrospective memory literature (Morris, Bransford, & Franks, 1977). Transfer-appropriate processing occurs in retrospective memory when the processing utilized while encoding items into memory matches the processes needed to retrieve that information. An example of this would be encoding a list of words using semantic processing, and requiring the semantic processing of items during the retrieval of that information. The match of the processes utilized from encoding to retrieval facilitates remembering. Declines in retrospective memory can occur when the processing needed for encoding and retrieval does not match. This finding has been extended to PM research, and is termed *task-appropriate processing* (Maylor, 1996). An example of task-appropriate processing as it occurs in the laboratory would be having the ongoing task require participants to make pleasantness ratings, while participants have to respond to a certain category of words as the PM cues (e.g., *animal*; Marsh et al., 2000). This requires semantic processing during the ongoing task with semantic processing being required to retrieve the PM cue from memory. Task-appropriate processing is also found when the ongoing task requires perceptual processing and the retrieval of a PM cue requires perceptual processing, such as when the ongoing task requires determining whether a word has two or more enclosed letters while holding the intention to respond to words that are spelled the same when presented forwards or backwards (i.e., palindromes; e.g., Marsh et al., 2000; Meier & Graf, 2000). Thus, task-appropriate processing results in improved PM performance, whereas task-inappropriate processing (i.e., semantic processing of items in the ongoing task while retrieval of a PM cue requires perceptual processing, or vice versa) results in decreased PM performance. Furthermore, task-appropriate processing has been found to result in more automatic processing of PM cues (Meiser & Schult, 2008) in line with the idea of spontaneous retrieval of PM cues proposed by the multiprocess framework of McDaniel & Einstein (2000).

In the Meiser and Schult (2008) study, task-appropriate processing resulted in more successful retrieval of PM cues and in reduced levels of interference to the ongoing task. Meiser and Schult had participants perform a lexical decision task (LDT) while holding an intention to make a PM response to either animal words (task-appropriate processing) or palindromes (task-inappropriate processing). Additionally, participants were given LDT instructions that emphasized either speed or accuracy when making their lexical decisions. Task-inappropriate processing resulted in longer RTs to the LDT and lower PM performance compared to task-appropriate processing. The authors suggest these results are due to task-appropriate processing resulting in more automatic retrieval of PM cues shown in higher rates of PM performance and lower rates of task interference than task-inappropriate processing. Further evidence of strategic monitoring given task-inappropriate processing is that a positive correlation was found between RTs to the ongoing task and PM performance in that condition. No relationship was found between RTs and PM performance for task-appropriate processing. Additionally, PM performance suffered under task-inappropriate processing conditions when resources were allocated more to the speed of making lexical decision versus accuracy of making lexical decisions. Under task-appropriate processing, PM performance did not differ depending on whether speed or accuracy was emphasized.

The effects of the match or mismatch of external context that have been found in the retrospective memory literature have also been extended to PM research. In the classic study by Godden and Baddeley (1975), participants learned a list of words either on land or under water. After a delay, participants were required to recall the list of words in either the same or different environment. Those who recalled the list of words in the matched environment showed better retrospective memory performance compared to those participants who recalled the list of words in the different environment. This type of manipulation of environmental context has been used in PM research (McDaniel et al., 1998). Participants who formed an intention in a certain laboratory room were more likely to retrieve the intention if tested in the same room as opposed to a different room. Related research has shown that if an intention is incidentally associated with one of two different ongoing tasks, such as when the instructions for the PM task were presented along with the instructions for one of the two ongoing tasks, retrieval of the PM cues increased if the PM cues were presented in the originally-associated task (Nowinski & Dismukes, 2005). That study also found that when the instructions for the PM task were associated with both ongoing tasks, PM performance was equal when the cues were presented in either task. Also related are the findings from Marsh, Hicks, and Cook (2006) showing that when PM cues are associated with a particular context of the ongoing task, PM performance is better when the PM cues are presented within the expected context compared to when the PM cues are presented outside of the expected context.

Research from Marsh, Hicks, and Cook (2005, 2006) found that participants will set an attention allocation policy when certain aspects of the ongoing task and PM task are apparent. Participants have been shown to allocate their attentional resources to the ongoing task and to the PM task differently when certain features of each task are made available. Marsh et al. (2005) observed changes in participants' attention allocation policies under task-appropriate versus task-inappropriate processing conditions when effort to the ongoing task was manipulated. In their Experiment 1, participants were directed to place high, medium, or low effort towards the ongoing task while holding an intention conforming to either task-appropriate or task-inappropriate processing of the PM cue. When participants were directed to place high effort towards the ongoing task, task interference was lower under task-appropriate processing conditions compared to task-inappropriate processing conditions. Interestingly, high effort towards the ongoing task resulted in lower rates of PM performance under conditions of task-appropriate processing, while low effort versus high effort to the ongoing task did not affect PM performance under task-inappropriate processing conditions. It should be important to note that while PM performance suffered under high effort placed to the ongoing task compared to the low effort condition for task-appropriate processing of PM cues, the PM performance for task-appropriate processing was nominally higher compared to task-inappropriate processing under the high effort condition (task-appropriate processing – M = .43; task-inappropriate processing – M = .36). Marsh et al. (2005) suggest that the reduction in task interference under high effort placed towards the ongoing task may reflect metacognitive strategies or attention allocation policies that do not necessarily guarantee higher levels of PM performance. Nevertheless, task-appropriate processing allowed for overall higher rates of PM performance.

In Marsh et al. (2006), participants were or were not informed of the specific context in which PM cues were to occur compared to a control condition that was given no intention. The procedure of the study involved three phases, two phases of an LDT divided by a questionnaire serving as the second phase. One group of participants who received the PM instructions that were informed of the specific context in which the PM cues were to be presented and were told that the PM cue would occur during the third phase of the procedure (i.e., the second phase of the LDT). In the other PM condition, participants were not provided this information. In the control condition, participants did not receive any PM instructions. Task interference was compared between each condition. The critical finding from this study is that the participants in the PM condition who were not told of the specific context in which the PM cues were to be presented showed higher levels of task interference during phase 1 of the procedure (i.e., the first phase of the LDT) compared to task interference for the participants who did receive the context-specific information. Participants in the PM condition who received the context-specific information showed similar levels of task interference in phase one as compared to the control condition. These studies suggest that attention can be flexibly allocated to the requirements of the ongoing task and the need to retrieve PM cues given the available information of the task conditions, but may result in differing levels of task interference and PM performance given the nature of the procedure.

This study was designed to investigate the effects of task-appropriate processing and of context variation in PM and to apply the results of two experiments to the formal multinomial processing tree (MPT) model utilized by Smith and Bayen (2004, 2005, 2006) that was developed to support the PAM theory. MPT models are a class of threshold models that include parameters assumed to measure the contributions of the various cognitive processes needed to elicit a given response in an experimental task (Riefer & Batchelder, 1988). MPT models assume probabilities for certain cognitive processes utilized by participants during a task. Estimates are assigned to parameters identified in the model that represent the probabilities of these cognitive processes occurring that may lead to a given response under certain conditions of a task. These probabilities are estimated via maximum likelihood estimation from the frequencies found in the raw data collected for the dependent variables of interest. The fit of a model is measured by goodness-of-fit tests. Once a model is successfully fit to the data, hypothesis tests are conducted by constraining certain parameters in order to measure the contribution of the assumed cognitive processes involved in the given results under certain conditions of a task. MPT models have successfully been used in investigations of serial recall from short-term memory (e.g., Hulme, Roodenrys, Schweickert, Brown, Martin, & Stuart, 1997), recognition memory and source memory (e.g., Bayen, Murnane, & Erdfelder, 1996), and false memory (e.g., Dodson, 2007). The MPT model devised by Smith and Bayen (2004) includes separate parameters for the preparatory attention process and retrospective memory process assumed necessary to successfully respond to PM cues, as well as parameters assumed to measure the memory and decision processes needed to successfully complete the ongoing task. An example of an MPT model similar to the one from Smith and Bayen and be found in Figure 1.

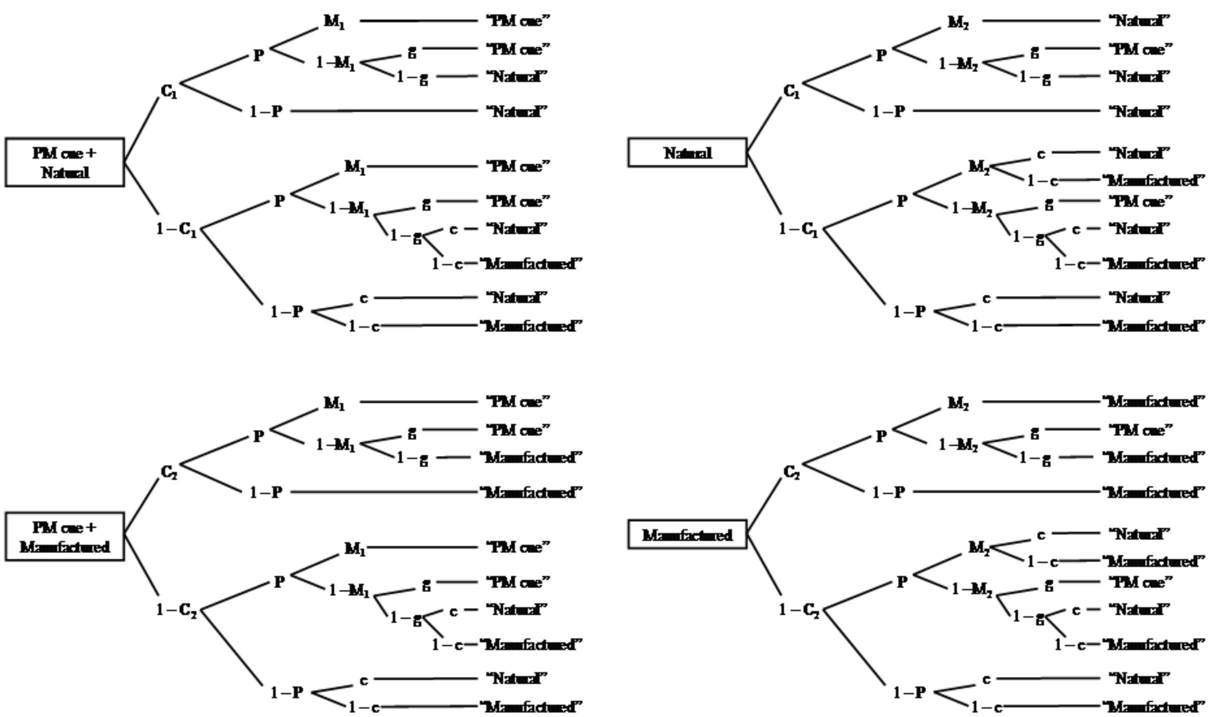

Figure 1. The multinomial model processing tree used in the study.

For the successful retrieval of a PM cue, Smith and Bayen's model proposed a parameter for preparatory attentional processes (the *P* parameter) to account for the resource demanding monitoring processes engaged during the ongoing task when a PM cue is expected to occur. As PAM theory proposes, if this process represented by this parameter is not engaged (i.e., when it equals 0), retrieval of a PM cue upon its presentation cannot occur. The model also includes parameters for the recognition of an item presented during the ongoing task as a PM cue or not a PM cue (the M_1 and M_2 parameters, respectively). The paths of these parameters, from P to M_1 or from P to M_2, are assumed to yield a correct response given whether the PM cue is present or not. The majority of the research using this MPT model in PM has focused on the preparatory attentional parameter of the model (P), with given manipulations showing the probability for this parameter to increase and decrease thus resulting in corresponding levels of PM performance. For the purposes of the current study, the retrospective memory components of the model are also of particular interest.

Experiment 1 of this study investigated the effects of task-appropriate processing. Experiment 2 investigated how PM performance is affected by the match or mismatch of contextual features associated with the PM cues and for items used in the ongoing task. In each experiment, participants were administered a series of questions meant to assess any metacognitive strategies or impressions regarding the perceived difficulty of the PM task, of the ongoing task, and of the task set as a whole. Separate groups of participants were administered these questions either before or after performing the primary task of interest – an ongoing task with the embedded PM cues. This was intended to assess whether participants adopt any strategies or attention allocation policies in their approach to the experiment given the requirements of each task, and how these reported strategies or policies may correspond to the observed patterns of results.

Both experiments used the same ongoing task, with participants instructed to decide whether a word represents an object that is found in the natural environment, or whether a word represents an object that is manufactured by humans. Thus, the ongoing task will require a binary decision. The PM cues used in each experiment included words that represent both natural objects and manufactured objects. The MPT parameters for preparatory attention and retrospective memory were compared between the conditions for each experiment. The parameters for the MPT model represent the following processes. The *C* parameter represents the probability of correctly judging a word as representing either a natural object or a manufactured object (C_1 and C_2, respectively). The *P* parameter represents preparatory attention. The M_1 parameter represents the probability of correctly responding to a PM cue. The M_2 parameter represents the probability of correctly judging a word presented during the ongoing task as not being a PM cue. The *M* parameter serves as the recognition threshold of determining when an item presented in the ongoing task as either being a PM cue or not. The *g* parameter represents the probability of guessing that a word is a PM cue. The *c* parameter represents the probability of guessing that a word represents a natural object. The MPT model used to fit the data for each experiment conforms to a four-parameter two-high threshold model. The parameter that corresponds to the retrospective memory component for PM performance (the *M* parameter), and the parameter that corresponds to the preparatory attention component (the *P* parameter), were subjected to hypothesis testing in each experiment. The fit of the models, and the hypothesis tests between conditions of each experiment, were conducted with the log-likelihood statistic G^2. The G^2 statistic is asymptotically chi-squared distributed (Hu & Batchelder, 1994), and a nonsignificant G^2 statistic indicates a good fit of the model to the data. The experiments were intended to further evaluate the validity of using MPT models in PM research under conditions that should influence the attentional and retrospective memory components needed for PM.

These theories of PM discussed above can offer several different predictions for the outcomes of each experiment. Task-appropriate vs. task-inappropriate processing of PM cues was examined in Experiment 1. The multiprocess framework would predict PM performance to be higher for task-appropriate processing compared to task-inappropriate processing. Task interference should be lower for task-appropriate processing compared to task-inappropriate processing. Additionally, task interference should have no relationship to PM performance under task-appropriate processing but task interference should be positively correlated with PM performance for task-inappropriate processing (Meiser & Schult, 2008). For Experiment 2, the multiprocess framework would predict no differences in task interference between conditions of the match vs. mismatch of contextual associations of the PM cues given the incidental nature of the manipulation. The context manipulation was intended to solely affect the memory processes associated with PM performance. Therefore, PM performance should be better for the reinstatement of the contextual association compared to the lack thereof.

For Experiment 1, the PAM model would predict that PM performance is a direct result of the use of preparatory attention processes, and this could be potentially be reflected in an overall positive relationship between PM performance and the levels of task interference. In regards to PM cue discrimination, represented by the *M* parameter in the MPT model, PAM would predict that task-appropriate processing would allow for better cue discrimination resulting in a higher *M* parameter estimate and higher PM performance compared to task-inappropriate processing. If PM performance is higher for task-appropriate processing compared to task-inappropriate processing, then PAM would predict that the *P* parameter estimate should also be higher for task-appropriate processing compared to task-inappropriate processing if preparatory attention is required for successful PM performance. For Experiment 2, the contextual manipulation should allow for differences in cue discrimination between the conditions. PAM predicts a greater *M* parameter estimate for the condition that allows for the reinstatement of a contextual association between the PM cues and the ongoing task compared to a lack of this reinstatement. While levels of task interference should not differ between the conditions given the incidental nature of the manipulation, the PAM model would predict increases in preparatory attention, the *P* parameter estimate, if the reinstatement of context results in higher rates of PM performance.

Attention allocation policies for participants might differ between the conditions of Experiment 1. Even though PM performance has been shown to be higher for task-appropriate processing compared to task-inappropriate processing, participants might approach the experiment differently depending on the type of PM instructions in light of the requirements of the ongoing task. Given the prior results showing lower levels of task interference for task-appropriate processing compared to task-inappropriate processing, participants should adopt a different attention allocation policy between the two conditions. Participants may realize that having to detect a PM cue that requires the use of, say, structural processing (e.g., words that have three *e*'s) while performing an ongoing task that requires semantic processing (e.g., a lexical decision task) is somewhat difficult, resulting in higher levels of task interference compared to task-appropriate processing. Experiment 2 utilizes an incidental manipulation of the context associated with the PM cues. Given that participants should have no awareness of the manipulation, their attention allocation policies should not differ. This should result in no differences in task interference between the conditions. The influence of the manipulation for Experiment 2 is only expected to affect memory and not attentional processes.

These theories reveal some different and competing predictions for some parts of this study. For PM performance, there are no specific differences in the predictions for the multiprocess framework and the PM model. Conditions that positively affect overall memory should allow for higher rates of PM performance, and this is predicted for both experiments. The concept of attention allocation does not directly address this issue given the current study. The primary difference among the theories lies in the level of attentional processes needed for successful PM. The multiprocess framework, and attention allocation policies, predicts lower levels of task interference for task-appropriate processing compared to task-inappropriate processing for Experiment 1. This is at odds with PAM, in that preparatory attentional resources are required for successful PM performance. If preparatory attention can be indexed by the attentional resources usurped by the PM task resulting in ongoing task interference, then preparatory attention should be higher for the condition that results in higher PM performance, contrary to the multiprocess framework, attention allocation, and previous findings from the literature, for Experiment 1. For Experiment 2, the multiprocess framework and PAM both predict higher levels of PM performance, or cue discrimination, given a contextual reinstatement. The multiprocess framework and attention allocation policy predicts no differences in task interference between the two conditions of this experiment. However, PAM would predict larger parameter estimates of P for the condition that results in higher PM performance. These theories are subject to investigation with the manipulations in the experiments for the current study.

This study investigates the contributions of attention and memory in the successful completion of delayed intentions. This study addresses how these processes are utilized in a laboratory procedure given the conditions of each experiment. The results for each experiment are expected to further delineate conditions in which greater or lesser degrees of attention are utilized or required in PM, as well as how conditions that affect retrospective memory affect PM performance in the same manner. This study attempts to aid in the further understanding of the attention and memory processes needed to notice and remember to perform an intended action.

Each experiment consisted of two parts with separate groups of participants. Experiments 1a and 2a had participants perform an ongoing task with embedded PM cues. Upon completion of the task, participants were administered a questionnaire meant to assess the use of any metacognitive strategies or attention allocation policies. Participants in Experiments 1b and 2b were administered the questionnaire prior to performing the ongoing task with embedded PM cues. The purpose of the design was to examine participants' adoption of any metacognitive strategies or attention allocation policies retrospectively (Experiments 1a and 2a) or prospectively (Experiments 1b and 2b), and how this may have affected task performance. The behavioral data from both experiments were fitted to an MPT model. The questionnaire data were intended to complement the quantitative data in order to yield more information concerning the occurrence of task interference and levels of PM performance in regards to how participants may perceive the difficulty of the overall task.

EXPERIMENT 1

The goal of this experiment was to replicate and extend the findings demonstrating improved PM performance and lower levels of task interference under conditions when PM cues are processed under task-appropriate versus task-inappropriate processing conditions. The data were fitted to the MPT model used by Smith and colleagues in order to assess the preparatory attention and retrospective memory processes responsible for successful PM performance. These parameters were subjected to hypothesis testing between the two processing conditions. Finally, a qualitative assessment was administered to participants in order to address the potential use of metacognitive strategies given the task demands. This assessment was administered either upon completion of the experiment (Experiment 1a), or prior to participants engaging in the test phase of the procedure in which PM cues were expected to appear (Experiment 1b). The results are addressed in order of the descriptive and inferential results of the behavioral data, the fitting and hypothesis testing of the MPT model, and correlations of the behavioral data and the qualitative assessment administered to participants. The results for each part of this experiment will be discussed in turn after the complete description of both parts of Experiment 1.

Experiment 1a

Method

Participants

Sixty-seven undergraduates from Louisiana State University participated in exchange for credit in a psychology class. Thirty-seven participants were randomly assigned to the task-appropriate processing condition. Thirty participants were randomly assigned to the task-inappropriate processing condition.

The first two questions of the post-experiment questionnaire assessed participants' memory of the PM instructions (i.e., memory for the conditions under which to respond, and for the response key). Participants who reported not remembering either the PM cues or the PM response were excluded from the analyses. This resulted in four participants being excluded, one participant from the task-appropriate processing condition and three participants from the task-inappropriate processing condition. This resulted in the analysis of 63 participants' data, 36 in the task-appropriate processing condition and 27 in the task-inappropriate processing condition.

Materials and Design

The ongoing task required participants to judge whether a word represented an object that naturally occurs in the environment (e.g., grass), or whether a word represented a manufactured object (e.g., refrigerator). The design consisted of one between-subjects factor. Participants were instructed to respond to PM cues that were presented either under task-appropriate processing conditions or under task-inappropriate processing conditions, with respect to the cognitive processing required by the ongoing task. For task-appropriate processing, participants were instructed to respond to words representing liquids that served as the PM cues. For task-inappropriate processing, participants were instructed to respond to words that contained three *e*'s.

All stimuli for the ongoing task were selected from the MRC psycholinguistic database (Coltheart, 1981), and consisted of medium frequency words (Kučera & Francis, 1967). One hundred fifty words were selected as stimuli. Half of the stimuli consisted of words that represented objects naturally found in the environment. The other half of the stimuli consisted of words that represented manufactured objects. For the task-appropriate processing condition, the words used as PM cues were *milk* and *pepsi*. For the task-inappropriate processing condition, the words that served as PM cues were *beetle* and *needle*. The experiment was administered to participants individually via personal computer using E-Prime 1.2 software (Schneider, Eschman, & Zuccolotto, 2002). The questionnaire used to assess the use of any metacognitive strategies is shown in Appendix A.

Procedure

The procedure consisted of two phases of the ongoing task: the baseline phase and the test phase. The baseline phase consisted of 50 ongoing task trials prior to the presentation of the PM instructions. The test phase consisted of 100 trials of the ongoing task. The complete instructions for the ongoing task are shown in Appendix B. Participants were instructed to press the key labeled “N” if the word represented a natural object, or to press a key labeled “M” if the word represented a manufactured object (the F and J keys, respectively). After the judgment, participants were prompted to press the ‘SPACE’ bar to advance to the next trial. Presentation of the type of word (natural or manufactured) was randomly determined. Participants were then given a set of eight practice trials, half representing natural objects and half representing manufactured objects, and were asked to decide what category they belong to in order to ensure full understanding of the ongoing task instructions. Participants were given feedback as to their accuracy in these practice trials. After participants demonstrated their understanding of the task, they continued to the baseline phase. Upon completion of the baseline phase, participants were given the PM instructions.

For the PM instructions, half of the participants were instructed to press the ‘F1’ key if they ever encountered a “liquid” word during the ongoing task. The other half of participants were instructed to make the same response if they encountered a word with three *e*’s during the ongoing task. The instructions specified that participants should make their ongoing task response prior to making their PM response for the trials on which the PM cues appeared. After being presented with the PM instructions, participants were given a 3-minute distractor task of arithmetic problems. After the distractor task, participants were prompted to begin the test phase of the ongoing task.

The PM cues were presented on trials 51 and 91 of the task. The order of the presentation of the PM cues was counterbalanced. Upon completion of the test phase, participants were administered the series of questions to assess the use of any metacognitive strategies towards the ongoing task and PM task.

Results

Behavioral Performance

PM performance was measured by the average of participants' correct PM responses to the cues when they were presented during the ongoing task. These data are shown in Table 1. PM performance was analyzed with one-way between-subjects analyses of variance (ANOVAs), with task-appropriate vs. task-inappropriate processing as the factor. The ANOVAs were conducted on the first PM cue, the second PM cue, and the overall proportion of correct PM responses. For overall PM performance, the ANOVA revealed no difference between the processing conditions, $F(1, 61) = 1.49$, $MSE = .14$, $p = .23$, $\eta^2_p = .02$, $p_{rep} = .69$. Additionally, no significant differences were found for performance on the first PM cue, $F(1, 61) = 1.18$, $MSE = .30$, $p = .28$, $\eta^2_p = .02$, $p_{rep} = .68$, and for the second PM cue, $F(1, 61) = 1.03$, $MSE = .26$, $p = .31$, $\eta^2_p = .02$, $p_{rep} = .63$. Although the trend in performance favored the task-inappropriate processing condition, this difference was not significant.

Table 1
Mean PM Performance by Experiment and Condition for Experiment 1

	PM Performance		
	1st PM cue	2nd PM cue	Proportion Correct
Experiment 1a			
Task-appropriate processing	.42 (.08)	.39 (.08)	.40 (.07)
Task-inappropriate processing	.56 (.10)	.52 (.10)	.54 (.08)
Experiment 1b			
Task-appropriate processing	.32 (.09)	.41 (.09)	.40 (.08)
Task-inappropriate processing	.70 (.09)	.67 (.09)	.68 (.08)

Note. The value in parentheses represents one standard error of the mean.

Task interference was measured as the change in the average median RTs to correct responses in the ongoing task from the baseline phase to the first 50 trials of the test phase prior to the presentation of the first PM cue. These data are shown in Table 2. Task interference was calculated by subtracting the baseline RTs from the test phase RTs, and is identified as the difference column in Table 2. For this score, a one-way between-subjects ANOVA revealed no difference in task interference between the task-appropriate vs. task-inappropriate processing conditions, $F(1, 61) = 1.79$, $MSE = 65641.51$, $p = .19$, $n^2_p = .03$, $p_{rep} = .72$. Additional ANOVAs conducted separately on the baseline and test phase RTs prior to the presentation of the first PM cue showed no differences between the conditions (baseline: $F(1, 61) = .17$, $MSE = 7070.56$, $p = .68$, $n^2_p = .003$, $p_{rep} = .38$; test: $F(1, 61) = 1.31$, $MSE = 115799.06$, $p = .26$, $n^2_p = .02$, $p_{rep} = .67$). The type of processing of the PM cues did not influence task interference.

Table 2
Mean Median Reaction Time (ms) by Experiment and Condition for Experiment 1

	Ongoing Task Reaction Time		
	Baseline phase	Test phase	Difference
Experiment 1a			
Task-appropriate processing	811.00 (36.02)	915.46 (47.68)	104.46 (24.58)
Task-inappropriate processing	832.41 (36.02)	1002.41 (59.90)	169.68 (45.89)
Experiment 1b			
Task-appropriate processing	846.53 (26.43)	933.93 (30.51)	87.40 (34.70)
Task-inappropriate processing	837.04 (38.52)	1073.09 (57.86)	236.06 (51.91)

Note. The value in parentheses represents one standard error of the mean.

To analyze these results further, bivariate correlations were conducted for PM performance and task interference. Overall, PM performance was positively correlated with task interference ($r = .53$; $p < .01$). For task-appropriate processing, a significant correlation was not observed ($r = .21$; $p = .23$). For task-inappropriate processing, PM performance significantly correlated with task interference ($r = .79$; $p < .01$). These patterns of correlations between the two conditions replicate the findings from Meiser and Schult (2008).

The MPT Model

The response frequencies from the test phase of the ongoing task that were used in the MPT model for Experiment 1 are shown in Appendix C. The first step in the model fitting procedure requires applying the model to the overall data collapsed over the two conditions. The next step involves fitting the model to the data from each condition separately. Finally, hypothesis testing is conducted by constraining, or equating, the *P* and the *M* parameters between the conditions to observe any potential differences between the parameters given task-appropriate vs. task-inappropriate processing of the PM cues. The parameter estimates for each condition are shown in Figure 2. The model provided an unsatisfactory fit to the overall data, G^2 (8) = 16.32, p = .04. Thus, caution should be taken in the interpretation of the hypothesis testing of the parameter estimates. Nevertheless, the model provided a satisfactory fit to the data for both the task-appropriate processing condition, G^2 (4) = 7.90, p = .10, and the task-inappropriate processing condition, G^2 (4) = 8.42, p = .08, when fitted separately. Hypothesis testing for the *P* and *M* parameters was undertaken by constraining each parameter to be equal across conditions; this model fit was compared to the original overall model fit when the parameters were not constrained and thus differs by one *df*. Constraining the *P* parameter resulted in a poor overall fit [G^2 (9) = 21.79, p = .01], which resulted in a significant difference from the unconstrained model fit, G^2 (1) = 5.47, p = .02. The parameter estimate for *P* was significantly higher for the task-inappropriate processing condition compared to the task-appropriate processing condition, suggesting that preparatory attentional processes were utilized to a greater degree when the PM cues were processed under task-inappropriate conditions compared to task-appropriate conditions. Similarly, constraining the *M* parameter across conditions resulted in an overall poor fit [G^2 (9) = 23.05, p = .01]. As compared to the unconstrained model, the parameter estimate for *M* was significantly higher for the task-appropriate processing condition compared to the task-inappropriate processing condition, G^2 (1) = 6.73, p = .01. This suggests that task-appropriate processing allowed for greater retrospective memory processes to be utilized upon the presentation of PM cues during the test phase of the ongoing task compared to task-inappropriate processing. However, caution should be taken in interpreting the results for the *M* parameter given the high value of the parameter estimate for the two conditions, especially for the ceiling effect of the task-appropriate processing parameter.

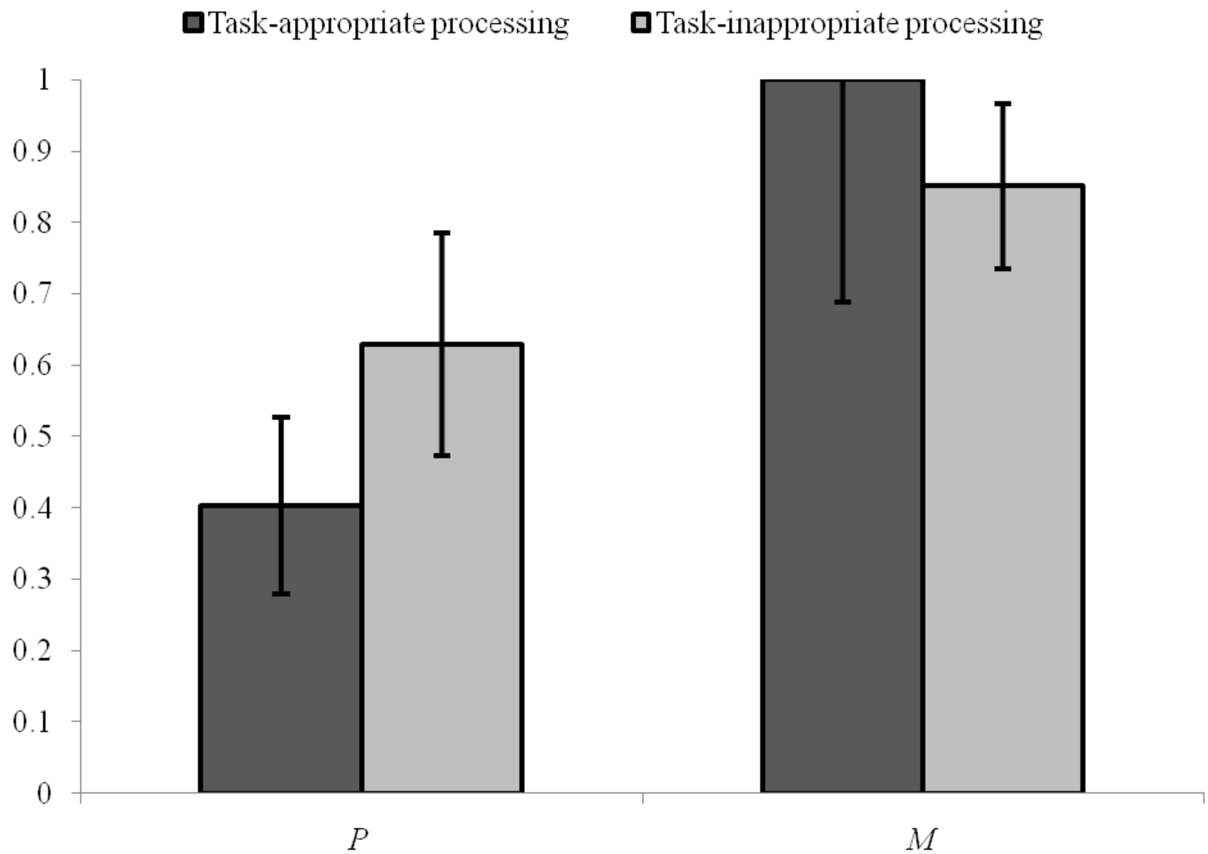

Figure 2. Experiment 1a parameter estimates for the *P* and *M* parameters by processing condition. Error bars represent 95% confidence intervals.

Qualitative Assessment

Bivariate correlations were used to analyze the relationship among participants' task perceptions, as administered through the post-experiment questionnaire, participants' PM performance, and participants' rates of task interference. The average ratings and correlations for the task-appropriate processing condition are shown in Table 3. The average ratings and correlations for the task-inappropriate processing condition are shown in Table 4. For the correlation tables, Questions 1 and 2 were not included – those questions were used to assess participants' memory for the PM cues and PM response. The questions are shown in Appendix A.

Table 3
Bivariate correlations for task-appropriate processing for Experiment 1a

Question #[a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	4.83	.33*	.19	.03
4. Ability to complete everyday intentions	5.50	.22	-.04	-.12
5. Ability to attend to everyday tasks	5.61	.20	-.26	-.18
6. Importance placed on the PM task	4.81	.54**	.22	.13
7. Importance placed on the ongoing task	5.89	-.06	.19	.27
8. Difficulty of the PM task	5.14	.32	-.08	-.21
9. Difficulty of the ongoing task	5.69	.12	.01	.02
10. Likelihood of a correct PM response	4.94	.68**	.004	-.11
11. Overall difficulty of the combined tasks	4.69	.43**	.002	-.12

Note. * $p < .05$; ** $p < .01$; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

No significant differences were found for any of the ratings between the conditions. For the task-appropriate processing condition, significant correlations were found only for PM performance. No significant correlations were found for task interference for this condition. PM performance was positively correlated with participants' overall rated memory abilities, the level of importance placed on performing the PM task, the likelihood of having correctly responded to the PM cues, and the ease of having to perform both the PM task and the ongoing task together.

Table 4
Bivariate correlations for task-inappropriate processing for Experiment 1a

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	4.67	.03	.06	-.002
4. Ability to complete everyday intentions	5.52	-.06	.02	.06
5. Ability to attend to everyday tasks	5.89	-.09	-.02	-.16
6. Importance placed on the PM task	4.37	.58**	.51**	.60**
7. Importance placed on the ongoing task	5.48	.14	.16	.20
8. Difficulty of the PM task	4.59	.41*	.44*	.47*
9. Difficulty of the ongoing task	5.44	-.07	.10	.04
10. Likelihood of a correct PM response	4.33	.68**	.47*	.57**
11. Overall difficulty of the combined tasks	4.22	.54**	.29	.28

Note. * $p < .05$; ** $p < .01$; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

For task-inappropriate processing, PM performance and levels of task interference were positively correlated with several questionnaire items. The level of importance placed on the PM task, the difficulty of performing the PM task, and the likelihood of having correctly responded to the PM cues was positively related to greater PM performance and greater levels of task interference. The ease of having to perform both the PM and ongoing tasks together also positively correlated with PM performance.

Experiment 1b

Method

Participants

Sixty-one undergraduates from Louisiana State University participated in exchange for credit in a psychology class. Thirty-four participants were randomly assigned to the task-appropriate processing condition. Twenty-seven participants were randomly assigned to the task-inappropriate processing condition. Five participants' data were excluded from the following analyses for reporting no memory of either the PM cues or the PM response. All of the excluded participants were from the task-appropriate processing condition, resulting in 29 participants in this condition.

Materials, Design, and Procedure

The details for this experiment were identical to those of Experiment 1a with one exception. Participants completed the procedure in the same manner as Experiment 1a, but were administered the questions regarding the potential use of metacognitive strategies and perceived task difficulty *prior* to continuing to that part of the procedure. This was done to assess whether participants established different attention allocation policies or metacognitive strategies given what their practice with the ongoing task and their knowledge of the PM instructions in the different processing conditions.

Results

Behavioral Performance

PM performance is shown in Table 1. Participants who processed the PM cues under task-appropriate conditions had significantly lower performance compared to participants who processed the PM cues under task-inappropriate conditions. This result was consistent for performance on the first PM cue, $F(1, 54) = 6.38$, $MSE = 1.47$, $p < .05$, $n^2_p = .11$, $p_{rep} = .94$, a marginally significant difference for the second PM cue, $F(1, 54) = 3.70$, $MSE = .89$, $p = .06$, $n^2_p = .06$, $p_{rep} = .86$, and a significant difference for overall PM performance, $F(1, 54) = 6.44$, $MSE = 1.16$, $p < .01$, $n^2_p = .11$, $p_{rep} = .96$. Contrary to prior research, task-inappropriate processing consistently yielded higher rates of PM performance compared to task-appropriate processing.

The RT data are shown in Table 2. No differences were found for the baseline phase, $F(1, 54) = .04$, $MSE = 1261.21$, $p = .84$, $n^2_p = .001$, $p_{rep} = .25$, but RTs were significantly longer in the test phase for task-inappropriate processing compared to task-appropriate processing, $F(1, 54) = 4.71$, $MSE = 270777.67$, $p < .05$, $n^2_p = .08$, $p_{rep} = .91$. Regarding the difference RTs, participants who processed the PM cues under task-inappropriate conditions had longer latencies to the ongoing task compared to participants who processed the PM cues under task-appropriate conditions, $F(1, 54) = 5.82$, $MSE = 308998.36$, $p < .05$, $n^2_p = .10$, $p_{rep} = .93$. The better PM performance in the task-inappropriate condition appears to be associated with greater task interference in this condition, as well.

As in Experiment 1a, bivariate correlations were conducted for PM performance and task interference. Overall, PM performance was positively correlated with task interference ($r = .47$; $p < .01$). For task-appropriate processing, a significant correlation was not observed ($r = .23$; $p = .23$). For task-inappropriate processing, PM performance significantly correlated with task interference ($r = .56$; $p < .01$). These patterns of correlations between the two conditions again replicate the findings from Meiser and Schult (2008).

The MPT Model

The parameter estimates for the task-appropriate and task-inappropriate processing conditions are shown in Figure 3. The model provided a good fit to the overall data, G^2 (8) = 8.90, $p = .35$. The model fit the data for both the task-appropriate processing condition, G^2 (4) = 1.87, $p = .76$, and the task-inappropriate processing condition, G^2 (4) = 7.03, $p = .13$. As in Experiment 1a, the parameter estimate for *P* was significantly higher for task-inappropriate processing compared to task-appropriate processing, G^2 (1) = 11.65, $p = .001$ (model fit: G^2 (9) = 20.55, $p = .01$). This suggests increased use of preparatory attention processes for task-inappropriate processing compared to task-appropriate processing of the PM cues. The parameter estimate for *M* was significantly higher for task-appropriate processing compared to task-inappropriate processing, G^2 (1) = 3.96, p = .046 (model fit: G^2 (9) = 12.86, p = .17). As in Experiment 1a, task-appropriate processing appears to have allowed for greater retrospective memory processes to be utilized upon the presentation of PM cues during the test phase of the ongoing task compared to task-inappropriate processing. However, again as in Experiment 1a, caution should be taken when interpreting the difference in the *M* parameter given the observed ceiling effect.

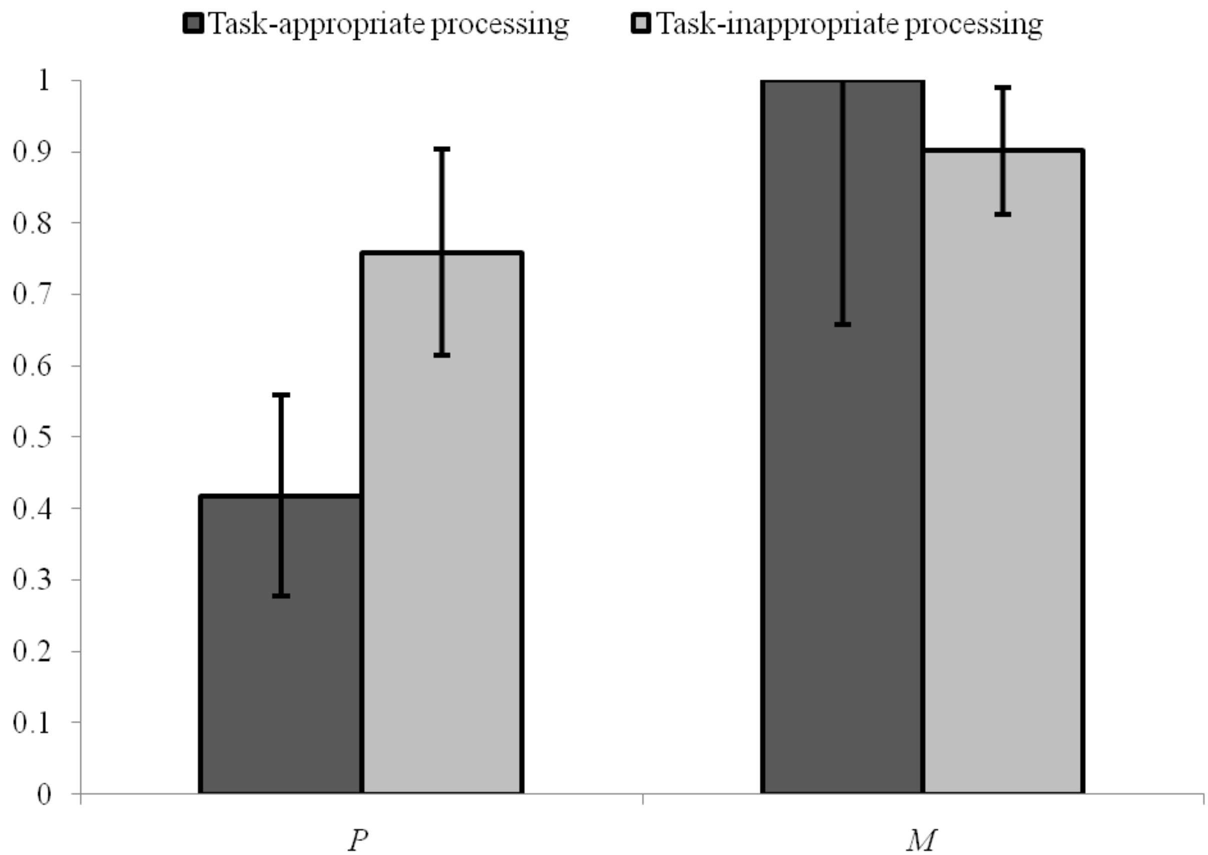

Figure 3. Experiment 1b parameter estimates for the *P* and *M* parameters by processing condition. Error bars represent 95% confidence intervals.

Qualitative Assessment

The questionnaire for this part of Experiment 1 was administered prior to the start of the test phase of the ongoing task. These questions are shown in Appendix A. The bivariate correlations and the average ratings for the task-appropriate processing condition are shown in Table 5. No significant correlations were found for this condition. The bivariate correlations and the average ratings for the task-inappropriate processing condition are shown in Table 6. The RTs to the test phase of the ongoing task was positively related to the level of ease of having to perform the PM and ongoing tasks together for the task-inappropriate processing condition. There were no other significant correlations.

Table 5
Bivariate correlations for task-appropriate processing for Experiment 1b

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	5.17	.23	.01	-.07
4. Ability to complete everyday intentions	5.72	.05	-.12	-.13
5. Ability to attend to everyday tasks	5.66	-.05	-.26	-.01
6. Importance placed on the PM task	5.90	.36	-.03	.11
7. Importance placed on the ongoing task	6.14	.26	.19	.20
8. Difficulty of the PM task	5.45	.05	-.11	-.01
9. Difficulty of the ongoing task	5.86	-.24	.21	.23
10. Likelihood of a correct PM response	5.66	.21	.05	.14
11. Overall difficulty of the combined tasks	5.14	.21	.03	.18

Note. * $p < .05$; ** $p < .01$; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

Table 6
Bivariate correlations for task-inappropriate processing for Experiment 1b

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	5.00	.10	.06	-.04
4. Ability to complete everyday intentions	5.96	.01	-.21	-.30
5. Ability to attend to everyday tasks	5.70	-.001	.03	.10
6. Importance placed on the PM task	5.48	.22	.29	.06
7. Importance placed on the ongoing task	5.74	.25	.28	.13
8. Difficulty of the PM task	4.74	-.12	.22	-.08
9. Difficulty of the ongoing task	5.37	-.02	.20	-.01
10. Likelihood of a correct PM response	5.07	-.14	.23	-.001
11. Overall difficulty of the combined tasks	4.59	.11	.42*	.18

Note. * p < .05; ** p < .01; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

Some differences were found between the conditions for the questions assessing the difficulty of performing the PM task and the likelihood of correctly responding to the PM cues. Participants who received the task-inappropriate processing instructions rated greater difficulty in having to performance the PM task, t (54) = 1.90, p = .062. Participants who received the task-appropriate processing instructions rated a greater likelihood of correctly responding to the PM cues, t (54) = 1.96, p = .055. No other differences were found in the ratings.

Discussion

The results in this experiment are contrary to prior research showing higher rates of PM performance for task-appropriate processing compared to task-inappropriate processing (e.g., Meier & Graf, 2000; Meiser & Schult, 2008). The behavioral results from Experiment 1a showed no differences in PM performance or task interference between task-appropriate and task-inappropriate processing. For Experiment 1b, higher rates of PM performance and higher levels of task interference were found for task-inappropriate processing compared to task-appropriate processing. When the data from Experiments 1a and 1b were combined, better PM performance emerged for the task-inappropriate condition (overall PM: F (1, 115) = 7.14, MSE = 1.31, $p <$ .01, n^2_p = .06, p_{rep} = .96), in addition to greater task interference (RT difference: F (1, 115) = 7.55, MSE = 335550.59, $p < .01$, n^2_p = .06, p_{rep} = .96). Although the effects of PM performance are contrary to previous research, the finding of increased PM performance being associated with higher levels of task interference for task-inappropriate processing replicates findings from Meiser and Schult (2008). While Meiser and Schult found the typical effect of higher PM performance for task-appropriate processing, they also found a positive correlation between task interference and PM performance for task-inappropriate processing. This is somewhat in line with the current findings of higher levels of task interference as well as higher PM performance for task-inappropriate processing compared to task-appropriate processing. For the current experiment, an overall positive correlation was found between PM performance task interference (r = .50, $p < .01$). This positive correlation was found for task-inappropriate processing (r = .68, $p < .01$) but no significant correlation was found for task-appropriate processing (r = .22, p = .08). This pattern of correlations was nearly identical for Experiment 1a (task-appropriate processing: r = .21, p = .23; task-inappropriate processing: r = .79, $p < .01$) and Experiment 1b (task-appropriate processing: r = .23, p = .23; task-inappropriate processing: r = .56, $p < .01$).

There were some issues with how the MPT model fit the data for each part of the experiment. The MPT model did not fit the overall data in Experiment 1a, but provided a satisfactory fit when each condition was fitted separately. The model for Experiment 1b satisfactorily fit the data, as well as each condition when fitted separately. The model also fitted the overall data for both parts of the experiment (G^2 (16) = 25.22, p = .07). For both parts of Experiment 2, the parameter estimate for *P* was greater for task-inappropriate processing compared to task-appropriate processing. The parameter estimate for *M* was greater for task-appropriate processing compared to task-inappropriate processing. According to the PAM model, the *P* parameter represents the preparatory attention processes necessary for successful PM performance. The difference observed in the hypothesis test of this parameter coincides with the behavioral results showing higher PM performance and greater levels of task interference for the task-inappropriate processing condition compared to task-appropriate processing. The differences observed in the *M* parameter, which is assumed to be the retrospective memory processes involved in PM, do not coincide with the behavioral results for PM performance. Note that this could be viewed as a virtue of the model, because it may reveal process differences that are masked by standard behavioral measures of performance. After all, theoretically one would expect the appropriateness of the processing to have an effect at the time the PM cues are retrieved, in addition to any possible differences in preparatory processing. Some caution should be taken, as this difference could be influenced by the ceiling effect for the parameter estimate in the task-appropriate condition.

While there were no differences observed in the behavioral results of Experiment 1a, participants in both conditions had significant positive correlations between PM performance and their ratings of the importance placed on completing the PM task and the likelihood of correctly responding to the PM cues. Additionally, participants in the task-inappropriate condition had significant positive correlations between levels of task interference and those two items on the questionnaire. No correlations of great interest were found for Experiment 1b.

The finding of more significant correlations on the qualitative assessment for Experiment 1a compared to Experiment 1b suggests that participants ratings reflected their performance better when asked for their impressions of the task after completing the experiment (i.e., postdictions of the task) compared to before engaging in the test phase of the ongoing task (i.e., predictions of the task). However, differences in the behavioral data between the conditions were only found for Experiment 1b. Even though there were a lack of correlations with the behavioral results for Experiment 1b, the order of having to answer the questionnaire items may have affected the behavioral results. Participants may have refreshed the PM and ongoing task instructions by having to make their ratings to both tasks prior to engaging in the test phase. This may have caused participants in the task-inappropriate processing condition to realize the difficulty of the PM task compared to the requirements of the ongoing task, thus resulting in higher PM performance along with higher levels of task interference compared to the behavioral results of Experiment 1a. However, *t*-tests revealed no differences in overall PM performance or task interference between Experiment 1a and Experiment 1b (PM performance: $t(117) = .94$, $p = .35$; task interference: $t(117) = .67$, $p = .50$). This result was the same for both task-appropriate processing (PM performance: $t(63) = .06$, $p = .95$; task interference: $t(63) = .41$, $p = .68$) and task-inappropriate processing (PM performance: $t(52) = 1.27$, $p = .21$; task interference: $t(52) = .96$, $p = .34$).

Some of these issues regarding the relationship between PM performance and task interference, the use of the MPT model, and how metacognitive strategies might influence PM performance were further investigated in Experiment 2. In this next experiment, participants were subject to a manipulation intended to result in differences in PM performance while having no effect on the levels of task interference between the conditions, because there should be no difference in the way participants approach the task between the conditions (i.e., in preparatory attentional processing). Unlike Experiment 1, where some participants appeared to approach the task-appropriate task differently than the task-inappropriate task, participants should be unaware of the manipulation in the next experiment. One issue under investigation is how the MPT model will fit the data if differences in PM performance are found without any differences in task interference. Another issue is how participants report their impressions of the task prospectively and retrospectively, and how the order of the questionnaire administration might influence performance, as it did in Experiment 1.

EXPERIMENT 2

The goal of this experiment was to test whether the match or mismatch of a contextual feature associated with a PM cue affected PM performance while having no effect on levels of task interference. The contextual feature associated with PM cues in this experiment was the background color and the font that PM cues were presented in at the time of encoding (i.e., intention formation). When PM cues were presented during the test phase of the ongoing task, participants were presented with the PM cues in either the same background color and font from encoding (the context-match condition), or a different background color and font from encoding (the context-mismatch condition). This manipulation was incidental in nature given that participants should have been unaware of the context manipulation. Any influence of the manipulation is expected to occur on PM performance without any differences in the processes assumed to be necessary to prepare for the encounter of PM cues. As such, task interference also should not differ, because participants were unaware of the manipulation prior to encountering the first PM cue. The data from this experiment was again fitted to the MPT model in the same manner as in Experiment 1. Participants were also administered the qualitative assessment either upon completion of the experiment (Experiment 2a) or prior to participants engaging in the test phase of the procedure in which PM cues were expect to appear (Experiment 2b). The results are again addressed in order of the descriptive and inferential results of the behavioral data, the fitting and hypothesis testing of the MPT model, and correlations of the behavioral data and the qualitative assessment administered to participants. The results for each part of this experiment will be discussed in turn after the complete description of both parts of Experiment 2.

Experiment 2a

Method

Participants

Fifty-nine undergraduates from Louisiana State University participated in exchange for credit in a psychology class. Twenty-eight participants were randomly assigned to the context-match condition. Thirty-one participants were randomly assigned to the context-mismatch condition. Five participants were excluded from the analyses due to not remembering either the PM cues or the PM response. This resulted in 54 participants, 24 in the context-match condition and 30 in the context-mismatch condition. All participants reported having no form of color blindness.

Materials, Design, and Procedure

The design and materials were similar to those used in Experiment 1. The match or mismatch of the background color and font, used for the encoding and retrieval of PM cues, served at the between-subjects factor. The items presented during the ongoing task were shown in ten different randomly presented background colors along with ten different fonts available through E-Prime 1.2. The colors consisted of red, yellow, lime, magenta, gray, blue, maroon, cyan, teal, and purple. The fonts consisted of Bauhaus 93, Blippo Light SF, Broadway, Commerce SF, Courier New, Times New Roman, Ultra Serif SF Italic, Verdict SF Bold, Viner Hand ITC, and Wide Latin. The color and font combination was randomly determined. As in Experiment 1a, participants were administered the questionnaire to assess the use of metacognitive strategies after completing the test phase of the ongoing task.

The test phase of the ongoing task consisted of 150 trials[1]. The 150 words used in Experiment 1, and 50 additional words selected from the MRC psycholinguistic database with the same constraints, were used as stimuli for this experiment. The PM cues used for this experiment were *milk* and *pepsi*. Immediately after the presentation of the PM instructions, participants encoded each PM cue in the gray background color and Wide Latin font. Participants had three seconds to encode each cue, presented one at a time. Participants were instructed to pay attention to the words as they were presented for encoding, and that they were to make a PM response if they ever encountered the word during the ongoing task regardless of the format it was presented in. The order of presentation at encoding and presentation during the test phase of the ongoing task were counterbalanced. During the test phase of the ongoing task, participants were presented with the PM cues in either the same background color and font, or a different background color (red) and font (Times New Roman) from encoding. The PM cues were presented on trials 101 and 141 during the test phase of the ongoing task.

Results

Behavioral Performance

PM performance is shown in Table 7. One-way between-subjects ANOVAs, with the context-match vs. context-mismatch conditions as the factor, showed no differences in PM performance for the first PM cue, $F(1, 52) = 1.02$, $MSE = .21$, $p = .32$, $n^2_p = .02$, $p_{rep} = .62$, the second PM cue, $F(1, 52) = .10$, $MSE = .02$, $p = .76$, $n^2_p = .002$, $p_{rep} = .32$, and overall PM performance, $F(1, 52) = .60$, $MSE = .08$, $p = .44$, $n^2_p = .01$, $p_{rep} = .54$. The match vs. mismatch of context from encoding to presentation of the PM cues did not influence PM performance, although the trend favored the match condition, as predicted.

Response latencies are shown in Table 8. As expected, task interference (i.e., the difference column) did not significantly differ between the conditions, $F(1, 52) = .10$, $MSE = 787.12$, $p = .76$, $n^2_p = .002$, $p_{rep} = .32$. The same pattern of results was consistent for the baseline,

Table 7
Mean PM Performance by Experiment and Condition for Experiment 2

	PM Performance		
	1st PM cue	2nd PM cue	Proportion Correct
Experiment 2a			
Context-match condition	.79 (.08)	.83 (.08)	.81 (.07)
Context-mismatch condition	.67 (.09)	.80 (.07)	.73 (.07)
Experiment 2b			
Context-match condition	.87 (.06)	.97 (.03)	.92 (.03)
Context-mismatch condition	.81 (.08)	.65 (.10)	.73 (.07)

Note. The value in parentheses represents one standard error of the mean.

$F(1, 52) = 3.00$, $MSE = 35300.42$, $p = .09$, $n^2_p = .06$, $p_{rep} = .82$, and test phases, $F(1, 52) = .83$, $MSE = 46629.92$, $p = .10$, $n^2_p = .05$, $p_{rep} = .81$. The type of context condition did not influence levels of task interference.

As in Experiment 1, bivariate correlations were conducted for PM performance and task interference. Overall, PM performance was not significantly correlated with task interference ($r = .10$; $p = .46$). For the context-match condition, a significant correlation was also not observed ($r = .26$; $p = .22$). For the context-mismatch condition, PM performance did not significantly correlate with task interference ($r = -.02$; $p = .91$).

The MPT Model

The response frequencies from the test phase of the ongoing task that were used in the MPT model for Experiment 2 are shown in Appendix D. The parameter estimates for the

Table 8
Mean Median Reaction Time (ms) by Experiment and Condition for Experiment 2

	Ongoing Task Reaction Time		
	Baseline phase	Test phase	Difference
Experiment 2a			
Context-match condition	875.27 (23.86)	944.94 (26.65)	69.67 (18.42)
Context-mismatch condition	823.82 (18.48)	885.80 (23.13)	61.98 (16.27)
Experiment 2b			
Context-match condition	848.74 (21.44)	942.35 (31.74)	93.61 (27.03)
Context-mismatch condition	820.08 (23.64)	921.63 (34.38)	101.56 (27.55)

Note. The value in parentheses represents one standard error of the mean.

context-match and context-mismatch conditions are shown in Figure 4. The model provided an acceptable fit to the overall data, G^2 (8) = 14.29, p = .07. The model fit the data for both the context-match condition, G^2 (4) = 6.14, p = .19, and the context-mismatch condition, G^2 (4) = 8.15, p = .09. No differences were found between the context-match and context-mismatch conditions in the parameter estimates for both the *P*, G^2 (1) = 1.42, p = .23 (model fit: G^2 (9) = 15.71, p = .07), and the *M* parameters, G^2 (1) = 0.47, p = .49 (model fit: G^2 (9) = 14.76, p = .10). However, ceiling effects were still found for the *M* parameter. According to the model, there were no differences in the use of preparatory attention or retrospective memory processes between the conditions for successful PM performance.

Qualitative Assessment

The bivariate correlations and the average ratings for the context-match condition are shown in Table 9. The bivariate correlations and the average ratings for the context-mismatch

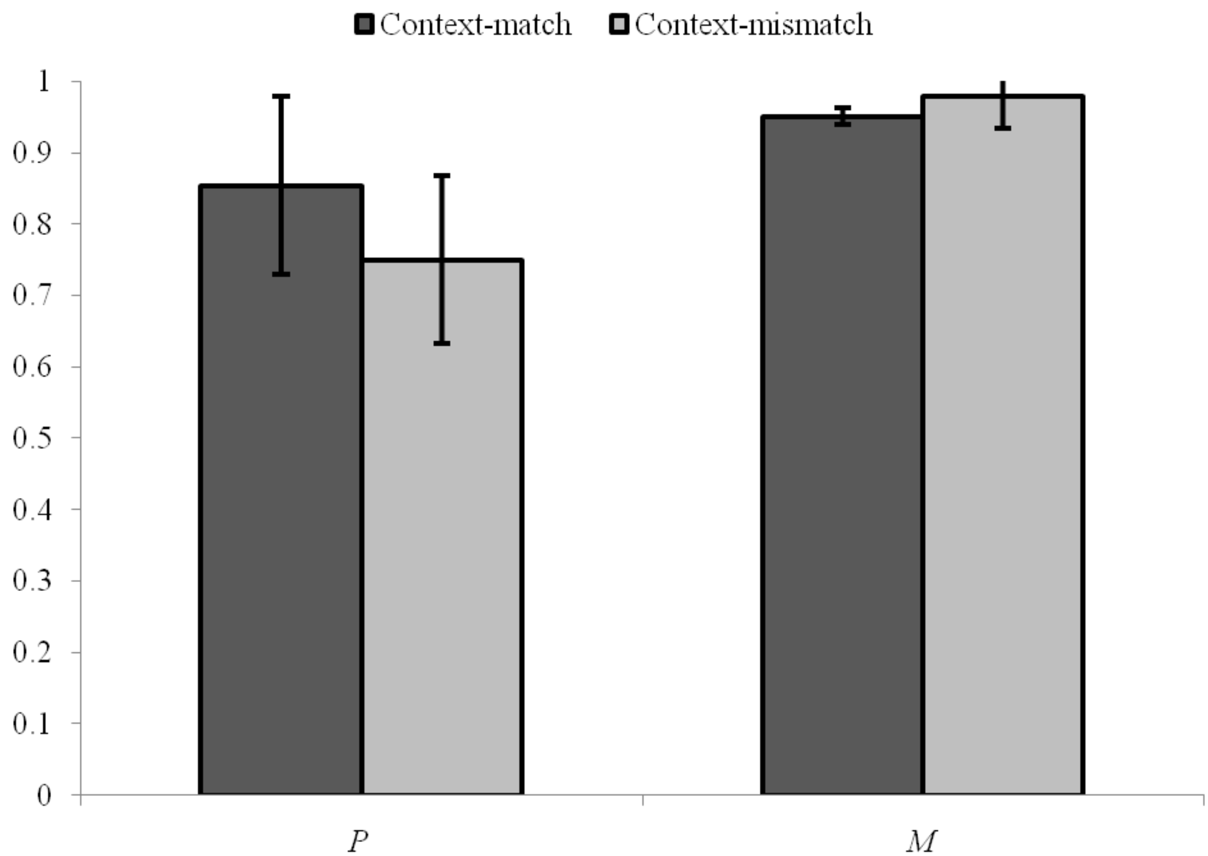

Figure 4. Experiment 2a parameter estimates for the *P* and *M* parameters by context condition. Error bars represent 95% confidence intervals.

condition are shown in Table 10. The only significant correlation found for the context-match condition was a positive relationship between the RT difference and the likelihood of having correctly responded to the PM cues. For the context-mismatch condition, PM performance positively correlated with participants' rated memory abilities, level of importance placed on the PM task, and the likelihood of having correctly responded to the PM cue. Task interference (RT difference) was positively correlated with participants' rated ability to successfully complete everyday intentions. No other significant correlations were found. The only difference in the ratings was observed for participants in the context-match condition reporting a greater

Table 9
Bivariate correlations for the context-match for Experiment 2a

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	5.25	-.10	-.11	-.18
4. Ability to complete everyday intentions	5.21	-.01	.06	.20
5. Ability to attend to everyday tasks	5.63	-.18	-.34	-.14
6. Importance placed on the PM task	5.88	.19	-.10	-.13
7. Importance placed on the ongoing task	5.96	.06	-.24	-.39
8. Difficulty of the PM task	5.88	.16	-.11	.18
9. Difficulty of the ongoing task	5.54	.20	-.10	-.07
10. Likelihood of a correct PM response	6.38	.34	.04	.49*
11. Overall difficulty of the combined tasks	5.58	-.12	-.19	.11

Note. * $p < .05$; ** $p < .01$; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

likelihood of successfully responding to the PM cues compared to the context-mismatch condition, $t\ (52) = 1.90$, $p = .063$.

Experiment 2b

Method

Participants

Sixty-one undergraduates from Louisiana State University participated in exchange for credit in a psychology class. Thirty-two participants were randomly assigned to the context-match condition. Twenty-nine participants were randomly assigned to the context-mismatch condition. Four participants were excluded from the analyses for not having memory for either the PM cues or PM response. One participant was removed from the context-match condition and three participants were removed from the context-mismatch condition. This resulted in the

Table 10
Bivariate correlations for the context-mismatch for Experiment 2a

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	5.20	.49**	-.12	-.16
4. Ability to complete everyday intentions	5.80	.40*	.23	.37*
5. Ability to attend to everyday tasks	5.77	.18	.26	.06
6. Importance placed on the PM task	5.90	.56**	-.03	-.11
7. Importance placed on the ongoing task	5.17	.16	.30	.16
8. Difficulty of the PM task	5.57	.04	.25	.33
9. Difficulty of the ongoing task	5.43	.11	-.02	-.07
10. Likelihood of a correct PM response	5.77	.59**	-.21	-.18
11. Overall difficulty of the combined tasks	5.00	.21	.11	.27

Note. * $p < .05$; ** $p < .01$; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

data analyses including 57 participants, 31 in the context-match condition and 26 in the context-mismatch condition. All participants reported having no form of color blindness.

Materials, Design, and Procedure

All details of this experiment are identical to those of Experiment 2a. The only difference was the administration of the questionnaire. As in Experiment 1b, the questionnaire was administered before participants engaged in the test phase of the ongoing task.

Results

Behavioral Performance

PM performance is shown in Table 7. The data were submitted to one-way between-subjects ANOVAs, with the context-match vs. context-mismatch as the factor. For overall PM performance, the context-match condition resulted in greater PM performance compared to the context-mismatch condition, $F(1, 55) = 5.93$, $MSE = .50$, $p < .05$, $n^2_p = .10$, $p_{rep} = .93$. This same result was found for PM performance for the second PM cue, $F(1, 55) = 11.18$, $MSE = 1.39$, $p < .01$, $n^2_p = .17$, $p_{rep} = .99$, but no difference was found for performance for the first PM cue, $F(1, 55) = .41$, $MSE = .06$, $p = .52$, $n^2_p = .01$, $p_{rep} = .49$. Outside of performance for the first PM cue, the context-match condition improved PM performance compared to the context-mismatch condition.

Task interference is shown in Table 8. As in Experiment 2a, task interference did not significantly differ between the conditions, $F(1, 55) = .04$, $MSE = 892.53$, $p = .84$, $n^2_p = .001$, $p_{rep} = .25$. The same pattern of results was consistent for the baseline, $F(1, 55) = .81$, $MSE = 11618.88$, $p = .37$, $n^2_p = .01$, $p_{rep} = .59$, and test phases, $F(1, 55) = .20$, $MSE = 6070.84$, $p = .66$. $n^2_p = .004$, $p_{rep} = .39$. Again, the manipulation did not affect the levels of task interference.

The patterns of the correlations were similar to those in Experiment 2a. Bivariate correlations were conducted for PM performance and task interference. Overall, PM performance was not significantly correlated with task interference ($r = .08$; $p = .58$). For the context-match condition, a significant correlation was also not observed ($r = -.08$; $p = .67$). For the context-mismatch condition, PM performance did not significantly correlate with task interference ($r = .20$; $p = .32$).

The MPT Model

The parameter estimates for *P* and *M* are shown in Figure 5. The model provided a satisfactory fit to the overall data, G^2 (8) = 10.94, $p = .20$. The model provided a satisfactory fit to the data for the context-match condition, G^2 (4) = 2.32, $p = .07$, and a satisfactory fit for the context-mismatch condition, G^2 (4) = 8.62, $p = .07$. The parameter estimate for *P* was significantly higher for the context-match condition compared to the context-mismatch condition, G^2 (1) = 6.93, p = .01 (model fit: G^2 (9) = 17.88, p = .04). No difference in the parameter estimate for *M* was found between the context-match and context-mismatch conditions, G^2 (1) = 0.06, p = .81 (model fit: G^2 (9) = 11.00, p = .28). According to the model, the context-match condition required greater rates of preparatory attention compared to the context-mismatch condition, while no differences in the use of retrospective memory processes were observed between the conditions.

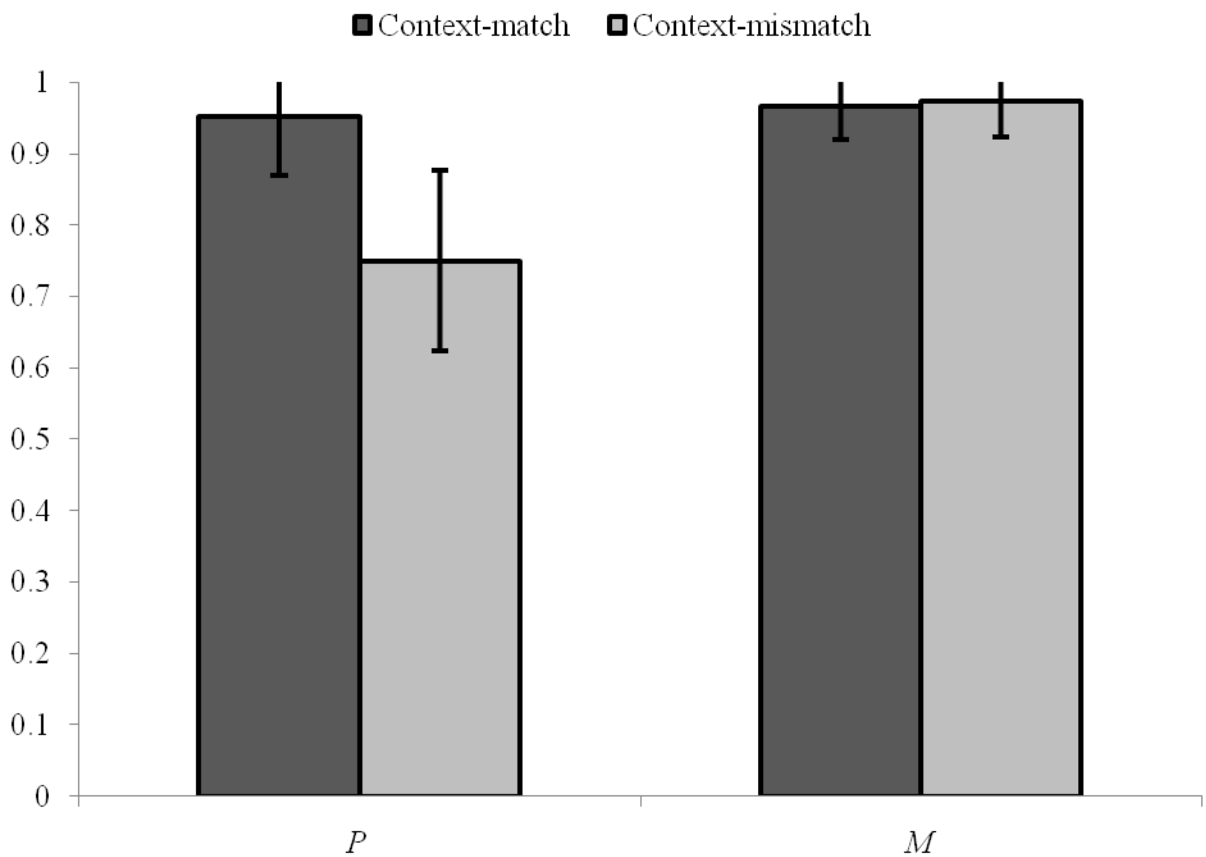

Figure 5. Experiment 2b parameter estimates for the *P* and *M* parameters by context condition. Error bars represent 95% confidence intervals.

Qualitative Assessment

The bivariate correlations and the average ratings for the context-match condition are shown in Table 11. For this condition, PM performance was positively correlated with rated memory abilities. RTs on the test phase of the ongoing task were positively correlated with the rating of the ease of having to make the ongoing task judgment. The bivariate correlations and the average ratings for the context-mismatch condition are shown in Table 12. PM performance was positively correlated with the likelihood of correctly responding to the PM cues. Task interference was negatively correlated with participants' subjective appraisal of their PM abilities and their attentional abilities. No other significant correlations were found and no significant differences were found for any of the ratings between the conditions.

Table 11
Bivariate correlations for the context-match for Experiment 2b

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	5.19	.39*	-.22	-.14
4. Ability to complete everyday intentions	5.65	-.15	.05	-.04
5. Ability to attend to everyday tasks	5.68	-.05	-.30	-.12
6. Importance placed on the PM task	5.65	-.11	.04	.17
7. Importance placed on the ongoing task	5.90	-.10	.16	.30
8. Difficulty of the PM task	4.71	-.09	.18	.21
9. Difficulty of the ongoing task	4.84	.12	.39*	.30
10. Likelihood of a correct PM response	5.39	.22	-.23	-.19
11. Overall difficulty of the combined tasks	4.61	.07	-.06	-.10

Note. * $p < .05$; ** $p < .01$; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

Table 12
Bivariate correlations for the context-mismatch for Experiment 2b

Question # [a]	Mean	Overall PM	Test Phase RTs	RT difference
3. Overall memory abilities	4.85	.37	-.24	-.26
4. Ability to complete everyday intentions	5.88	-.08	-.42*	-.31
5. Ability to attend to everyday tasks	6.12	.03	-.43*	-.40*
6. Importance placed on the PM task	6.23	.13	.17	.18
7. Importance placed on the ongoing task	6.35	-.22	.14	.08
8. Difficulty of the PM task	4.96	.35	.21	.24
9. Difficulty of the ongoing task	5.27	.11	-.35	-.22
10. Likelihood of a correct PM response	5.42	.46*	.03	.03
11. Overall difficulty of the combined tasks	4.92	-.14	.11	.18

Note. * p < .05; ** p < .01; [a] Questions 1 and 2 are not included in the table. They were used to assess participants' memory for the PM task.

Discussion

For the behavioral results, no differences were found in PM performance and task interference between the conditions in Experiment 2a. In Experiment 2b, greater PM performance was found for the context-match condition compared to the context-mismatch condition, but no differences were found for levels of task interference. This pattern of results was found when the data from both parts of the experiment combined were analyzed (overall PM: F (1, 107) = 4.41, MSE = .49, p < .05, n^2_p = .04, p_{rep} = .90; RT difference: F (1, 107) = .00, MSE = .47, p = .99, n^2_p = .00, p_{rep} = .02). The manipulation was successful in allowing for greater PM performance for the context-match compared to the context-mismatch condition but did not influence the levels of task interference between the two conditions. No significant correlations were found between PM performance and task interference, and no differences were found in PM performance or task interference between Experiment 2a and Experiment 2b.

The MPT model provided satisfactory fits to the data from Experiments 2a and 2b, as well as from each condition for each part of the experiment. The MPT model also provided an acceptable fit to the overall data for Experiment 2 (G^2 (16) = 25.24, p = .07). For Experiment 2a, no differences were found in the hypothesis tests for the parameter estimates for *P* and *M* between the conditions. This finding coincides well with the behavioral results from this part of the experiment. For Experiment 2b, the hypothesis test resulted in a difference in the parameter estimate for *P*, with a significantly higher parameter estimate for the context-match condition compared to the context-mismatch condition. No differences were found for the parameter estimate for *M* between the conditions. These findings from the model do not coincide well with the behavioral results from this part of the experiment. PM performance was higher for the context-match condition compared to the context-mismatch condition while task interference did not differ. The parameter estimates of the model do not correspond to the behavioral results. Given the results and the assumptions of the PAM model, the parameter estimate for *M* should be higher for the context-match condition as compared to the context-mismatch condition, while no differences should be found in the parameter estimate for *P*. In the current MPT model, the *P* parameter appears to correspond more with the differences in PM performance and not task interference. However, ceiling effects occurred for the parameter estimate of *M*. This may warrant caution in the interpretation of the MPT model for this experiment.

While not very informative, a couple of correlations of interest emerged in Experiment 2a. Significant positive correlations were found in Experiment 2a for task interference and the likelihood of correctly responding to the PM cues for the context-match condition. Overall PM performance was positively correlated with reported importance placed on the PM task and PM response likelihood. No significant correlations were found in Experiment 2b. Similar to Experiment 1, differences in the behavioral results were only found in Experiment 2b. Again, even though participants' predictions of the task did not correlate with task performance, having to make their ratings of impressions of the task prior to engaging in the test phase of the ongoing task may have allowed an opportunity for participants to refresh the intention or to rehearse the PM cues they had just encoded. This extra opportunity to refresh the intention may have allowed for this context manipulation to affect PM performance while this opportunity was unavailable in Experiment 2a. If this is the case, it is particularly interesting that the context manipulation influenced only PM performance in Experiment 2b while leaving task interference essentially equal between the conditions. Overall this experiment instantiated a novel manipulation that affected PM performance while not influencing levels of task interference.

While the overall results in the current set of experiments are informative, several issues must be addressed given the prior literature and the assumptions proposed by several relevant theories of PM. The results from Experiment 1 do not replicate prior research investigating task-appropriate processing. The MPT model generally appears to fit the data from each experiment well, but the hypothesis testing raises some questions concerning how the model treats the data and how the parameter estimates are affected given differences in the behavioral performance. Finally, it appears participants may approach the task differently depending if participants are queried as to their impressions of the experiment before or after the test phase of the ongoing task.

GENERAL DISCUSSION

The goals of this study were to investigate the attention and memory processes associated with PM, and to apply a formal model to the data that estimates these processes and their levels of contribution to PM performance. Manipulations of task-appropriate processing and contextual associations of the PM cues were used to address these issues. The results from Experiment 1 showed higher rates of PM performance and higher rates of task interference when PM cues were processed under task-inappropriate conditions compared to task-appropriate conditions. These effects were exaggerated in conditions when a questionnaire was inserted between the intention formation phase and the PM cue presentation phase. The results from Experiment 2 showed higher rates of PM performance when the associative contextual features of the PM cues matched from encoding to retrieval compared to when they mismatched. Analogous to Experiment 1's findings, the match effect in Experiment 2 was exaggerated when a questionnaire was inserted between the intention formation phase and the PM cue presentation phase. Levels of task interference did not differ between the conditions in Experiment 2. For both experiments, the MPT model generally fit the data well, but high levels associated primarily with the *M* (retrospective memory) parameter in the model, and the pattern of differences in parameter estimates between some experimental conditions, prompt questions regarding the application of the MPT model in these experiments.

The results from Experiment 1 do not replicate previous findings demonstrating higher rates of PM performance for task-appropriate processing as compared to task-inappropriate processing (e.g., Marsh et al., 2000; Meier & Graf, 2000; Meiser & Schult, 2008). However, the experimental results do replicate the finding of higher levels of task interference being associated with improved levels of PM performance for task-inappropriate processing (Meiser & Schult, 2008). While the current findings do not replicate PM performance, they can be explained in terms of the influence of attention and perceived PM task importance for the overall patterns of performance, specifically in that the PM advantage for the task-inappropriate processing conditions was caused by extensive preparatory attentional processing. The response latencies to ongoing task trials were significantly slower as compared to task-appropriate conditions and the parameter *P* in the MPT model was larger in this condition. What did not occur was the expected theoretical advantage in the better processing overlap between the ongoing task decisions and the nature of the intention in the task-appropriate conditions.

One candidate cause of the slowing found in the task-inappropriate processing conditions is participants' perceptions regarding the difficulty of PM retrieval in this condition. It is reasonable to assume that people realize the difficulty in finding words containing three particular letters, while at the same time processing a semantic attribute of the words for the ongoing task. Interestingly, the questionnaire items directly addressing predicted difficulty of the ongoing task and PM task showed that people in the task-appropriate conditions rated these tasks as higher in difficulty. However, another questionnaire item addressed participants' predicted likelihood of successful PM responses—in this case those in the task-inappropriate conditions rated this as less likely. Although PM responses were in fact more likely, the difference in the rating of this particular questionnaire item is consistent with the notion that more difficulty was perceived in the task-inappropriate conditions. More work will need to be done to better implicate perceptions of task difficulty, or alternative theoretical mechanisms, for the greater task interference in the task-inappropriate processing conditions. One other likely cause of the slowing is that questionnaire items in Experiment 1b caused people to simply place more importance on the PM task. Recall that PM performance was higher overall in Experiment 1b as opposed to Experiment 1a. Direct manipulations of task importance have been shown to create higher levels of task interference (e.g., Smith & Bayen, 2004). Regardless, it appears that the extensive preparatory processing applied in the task-inappropriate conditions was enough to outweigh any theoretical benefit that might have accrued in the task-appropriate conditions. This result is consistent with Marsh et al.'s (2005) discussion of the flexibility of attentional allocation policies that are set by participants.

Turning to Experiment 2, manipulating the match vs. mismatch of the background color and font associated with the encoding and retrieval of PM cues affected performance, but not levels of task interference. These findings were as expected theoretically. The intention encoding context was identical in all conditions and the critical manipulation occurred only as PM cues were physically presented in the ongoing task. Therefore, response latencies on the ongoing task should not have differed among the various conditions; and they did not. Theoretically, this implies that preparatory attentional processing should also have been identical in these conditions. However, the MPT modeling results of Experiment 2b revealed significant differences in parameter *P*, which does not accord either with the theoretical predictions or with the response latency data. Note also that the *M* parameter differences one might predict from the PAM theory were not found, although these estimates were generally high no matter the conditions. Implications of these MPT model parameter estimates will be discussed in a separate section below. Significant differences were only found for Experiment 2b, when the qualitative assessment was administered prior to the test phase of the ongoing task. Again, this may have allowed participants to refresh or rehearse the intention, or consider it generally more important, thus influencing their attention allocation policies or metacognitive strategies.

The overall results from Experiments 1 and 2 can be explained by some of the assumptions common to the multiprocess framework and the PAM model. Given that greater levels of PM performance appeared to be in part due to greater levels of task interference for task-inappropriate processing, the multiprocess framework would suggest that greater levels of strategic monitoring occurred for in this condition resulting in the differences in performance compared to the task-appropriate processing condition. Such strategic monitoring (or preparatory attentional processes) may trump retrieval conditions that may otherwise improve performance (i.e., focal or task-appropriate processing conditions). Experiment 2 provides a counterpoint example, in that ongoing task latencies were identical in both Experiments 2a and 2b in both conditions, and context-match conditions improved PM performance. Another consideration of the mixed findings in Experiment 1 may be the quality of the task-appropriate conditions. Although the task-appropriate conditions were certainly more 'appropriate' relative to the inappropriate conditions, they may not have matched the ongoing task processing enough to provide a clear retrieval advantage upon processing of the PM cues.

For Experiment 1, some of the predictions offered by all of the theories of PM discussed in the introduction can account for the patterns of performance. While PM performance was lower for task-appropriate processing compared to task-inappropriate processing, the levels of task interference observed between the two conditions supports the predictions made by the multiprocess framework and replicates prior research (Meiser & Schult, 2008). Task interference was lower for task-appropriate processing and was not related to PM performance for that condition. Task interference was higher for task-inappropriate processing and was positively correlated with PM performance. The multiprocess framework does not appear to support the rates of PM performance observed in this experiment. The predictions made by the multiprocess framework for Experiment 2 do appear to support the model. Task interference did not differ between the context-match and context-mismatch conditions given the incidental nature of the manipulation and the focal processing allowed for the PM cues. Additionally, PM performance was affected by the match vs. mismatch of the encoding and retrieval contexts, with higher PM performance for the context-match condition. The results for this experiment lend support to support to the predictions made by the multiprocess framework.

PAM partially accounts for the results of Experiment 1. Levels of preparatory attention, shown in the *P* parameter estimates, were higher for task-inappropriate processing compared to task-appropriate processing, and this appears to reflect the patterns of PM performance and task interference. However, cue discrimination, shown in the *M* parameters estimates, did not differ between the two conditions while participants clearly showed higher levels of PM performance for task-appropriate processing compared to task-appropriate processing. The ease of cue discrimination should be higher for the condition that yielded higher levels of PM performance. The PAM theory does not support this finding. The PAM theory has greater trouble accounting for the findings of Experiment 2. The parameter estimates for *P* were higher for the context-match condition compared to the context-mismatch condition, while the parameter estimates for *M* do not differ between the conditions. These patterns in the MPT model do not appear to reflect the behavioral results for PM performance and task interference. The context manipulation should have affected the parameter estimates for cue discrimination and not preparatory attention. This was not the case for this experiment.

The attention allocation policies set by participants prior to engaging in the test phase of the ongoing task can explain the observed levels of performance in Experiment 1. Given that both PM performance and task interference were higher for task-inappropriate processing compared to task-appropriate processing, this appears to indicate that participants who received the task-inappropriate processing instructions may have realized the greater difficulty of the task compared to participants who received the task-appropriate processing instructions. Participants appear to have allocated their attention to the PM task to a greater degree for task-inappropriate processing compared to task-appropriate processing, resulting in the observed results. Participants' attention allocation policies did not appear to be affected by the manipulation implemented in Experiment 2. Given the incidental nature of the context manipulation in this experiment, attention allocation policies should not have differed between the conditions. This appears to be reflected in the similar levels of task interference for the conditions. The greater rates of PM performance found for the context-match condition compared to the context-mismatch condition appears to be due to the match of the context of the PM cues from encoding to retrieval specifically affected PM cue detection.

The multiprocess framework and participants' adoption of some kind of attention allocation policy appears to best support the current findings. The PAM theory has a bit more trouble explaining the given results, especially in regards to the parameter estimates produced by the MPT model. The PAM theory makes specific predictions regarding the use of preparatory attention and cue discrimination that should result in successful PM performance. While this theory was partly supported by the results of Experiment 1, the results from Experiment 2 do not coincide well with the assumptions of the theory and MPT model. Participants' overall performance in Experiment 1 can be explained well by the multiprocess framework and the use of certain attention allocation policies given that the levels of PM performance and task interference were higher for the task-inappropriate processing condition compared the task-appropriate processing condition. For Experiment 2, the results of the levels of task interference are completely in line with the predictions made by these theories. The differences in PM performance appear to be the result of the effect the context manipulation on the retrospective memory processes associated with PM. This result is not supported by PAM at all, but this does appear to have implications for the multiprocess framework and the instantiation of participants' attention allocation policies.

Further Consideration of the MPT Parameter Estimates

An important issue for the MPT model is how the model fit the data from both experiments, relative to the theoretical processes implied by the parameters themselves. Consider first the *P* parameter, which ostensibly indexes preparatory attention. Although this parameter may reflect attentional processes other than what is indexed by response latency slowing, or task interference, such slowing is generally considered a hallmark attribute of strategic monitoring or preparatory attention. Therefore, questions arise when patterns of task interference do not correlate with estimates of *P*. In Experiment 1, there was no such problem. But in Experiment 2, the *P* parameter changed across the context-match vs. context-mismatch conditions even though response latencies did not differ. An issue with the current study is that only two PM cues were presented to participants out of 100 or 150 trials of the ongoing task. This results in a proportion of PM cues to ongoing task trials of 2% for Experiment 1 and 1.33% for Experiment 2. All previous studies that have used the MPT model in PM research have proportions of PM cues to ongoing task trials of 8% to 12% (Smith & Bayen, 2004, 2005, 2006). This can also explain the trouble the MPT model had in fitting the data from each experiment. An important issue to consider is that the *P* parameter estimate rises generally with more frequent PM responses in a condition, whether those responses are correct or not. In other words, although researchers generally draw parallels between this parameter and response latencies, the parameter is directly affected by the sheer frequency of PM responses. Thus, these two estimates of performance will not always be in concert. Although there is no reason to suspect differences in preparatory attention in the context-match vs. context-mismatch conditions of Experiment 2b, the model behaves as though such differences exist.

Moreover, one would expect that the better performance supported by context-match conditions would be reflected in some estimate of retrospective memory ability. Yet it is odd that the task-appropriate conditions in Experiment 1 show higher levels of the *M* parameter, when these conditions also produce much worse overall PM performance. In fact, the *M* parameter in the MPT model applied here reflects recognition discriminability, or the ability to respond correctly to PM cues relative to responding incorrectly to non-PM cues (i.e., false alarms). It turns out that participants in the task-appropriate conditions did not commit as many PM false alarms (see Appendix C), and therefore a higher estimate of *M*, despite the fewer PM hits overall. This difference in *M* makes theoretical sense, because task-appropriate conditions should promote better recognition of PM cues as opposed to non-cues. But this difference in the *M* parameter contrasts sharply with the overall differences in PM responses. In general, *M* is close to ceiling in most of the conditions of Experiments 1 and 2 because people rarely made false alarms to PM cues. In this sense, the *M* parameter can only be used as an index of retrospective memory for PM as a measure of discrimination, not as some overall index of the quality of the retrieval environment. Imagine one condition of a PM study in which PM accuracy was 50% and another condition that was 90% (not unlike the size of the differences in Experiment 1). If people in neither condition committed PM false alarms, the *M* parameter would, by definition, be 1.0 because people could perfectly discriminate PM cues from non-cues. But such a finding should not be taken to imply that retrospective memory processes were identical in these two conditions, especially if nothing else indicates differences in preparatory attentional process. This was much the case in Experiment 2.

A strong implication of the foregoing analysis is the MPT model of PM by Smith and colleagues is only appropriate for use when sufficient PM false alarms are made to bring the *M* parameter off of ceiling. However, the existence of PM false alarms also calls into the question the integrity of the PM instruction and how well it was encoded by participants in the first place. Therefore, having questionnaires to assess whether people can report the general conditions that prompt PM responding are essential. When PM false alarms occur because people cannot remember the conditions for PM retrieval, then these false alarms are not valid representations of performance. This is one reason why such questionnaire responses were used to eliminate people from data analysis in the present study. When PM false alarms occur because an item matches the conditions for PM retrieval partially, then these false alarms may be indicative of less-than-perfect discrimination. This is what the *M* parameter in the MPT model reflects.

Placement of the Qualitative Questionnaire Assessment

One important aspect that is clear from the data from both experiments is that participants appeared to have set different attention allocation policies given the order of the administration of the qualitative assessment. The most salient and significant differences observed between the conditions for each experiment were confined to those conditions in which participants received the qualitative assessment prior to engaging in the test phase of the ongoing task. It appears that participants in these conditions approached the task differently as compared to those who were administered the questionnaire after completing the entire experiment. Receiving the questionnaire prior to performing the test phase may have resulted in more emphasis or attention being given to the task demands causing the observed behavioral differences to emerge. There is mixed evidence for a difference in perceived task difficulty from the questionnaire responses themselves. In Experiment 1b, participants given the task-inappropriate processing instructions may have recognized the difficulty of having to retrieve those PM cues, causing a greater degree of attention to be allocated to that intention compared to task-appropriate processing. This could partly explain the differences in PM performance and task interference between the conditions. The differences found in Experiment 2 are interesting in that the order of the administration of the questionnaire appears to affect whether or not PM performance differed based on the context-match manipulation, but the emergence of the effect in Experiment 2b was not due to any significant increase in the levels of task interference when compared to Experiment 2a. Thus, having the questionnaire administered prior to the test phase may have caused participants to rehearse the PM cues and the PM instructions, thereby causing PM performance to be more sensitive to the manipulation. Whatever possible differences in attention allocation policies adopted by participants between Experiments 2a and 2b, this was only apparent in PM performance but not task interference. Even though administering the questionnaire prior to the test phase may have only increased perceived task importance, this was not found in the levels of task interference for Experiment 2. Differences in Experiment 2b are most clearly attributable to the better-matching retrieval environment, given the context-match condition vs. the context-mismatch condition, as opposed to any sort of preparatory attention differences.

Participants' task impressions better corresponded to their levels of performance when administered the questionnaire after performing the test phase of the ongoing task. This was especially apparent in participants' ratings of PM task importance, likelihood of PM cue retrieval, and the difficulty of having to perform the overall test phase of the task. Participants' retrospective ratings of the task well reflected their levels of performance. Participants appeared to have recognized the difficulty of the overall task as well as their level of performance given the task demands. While administering the questionnaire prior to the test phase could have altered participants' attention allocation policies or approaches to the task resulting in the observed differences between the conditions, their ratings did not correspond to performance. If participants were using any metacognitive strategies in their approach to the task, this was not reflected in these prospective ratings.

CONCLUSIONS

The goals of this study were to investigate the effects of task-appropriate processing and context on the attention and memory processes necessary for PM performance. The study also intended to test the validity of the use of an MPT model in an investigation of PM. While the results from Experiment 1 do not replicate previous findings of the effect of task-appropriate processing, the current results can be explained in terms of the significantly higher levels of task interference that were associated with the higher levels of PM performance for task-inappropriate processing. A novel manipulation was used in Experiment 2, and this resulted in higher rates of PM performance given the reinstatement of contextual features associated with the PM cues from the time of encoding to retrieval. PM performance declined when these contextual features were not reinstated at the time of the presentation of the PM cues in the ongoing task. No differences in task interference between the conditions were found given the incidental nature of the manipulation. The effects for each experiment were concentrated in Experiments 1b and 2b, suggesting that the influence of administering the qualitative assessment prospectively resulted in performance being more sensitive to the manipulations under investigation. Of particular concern is the manner in which the MPT model fit the data and the resulting parameter estimates representing preparatory attention and retrospective memory processes.

This study succeeded in demonstrating differences in the contributions of attention and memory processes that influence PM. In Experiment 1, attention appeared to be necessary for an advantage in PM. In Experiment 2, the manipulation affected PM performance without any difference in the use of attentional resources as indexed by the levels of task interference. Approaches to the test phase of the ongoing task, or the instantiation of an attention allocation policy, appears to have influenced performance depending on when participants were subjected to the qualitative assessment. Performance was more sensitive to the manipulations of each experiment given the prospective administration of the qualitative assessment. An important aspect of the study concerned how the MPT model fitted the data. Given the conditions of each experiment, the MPT model did not provide suitable support for the observed behavioral results. While the model is supported in some instances, it does not appear to generalize to the current design. Greater attention should be paid to these issues of attention and memory, and their contributions to PM, as well as the use of this MPT model in the evaluation of PM task performance.

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FOOTNOTE

[1] The original method and procedure of Experiment 2 only included the background color manipulation for the context, and required participants to perform 100 trials of the ongoing task with PM cues presented on trials 51 and 91 as in Experiment 1. This resulted in ceiling effects for PM performance. Thus, changes were made to this experiment resulting in the currently reported version.

APPENDIX A

QUESTIONNAIRE FOR EXPERIMENTS 1 AND 2

Question 1

Do you remember what set of words you are/were expected to make a special response to while judging whether words represent natural or manufactured objects? (Yes or No)

Question 2

Do you remember what key you are/were suppose to press for the special response to those words? (Yes or No)

Question 3

How good is your memory? (1 to 7 scale; 1 = very bad, 7 = very good)

Question 4

How good is your ability to remember to complete intended actions, such as making a scheduled phone call or showing up for a meeting with your professor? (1 to 7 scale; 1 = very bad, 7 = very good)

Question 5

How good is your ability to attend to everyday tasks, such as driving a car or paying attention to details of a story you are reading? (1 to 7 scale; 1 = very bad, 7 = very good)

Question 6

Given the details of this experiment, and being required to make a special response to **PM cues** while having to judge whether words represent natural or manufactured objects, how much importance will/did you place on making the special response to the **PM cues**? (1 to 7 scale; 1 = very little, 7 = very much)

Question 7

How much importance will/did you place on making your judgments to words representing natural or manufactured objects? (1 to 7 scale; 1 = very little, 7 = very much)

Question 8

How difficult do/did you think it will be/was to make the special response to **PM cues**? (1 to 7 scale; 1 = very difficult, 7 = not difficult at all)

Question 9

How difficult do/did you think it will be/was to make judgments as to whether words represent natural or manufactured objects? (1 to 7 scale; 1 = very difficult, 7 = not difficult at all)

Question 10

How likely is it that you will be/were able to make the special response to the **PM cues**? (1 to 7 scale; 1 = not very likely, 7 = very likely)

Question 11

Overall, how difficult do/did you think it will be/was to make the special response to the **PM cues** while at the same time having to judge whether words represent natural or manufactured objects? (1 to 7 scale; 1 = very difficult, 7 = not difficult at all)

Note: "PM cues" in bold were replaced with either the category (Experiment 1) or specific words (Experiment 2) with which participants were instructed to make their PM response.

APPENDIX B

ONGOING TASK INSTRUCTIONS

For this experiment, you will be required to perform something called a ‘category judgment task’. For this task, you will be presented with a series of words that represent either objects that are found in the natural environment or objects that are manufactured by human beings. Examples of some words that will represent natural objects are *forest, tulip, tree, rain,* etc. Examples of some words that will represent manufactured objects are *refrigerator, hat, painting, necklace,* etc. The words that will be presented will clearly represent objects that can be classified to either the ‘natural’ category or the ‘manufactured’ category. We are not trying to trick you. Please make your responses by pressing the key labeled *N* when deciding whether a word represents a natural object or press the key labeled *M* when deciding whether a word represented a manufactured object. Please make your responses as quickly and as accurately as possible. After you make your judgment press the *SPACE* bar to continue to the next trial. You will now be given a couple of practice trials to ensure your understanding of the task. You will be provided feedback as to the accuracy of your judgments.

APPENDIX C

RESPONSE FREQUENCIES FOR EXPERIMENT 1

	Response Type		
Item Type	Y (NAT)	N (MAN)	PM
PM cue, Natural	p_{11}	p_{12}	p_{13}
PM cue, Manufactured	p_{21}	p_{22}	p_{23}
nonPM cue, Natural	p_{31}	p_{32}	p_{33}
nonPM cue, Manufactured	p_{41}	p_{42}	p_{43}

Note: Each cell represents response frequencies from all participants.

$M_1 = M_2 = M$, $g = .02$, $c = .50$

$$P = p_{33} / g + (p_{13} - p_{33})$$

$$M = (p_{13} - p_{33}) / P$$

$$C_1 = 1 - \{ p_{12} / [(1 - c) (1 - p_{13})] \}$$

$$C_2 = 1 - \{ p_{41} / [c (1 - p_{33})] \}$$

Experiment 1a task-appropriate processing

Item Type	Response Type Y (NAT)	N (MAN)	PM
PM cue, Natural	19	3	14
PM cue, Manufactured	3	18	15
nonPM cue, Natural	1675	109	0
nonPM cue, Manufactured	40	1747	0

Experiment 1a task-inappropriate processing

Item Type	Response Type Y (NAT)	N (MAN)	PM
PM cue, Natural	10	1	16
PM cue, Manufactured	1	13	13
nonPM cue, Natural	1268	66	5
nonPM cue, Manufactured	43	1289	0

Experiment 1b task-appropriate processing

Item Type	Response Type		
	Y (NAT)	N (MAN)	PM
PM cue, Natural	14	2	11
PM cue, Manufactured	1	15	12
nonPM cue, Natural	1361	74	0
nonPM cue, Manufactured	38	1400	0

Experiment 1b task-inappropriate processing

Item Type	Response Type		
	Y (NAT)	N (MAN)	PM
PM cue, Natural	8	0	19
PM cue, Manufactured	2	7	18
nonPM cue, Natural	1273	57	1
nonPM cue, Manufactured	36	1293	3

APPENDIX D

RESPONSE FREQUENCIES FOR EXPERIMENT 2

Experiment 2a context-match

Item Type	Response Type Y (NAT)	 N (MAN)	 PM
PM cue, Natural	4	0	20
PM cue, Manufactured	1	4	19
nonPM cue, Natural	1681	96	0
nonPM cue, Manufactured	39	1743	2

Experiment 2a context-mismatch

Item Type	Response Type Y (NAT)	 N (MAN)	 PM
PM cue, Natural	7	1	22
PM cue, Manufactured	2	6	22
nonPM cue, Natural	2096	136	0
nonPM cue, Manufactured	51	2172	1

Experiment 2b context-match

Item Type	Response Type		
	Y (NAT)	N (MAN)	PM
PM cue, Natural	1	0	30
PM cue, Manufactured	0	4	27
nonPM cue, Natural	2180	113	1
nonPM cue, Manufactured	38	2260	1

Experiment 2b context-mismatch

Item Type	Response Type		
	Y (NAT)	N (MAN)	PM
PM cue, Natural	5	2	19
PM cue, Manufactured	1	6	19
nonPM cue, Natural	1845	86	1
nonPM cue, Manufactured	30	1900	0

VITA

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