Journal of Experimental Psychology:
Learning, Memory, and Cognition
2005, Vol. 31, No. 1, 68–75

0278-7393/05/$12.00 DOI: 10.1037/0278-7393.31.1.68

On the Relationship Between Effort Toward an Ongoing Task and Cue Detection in Event-Based Prospective Memory

Richard L. Marsh
University of Georgia

Jason L. Hicks
Louisiana State University

Gabriel I. Cook
University of Georgia

In recent theories of event-based prospective memory, researchers have debated what degree of resources are necessary to identify a cue as related to a previously established intention. In order to simulate natural variations in attention, the authors manipulated effort toward an ongoing cognitive task in which intention-related cues were embedded in 3 experiments. High effort toward the ongoing task resulted in decreased prospective memory only when the cognitive processing required to identify the cue was similar to the cognitive processing required to complete the ongoing activity. When the required processing was different for the 2 tasks, cue detection was not affected by manipulated effort, despite there being an overall cost to decision latencies in the ongoing tasks from possessing the intention. Resource allocation policies and factors that affect them are proposed to account for ongoing vs. prospective memory task performance.

When an activity cannot be carried out immediately, people must establish an intention in memory to perform it at a later time. Such memories are labeled prospective memories to denote their forward-looking nature and to distinguish them from retrospective memories for events that transpired in one's personal past. One class of intentions that has received a great deal of scrutiny is event-based prospective memory. Such intentions are characterized by a cue in the environment triggering remembering to perform the intended action. For example, a key placed in the middle of a stove may serve as a good reminder to return it to the friend from whom it was borrowed. Recent issues in this literature have concerned specifying those conditions in which significant attentional capacity is (or is not) required to notice the cue as relevant to an intention. The present study bears directly on these issues, and more specifically, simulates in the laboratory one factor that may mediate event-based prospective memory in the real world. We begin by introducing the theoretical intuitions that led us to conduct this study, and then address how the present inquiry informs the more general issues surrounding the attentional requirements of event-based cue detection.

In laboratory-based analogues of event-based prospective memory tasks, cues are embedded in an ongoing activity, and participants who detect them must make some overt action in place of the ongoing task response (or in addition to it). Examples of ongoing activities include performing lexical decisions, rating sensibleness of sentences, naming famous faces, performing various word rating tasks, or engaging in reading comprehension (e.g., Einstein, McDaniel, Smith, & Shaw, 1998; Ellis, Kvavilashvili, & Milne, 1999; Maylor, 1996; McDaniel, Robinson-Riegler, & Einstein, 1998). Intentions have included knocking on the table, pressing a key on a keyboard, circling an item number, marking an *X*, and so forth. The ongoing task simulates real-world engagement in an activity at the time at which a cue appears in the environment. When the importance of the ongoing task is emphasized, participants are likely to perform more poorly on the prospective memory task (e.g., Kliegel, Martin, McDaniel, & Einstein, 2001, 2004). It is not surprising that when more emphasis is placed on the prospective memory task, the reverse is true. It is presumable that a sort of dual-task tradeoff exists between the effort and attention placed on the ongoing versus prospective tasks (cf. Marsh & Hicks, 1998).

Our intuition was that attention and effort may naturally wax and wane over an ongoing task in much the same way in which attention varies over the course of any task with a significant duration to it (Parasuraman, 1998). Therefore, cue detection may be mediated by the attentional allocation policy in force at the time at which a cue occurs in the environment (cf. Marsh, Hicks, Cook, Hansen, & Pallos, 2003; West, Krompinger, & Bowry, in press). If relatively more effort is being devoted to the ongoing task, then fewer resources may be available to detect a cue that occurs at that time. By contrast, when attention or effort has waned away from the ongoing task, a cue may be detected more readily, because more resources are available. Of course, in a limiting case, when attention is withdrawn almost entirely from the entire task set, both the ongoing task and prospective memory will suffer, thereby

Richard L. Marsh and Gabriel I. Cook, Department of Psychology, University of Georgia; Jason L. Hicks, Department of Psychology, Louisiana State University.

We thank James Crownover, Esther Pae, Robert Pelfrey, and Austin Cope for their valuable assistance in collecting the data.

Correspondence concerning this article should be addressed to Richard L. Marsh, Department of Psychology, University of Georgia, Athens, GA 30602-3013. E-mail: rlmarsh@uga.edu

making the opposite predictions conceivable under some circumstances. But nevertheless, we predicted that natural changes in attentional allocation policies can be simulated in the laboratory, and that these changes in policy may govern, in part, event-based cue detection. To study these changes, we manipulated effort toward the ongoing activity by signaling each trial as requiring high, medium, or low effort toward the ongoing activity. If attentional allocation policies affect cue detection, high effort toward the ongoing task may result in worse cue detection as compared with when only low effort is exerted. However, this reciprocal relationship may only hold if the ongoing and prospective tasks compete for limited resources. When this competition would occur may be predicted by task-appropriate processing, as we discuss next.

According to Maylor's (1996, 1998) task-appropriate processing ideas, ongoing activities that focus participants on the relevant features of a cue will improve cue detection, whereas processing that does not focus attention on those features will result in worse cue detection (see also Marsh, Hicks, & Hancock, 2000). To be more specific, if participants hold a semantic intention (e.g., to detect cues denoting animals), and the ongoing task is semantic (e.g., a lexical decision task), cue detection should be better as compared with holding an orthographic intention (e.g., to detect palindromes). All past studies demonstrating task-appropriate processing have been conducted under full attention when participants were responding at a leisurely pace. Therefore, we predicted that we would find task-appropriate processing on low-effort trials. On high-effort trials, when the attention usurped by the ongoing task is useful to cue detection, performance should decline. However, when the attention is not useful, as would be the case with task-inappropriate processing, decreasing the amount of attention available for cue detection should not reduce cue detection at all. For example, in a semantic ongoing task, high-effort trials should decrease the detection of semantic event-based cues (animals), but detection of orthographic cues (palindromes) should not suffer. We predicted that only when the processing resources usurped by high effort toward the ongoing task are functionally helpful to detecting cues would there be an effect on cue detection.

Beyond the primary purpose of simulating the waxing and waning of attention and effort that may occur more naturally, testing these ideas may have consequential ramifications for why task-appropriate processing occurs in this literature, as well as for the multiprocess view of prospective memory (McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004). If the outcomes are as predicted, then those results would strongly suggest that task-appropriate processing is a consequence of having enough attentional resources to detect the cue when the ongoing activity focuses attention on the relevant features of the cue. In other words, the task-appropriate processing effect actually requires sufficient resources to emerge. In the multiprocess view, automatic cue detection can occur, because the ongoing task focuses attention on the relevant features of the cue. However, if our analysis is correct, then the multiprocess view will have to accommodate the idea that task-appropriate processing is not necessarily a factor that leads to automatic cue detection. Of course, the foregoing analysis need not be correct. One straightforward alternative prediction is that detecting cues when the ongoing processing does not focus attention on the relevant features of the cue (i.e., task-inappropriate processing) will actually require more attentional resources. In this case, manipulated effort will have an even more deleterious effect on cue detection under conditions of task-inappropriate processing.

Besides manipulated importance of the two tasks (Kliegel et al., 2004; Smith & Bayen, 2004), there are a number of findings in the event-based prospective memory literature that converge on our predictions about attention and cue detection. First, dividing attention with an additional task beyond the ongoing and prospective tasks can detrimentally affect cue detection, suggesting that cue detection can require some optimum level of centrally mediated resources (Marsh & Hicks, 1998). Second, ongoing tasks that inherently absorb central executive resources (in the absence of divided attention) also can reduce event-based prospective memory (Marsh, Hancock, & Hicks, 2002). Third, populations that have compromised resources, such as older adults and those with neuropsychological disorders, can have deficits in event-based prospective memory (e.g., Burgess, Quayle, & Frith, 2001; Cherry & LeCompte, 1999; Elvevag, Maylor, & Gilbert, 2003; Maylor, 1996, 1998). Consequently, there is ample support for the idea that event-based prospective memory can require resources. However, there has never been a within-subjects manipulation of attentional allocation to assess event-based cue detection, and therefore, these previous studies do not address the issue that cue detection can vary over the course of an ongoing task as a function of shifting attentional allocation policies.

The outcomes of the present study also bear on issues concerning whether cue detection requires attention more generally. McDaniel et al. (2004) have argued in their multiprocess theory that cue detection may require resources in some circumstances but may be automatic in other circumstances (also see McDaniel & Einstein, 2000). To be more specific, prospective memory will require little or no resource capacity when the ongoing task focuses attention on relevant features of the cue, when the cue is salient, and when a strong association exists between the cue and the action to be performed. By contrast, Smith (2003) has argued in her preparatory attention and memory (PAM) theory that event-based prospective memory always requires attentional capacity. Using the conditions for automatic cue detection specified by McDaniel et al., Smith found that possessing an intention slowed lexical decision latencies (the ongoing task) as compared with having no intention at all (see also Smith & Bayen, 2004). Therefore, possessing an intention appears to have absorbed resources that otherwise would have made lexical decisions faster, and this outcome is consistent with the resource tradeoff interpretation discussed earlier.

Although Smith (2003) labeled the slowing of latencies a monitoring effect, we prefer the term *task interference*, because monitoring connotes an active, strategic process of searching for intention-related cues, and most participants we have interviewed do not report adopting this approach (cf. Einstein & McDaniel, 1996; Kvavilashvili & Mandler, 2004). In the following experiments, participants were asked to form the intention to make an extra keypress when they detected exemplars from a particular category (e.g., animals or palindromes; Ellis & Milne, 1996; Marsh et al., 2000). Three cues appeared on high-effort trials, and three occurred on low-effort trials that manipulated how attentive participants should be toward making the ongoing task judgment (which were lexical decisions in Experiments 1 and 3). As mentioned earlier, we predicted that when the ongoing and prospective memory tasks competed for a similar pool of resources, which should be the case on high-effort trials, then cue detection would suffer as compared with low-effort trials, when competition for resources would be less. In other words, cue detection may only suffer when the intention and the ongoing task are both, say, semantic in nature and compete for the same pool of resources.

Experiment 1

We tested three conditions in which we manipulated high, medium, and low effort toward the ongoing activity. One condition held a semantic intention, another held an orthographic intention, and the third was not given any intention at all. Three trials of high effort were followed by three trials of medium effort, which were followed by three trials of low effort, and so forth. As such, attentional allocation policies simulated a sinusoidal-type variation of effort toward the ongoing task. Cues occurred on either high- or low-effort trials, and we tested the no-intention control condition to evaluate whether task interference would be obtained with this particular within-subjects manipulation of attention. If task interference were obtained, reaction times to the lexical decision task would be slower when participants had an intention compared with when they did not (Marsh et al., 2003; Smith, 2003).

Method

Participants. Undergraduates from the University of Georgia volunteered in exchange for partial credit toward a course requirement. Each participant was tested individually in sessions that lasted approximately 25 min. Participants were quasi-randomly assigned to the three experimental conditions, which included a no-intention control condition, the intention to respond to animal words, and the intention to respond to words that were palindromes. Thirty volunteers were supposed to be tested in each condition, but accidentally, 2 extra people were tested in the palindrome condition. All participants were native English speakers in this and subsequent experiments.

Materials and procedure. The parameters of the ongoing lexical decision task were similar to those we have used successfully on previous occasions (e.g., Marsh et al., 2003; Marsh, Hicks, & Watson, 2002). There were 210 trials, with equal numbers of valid English words and pronounceable nonwords. We chose the 105 valid words from the Kučera and Francis (1967) normative compendium. We created the nonwords by changing one or two letters in 105 different words (e.g., *plour*). We chose 6 animal words and 6 palindrome words (e.g., *civic*) as cues and, these were randomly assigned anew for each participant to the 6 trials in which cues occurred. Because the intention was a between-subjects variable, a given participant experienced either the animals or the palindromes, not both. We obtained the palindromes from a compendium compiled by Chism (1992).

We manipulated effort by instructing participants that when they heard a series of three rapid, high-pitched beeps initiating a trial, they should try and make their lexical decision as quickly and accurately as they could by allocating as much effort as they could muster. These were high-effort trials. By contrast, when they heard a single, longer, low-pitched tone, they were told to respond more deliberately and with a more relaxed pace. Medium-effort trials were described as exerting effort and attention that fell somewhere in between the high- and low-effort trials, and these trials were signaled by two medium-pitched beeps. Each trial began with a fixation point and the signal tone(s), a delay of 600 ms ensued to allow participants to adopt the appropriate mindset for that type of trial, and then the letter string replaced the fixation point. The letter string remained on the screen until a word or nonword response was made using the home keys, and then a 1,750-ms intertrial interval occurred, during which the screen was blank.

As mentioned earlier, effort was blocked in a sinusoidal-type fashion in which triplets of trials were rotated through the sequence of high, medium, low, medium, high, medium, and so on for a total of 70 blocks. Cues occurred on trials numbered 26, 68, 98, 128, 170, and 200, which always corresponded to the middle trial in a triplet of a particular three-trial effort block. Three of these event-based cues occurred on high-effort trials, and three occurred on low-effort trials (and these appeared in an alternating pattern). Consistent with our previous work, participants in the animal-intention condition were instructed that if they encountered an animal word (*monkey* was given as a nontested example), then they should make their ongoing task response (press the word key) first and then press the / key. Participants in the palindrome-intention condition received otherwise identical instructions but were asked to respond to palindromes. For this condition, we also explained that palindromes are words that are spelled the same way both forward and backward. Participants read all of the instructions from the computer monitor and then listened to the experimenter reiterate them. After any questions were answered, participants engaged in a puzzle task for 5 min as a distracting activity before the lexical decision task was commenced without any reiteration of the prospective memory task.

Results and Discussion

Unless otherwise stated, the probability of a Type I error does not exceed 5% in any of the statistical analyses. In analyzing reaction times to the lexical decision task, we excluded incorrect trials (percentages are given in Table 1) and latencies exceeding 2.5 standard deviations from a participant's grand mean (averaging 0.8%). Event-based prospective memory was counted as correct if the / key was pressed on the trial in which the cue word appeared. Late responses in which the key was pressed on the following trial were too infrequent to change the pattern of results (cf. Marsh et al., 2003). The data are summarized in the top portion of Table 1. In the first six data columns, we report reaction times and accuracy (respectively) to words occurring on low-, medium-, and high-effort trials in order to capture how participants were approaching the ongoing task and the manipulation of effort. None of these latencies include trials on which a prospective memory cue appeared (for such an analysis, see Marsh et al., 2003; Marsh, Hicks, et al., 2002). The last two columns represent the average percentage of event-based cues that were detected on low- and high-effort trials.

For latencies to the ongoing task, we conducted a 3 (condition) × 3 (effort) mixed-model analysis of variance (ANOVA). Participants in all three conditions increased their speed from the low- to the medium- to the high-effort trials, $F(2, 178) = 53.99$, $MSE = 3876.43$. In addition, the two conditions that were given an intention displayed slower latencies relative to the no-intention control condition, indicating significant task interference, $F(2, 89) = 18.66$, $MSE = 42882.06$. That effect has been reported previously (Smith, 2003; Smith & Bayen, 2004). There was no statistical Condition × Effort interaction. Task interference was quite robust when holding the intention to respond to palindromes (averaging about 175 ms) but was somewhat smaller for the animal intention (about 70 ms). Although caution must be exercised when accuracy is so close to ceiling performance, we believe that there is little evidence of a speed–accuracy tradeoff within the ongoing task, insofar as accuracy was only a percentage or two lower as more effort was placed on the lexical decision task, $F(2, 178) < 1$, $MSE = 14.05$, *ns*. In addition, accuracy did not differ as a function

Table 1
Average Reaction Times (in ms) and Accuracy (in Percentages) to the Ongoing Task and Prospective Memory Performance (in Percentages) for Experiments 1–3

	Ongoing Task							
	Reaction times			Accuracy			Prospective memory	
Experiment and condition	Low	Medium	High	Low	Medium	High	Low	High
Experiment 1								
No intention	635	595	545	97	97	96		
Animal intention	700	662	631	96	95	95	58	43
Palindrome intention	832	789	705	97	97	96	33	36
Experiment 2								
No intention	635	578	529	97	98	96		
Animal intention	771	702	624	98	96	98	65	67
Palindrome intention	781	702	598	97	98	97	84	69
Experiment 3								
Animal intention	712	673	627	98	97	96	68	49
Palindrome intention	819	752	684	97	96	95	46	42

of condition, and there was no statistical interaction. These results facilitate interpretation of the cue detection results considered next.

We analyzed cue detection with a 2 (intention: animal vs. palindrome) × 2 (effort: low vs. high) ANOVA, which indicated a significant two-way interaction, $F(1, 60) = 4.15$, $MSE = 574.87$. Event-based prospective memory on the low-effort trials was better in the animal condition (58%) than it was in the palindrome condition (33%), $t(60) = 2.89$. Therefore, a task-appropriate processing effect was found in which the semantic orientation of processing in the lexical decision task benefited detection of animal cues relative to the palindrome cues. Moreover, high effort toward the ongoing task had a deleterious effect on the detection of animal cues, $t(29) = 2.21$, but it did not significantly affect the detection of palindrome cues, $t(31) < 1$. To restate this outcome in a different way, the significant difference in prospective memory that was present on low-effort trials was greatly attenuated and not statistically different on high-effort trials (43% vs. 36%), $t(60) < 1$, *ns*.

Consequently, these results indicate that resources usurped by manipulated effort toward the ongoing task mediate prospective memory performance but appear to do so only when those resources are functionally useful to cue detection processes. In the present case, semantic processing in the lexical decision task appears to share resources with cue detection of animals but not with similar processes used to detect palindromes that have unique orthography. In addition, greater task interference in the palindrome condition relative to the no-intention control condition resulted in worse cue detection; this highlights a dissociation between overall task interference and actual cue detection (Marsh et al., 2003, made this same point). In other words, slower latencies compared with a no-intention control do not always ensure better prospective memory. One potential concern with this argument might be that cue detection is fairly low in the palindrome condition even on low-effort trials. Although this is true, performance most certainly was not on a functional floor, because we have obtained cue detection results that are even worse than those obtained here with palindromes (Hicks, Marsh, & Russell, 2000). However, we conducted Experiment 3 to conceptually replicate the current results and thereby assuage any concerns in this regard.

We believe that there may be two consequential implications of the results from this experiment. First, task interference has been depicted previously as an attentional allocation policy away from the ongoing task that benefits prospective memory (Marsh et al., 2003; Smith, 2003). Although this may true, beyond some optimum level of centrally mediated resources indicated by task interference, cue detection benefits from the availability of some specific processing resources as well. Thus, a model like Smith's PAM account, which specifies a single type of preparatory attention, may need to be revised slightly to account for more than one type of resource allocation and, perhaps, even more than one type of resource itself. Second, in the multiprocess view, task-appropriate processing is characterized as leading to relatively automatic cue detection. The results from this experiment, to the contrary, suggest that the benefit of an ongoing process that focuses attention on the relevant features of the cue occurs because capacity consuming processing is being used. When that capacity is reallocated toward high effort on the ongoing task, cue detection suffers. In this sense, the multiprocess view may need to clarify those conditions that lead to automatic versus nonautomatic detection of event-based cues.

On the whole, the outcomes from this experiment strongly suggest that the simulated waxing and waning of effort in performing the ongoing activity can affect event-based cue detection, and such variation is likely to operate in real-world settings (Parasuraman, 1998). In those latter cases, cues or reminders about a previously established intention may go undetected when much of one's attention is directed to performing well on an ongoing cognitive task. A task-interference effect from holding an intention was also obtained. We believe that task interference from holding an intention represents a general cost that is established by attentional allocation policies directed at the entire task set of performing both the ongoing and prospective memory tasks. By contrast, the manipulation of effort may not be a general cost but, rather, a momentary expenditure of resources that participants allocate to making their judgment more quickly but no less accurately. Although both factors may mediate cue detection, this experiment provides evidence that transient allocations of attention can certainly affect cue detection.

Experiment 2

We believed that it was necessary to conceptually replicate the results of Experiment 1 using a different ongoing task. In Experiment 2, cues were embedded in an ongoing task that was orthographic in nature. To be more specific, participants saw only words and were asked to make yes–no decisions about whether double contiguous letters were present (e.g., *book* vs. *block*). The predictions for Experiment 2 were essentially the same as they were for Experiment 1, except that fulfilling the palindrome intention should now suffer when high effort is devoted to the ongoing task, and fulfilling the animal intention should be relatively unaffected by the effort manipulation. High effort toward an orthographic task should usurp resources that otherwise would be useful in detecting the orthographic cues, but those same resources may not be functionally useful in detecting the semantic cues.

Method

Participants. Ninety-three University of Georgia undergraduates volunteered in exchange for partial credit toward a course research requirement. Each participant was tested individually in sessions that lasted approximately 30 min. Thirty-one participants were assigned quasi-randomly to each of the three conditions, which included a no-intention control, an animal-intention, and a palindrome-intention condition. No participant had been tested in Experiment 1.

Materials and procedure. The software was revised to present 210 words randomly. Half of these words had two contiguous letters that were the same (e.g., *speech*), and half did not (e.g., *march*). Participants were asked to make a yes–no decision about the presence of repeated contiguous letters by pressing one of the two home keys. Effort was manipulated in all three conditions in a manner identical to that of Experiment 1. The 6 animal or 6 palindrome words replaced the words on the designated trials, 3 of which were high-effort trials, and 3 of which were low-effort trials. After reading all instructions from the computer monitor, the experimenter reiterated them, answered any questions, and engaged the participant in a 5-min distractor activity (a puzzle task). The contiguous-letter task was commenced without any mention of the intention. The no-intention control condition did not receive any information about either animals or palindromes.

Results and Discussion

Trimming eliminated 0.7% of the data. The results are summarized in the middle of Table 1. As expected, there was a task-interference effect from holding either intention as manifested in slower ongoing task latencies in those two conditions as compared with the no-intention control condition. Task interference was approximately 150 ms in both conditions. In the 3 (condition) × 3 (effort) mixed-model ANOVA, a significant effect of condition was obtained, $F(2, 90) = 14.44$, $MSE = 28695.60$, as well as a significant effect of effort, $F(2, 180) = 169.94$, $MSE = 2885.75$, but no interaction was present. As with the lexical decision task used in Experiment 1, more effort devoted to the contiguous-letter judgments increased the speed of responding. Also similar to Experiment 1, there was no evidence of a speed–accuracy tradeoff in this experiment insofar as accuracy was a function of neither effort nor assigned condition (both $F\text{s} < 1$). But again we note that this conclusion may not generalize to tasks that yield performance in a different range of the response scale. Moreover, the presence or absence of such a tradeoff is not central to this investigation.

A task-appropriate processing effect was obtained for event-based cue detection in this experiment on low-effort trials, but this time it favored the palindrome intention. The 2 (intention: palindrome vs. animal) × 2 (effort: low vs. high) ANOVA on cue detection yielded a significant two-way interaction, $F(1, 60) = 5.69$, $MSE = 403.23$. When participants were engaged in the orthographic task of finding contiguous double letters under low effort, they detected more palindrome cues (84%) than they did animal cues (65%), $t(60) = 2.19$. In addition, high effort reduced detection of palindrome cues (69%), $t(30) = 2.72$, but it did not affect detection of animals cues (67%), $t(30) < 1$, *ns*. These outcomes resulted in no task-appropriate processing effect on high-effort trials, $t(60) < 1$, *ns*. As described earlier, high effort toward the ongoing task usurped resources that could have been used to detect the palindrome cues. Deployment of those same resources toward the letter judgment task did not reduce detection of the animal cues, indicating that those resources were not functionally useful to prospective memory processes when holding a semantic intention.

If one examines performance across Experiments 1 and 2, a three-way interaction on cue detection should be found. Namely, detecting animal cues should be affected by effort toward the lexical decision task but not by effort toward the contiguous-letter task, and detecting palindrome cues should be affected by effort toward the contiguous-letter task and not toward lexical decision. Indeed, when all of the data are analyzed in this fashion, the three-way interaction is present, $F(1, 120) = 9.58$, $MSE = 489.05$. Thus, this analysis provides strong support for the idea that task-appropriate processing requires resources to emerge. One potential fly in the ointment is that detecting animal cues should have been worse in this experiment than it was in Experiment 1 for low-effort trials, but it was not. Detection was slightly higher in this experiment. We cannot unambiguously pinpoint why this occurred, but it probably represents a difference in the two ongoing tasks. In Morris, Bransford, and Frank's (1977) original demonstration of transfer-appropriate processing, they found a similar asymmetry. With a phonetic recognition test sequence, phonetic study produced better memory than semantic study. With a semantic recognition test, the reverse was true, but the phonetic study condition resulted in better memory for the semantic test than the phonetic test condition. Results such as this tend to make us believe that the task-appropriate processing conditions being studied here are best made within a given type of ongoing activity rather than across different ongoing tasks. Moreover, cross-experimental comparisons can be very tricky to interpret, so we note that this does not replicate the task-appropriate processing effect that has been demonstrated within a given experiment (e.g., Marsh et al., 2000).

Experiment 3

In this last experiment, we briefly address a concern about performance in Experiment 1 that we raised earlier and that was raised in the review process. That concern is that performance in the palindrome condition was quite low. However, in that experiment, all of the stimuli were presented in uppercase letters. With an orthographic intention, the stimulus materials may have worked against finding words that were spelled the same way backward and forward. In Experiment 3, the ascenders and descenders of lowercase letters should facilitate finding the palindrome cues. We reasoned that replicating the two intention conditions from Experiment 1 with more distinctive stimuli would raise cue detection performance. If manipulated effort does not affect detection of palindrome cues in a lexical decision task, we should replicate the cue detection results of Experiment 1 in a different range of the response scale.

Method

Participants. University of Georgia undergraduates volunteered in exchange for partial credit toward a course research requirement. Each participant was tested individually in sessions that lasted approximately 25 min. Participants were assigned either to the animal-intention ($N = 34$) or the palindrome condition ($N = 35$).

Materials and procedure. This experiment was identical to Experiment 1 in all of its essential properties, save two. First, the stimulus materials were all lowercase letters. Second, we did not replicate the no-intention control group, because task interference has been demonstrated numerous times already, both in the literature and again in Experiments 1 and 2.

Results and Discussion

The data are summarized at the bottom of Table 1. Trimming eliminated 0.6% of the data. As in Experiments 1 and 2, reaction time decreased as more effort was exerted in making a response to the ongoing activity, $F(2, 134) = 23.40$, $MSE = 8876.58$. Notice that overall reaction times were similar to those obtained in Experiment 1. However, unlike the previous two experiments, in Experiment 3, increased effort toward the ongoing activity did significantly reduce accuracy of the lexical decision judgment, $F(2, 134) = 8.13$, $MSE = 12.09$. Thus, we cannot claim, even at these very high rates of accuracy, that there was no evidence of a speed–accuracy tradeoff. Nevertheless, the critical data concern cue detection, which was analyzed with a 2 (intention: palindrome vs. animal) × 2 (effort: low vs. high) ANOVA, which yielded a significant two-way interaction, $F(1, 67) = 3.99$, $MSE = 436.72$, $p = .05$. The overall detection of palindrome cues was 9% higher in this experiment than it was in Experiment 1. Thus, we were moderately successful at raising performance. Even having done so, the detection of animal cues suffered under high as compared with low effort, $t(33) = 3.96$, whereas there was no statistical difference in palindrome detection as a function of effort, $t(34) < 1.0$. We believe that these data replicate the pattern of effects found in Experiment 1 and support the general principle that task-appropriate processing requires resources to be observed. We now consider more generally what the results from this study indicate about resource allocation issues and successfully completing event-based intentions.

General Discussion

The empirical results from this study can be summarized as follows. Manipulated effort and attention toward the ongoing task was manifested by participants speeding their responses. This increased effort resulted in significantly worse event-based cue detection when the cognitive analysis required for the ongoing task was also required for detecting that the cue was relevant to a previously established intention. To be more specific, increased effort in semantic analysis of a letter string reduced detection of semantic cues but not orthographic ones, and high effort in analyzing a word orthographically reduced detection of orthographic prospective memory cues but not semantic ones. In addition, as highlighted by the results of Experiments 1 and 2, task interference was manifested by participants slowing their decisions in the ongoing task when holding an intention as compared with no-intention control conditions. In this regard, the effort manipulation introduced in this article appears to be somewhat independent from the task-interference effects that have been reported previously (Marsh et al., 2003; Smith, 2003). The challenge before us was to outline several factors that influence attentional allocation policies and how those factors would affect event-based prospective cue detection.

We believe that task interference arises from attentional allocation policies that participants set at the outset of the entire task set. For example, participants may decide how demanding finding the cues will be in the ongoing activity. Of course, they may adjust this policy as they gain practice with the task. Other factors, such as divided attention and goal neglect, may also affect this initial allocation policy. Marsh and Hicks (1998) divided attention using a third task that was unrelated to the ongoing activity and the prospective memory task. When the divided-attention task was demanding, presumably of central executive resources, performance on both the ongoing and prospective memory tasks suffered. When the task used to divide attention was less demanding, performance on both the ongoing and prospective memory tasks was better. We have replicated these results in an unpublished study using a lexical decision task and found that a third, demanding task slows decision latencies relative to a less demanding one. Cue detection also suffered with the more demanding divided-attention task. Therefore, the overall slowing of decision latencies can reflect metacognitive strategies about how to approach a task set, but it does not guarantee that cues will be better detected. In this sense, a dissociation exists in which slowing of overall latencies can be associated with better or worse cue detection. Whether better or worse cue detection is obtained depends on how attentional resources are deployed and whether those resources are useful to cue detection. This relationship should hold in other studies using divided attention in an event-based prospective memory task (e.g., Einstein et al., 1998; Einstein, Smith, McDaniel, & Shaw, 1997).

Another attentional factor affecting cue detection is goal neglect, which has been reported as momentary lapses of intention (MLIs) by West and Craik (1999; also see Duncan, Emslie, Williams, Johnson, & Freer, 1996). MLIs occur when attention is directed away from the entire ongoing task and the prospective memory task embedded within it (i.e., the entire task set). In these cases, people may be thinking about transient thoughts such as their children, where they have to be later in the day, a daydream, or more generally, any stimulus-independent thoughts (SITs) that detract attention away from the entire task set (Teasdale, 1989; Teasdale et al., 1995). The argument about SITs is particularly appropriate here insofar as Teasdale et al. claim that SITs require central executive resources in much the same way that Marsh and Hicks (1998) claimed that only divided-attention tasks that tap central executive resources reduce both event-based prospective memory and ongoing task performance. Therefore, the argument is that the positive relationship between effort and cue detection is determined by an initial allocation of attention (effort) toward the entire task set, and variables that might change that allocation over time include attention toward an external task or thoughts unrelated to the ongoing task. We have made this argument before, albeit in a weaker form (Marsh, Hancock, et al., 2002).

Once an overall attentional allocation policy has been made, a negative relationship between cue detection and effort toward the ongoing task can be found if (and only if) cue detection requires the same shared resources necessary to perform well on the ongoing task. In these cases, cue detection will be influenced by manipulated or more natural variations in attention across time in performing a task. Thus, task-appropriate processing occurs when there are sufficient resources that are not devoted to the ongoing task to allow cue detection. Increased effort toward the ongoing task can decrease cue detection, because fewer resources are available to perform the prospective memory task.

The PAM model seems to predict that slowed decision latencies to an ongoing task are functionally useful to event-based prospective memory (Smith, 2003; Smith & Bayen, 2004). Our point is that evidence concerning decision latencies needs to be informed, or perhaps supplanted by, issues of how attention is deployed, because either faster or slower decision latencies can be associated with a decrease in cue detection. When general attention has lapsed away from the entire task set or has become focused on some external task or thought, then this slower, inattentive processing in the ongoing task will result in cues going undetected. By contrast, faster ongoing task latencies, such as those on the high-effort trials herein, represent more attention to performing that task, and if cue detection competes for the same resources, prospective memory can lose out. The variable relationship between reaction time and cue detection indicates that a single attentional factor, such as that specified in Smith's (2003) PAM model may be insufficient to describe adequately event-based prospective memory performance. That theory specifies that slower ongoing task latencies are associated with better cue detection, but as we have just described, the situation is more complicated. Nonetheless, the PAM model represents an extremely good start at tackling these issues.

The foregoing analysis highlights a point that we raised in the introduction to this article. Manipulations of the relative importance of fulfilling the intention versus performing well on the ongoing task can affect event-based cue detection (Kliegel et al., 2001, 2004), as can dividing attention with a sufficiently demanding task (Marsh & Hicks, 1998). However, they may do so for different reasons. Dividing attention with a third task may disrupt or reduce attention to the entire task set by reducing more centrally mediated resources to monitoring task performance. In this case, it is an experimental manipulation that simulates MLIs or goal neglect. By contrast, manipulating the relative importance of the ongoing versus the prospective memory task may represent a different kind of tradeoff of attention already allocated to the task set in much the same way that the manipulations of effort operated in the three experiments in this study. Therefore, both relative task importance and effort simulate more natural variables such as the waxing and waning of attention within a task set.

The findings from this study indicate that task-appropriate processing does not make cue detection automatic, as specified in McDaniel et al.'s (2004) multiprocess view, but rather that cue detection is relatively automatic under conditions of task-inappropriate processing when the ongoing task does not focus attention on the relevant features of the cue. In McDaniel et al.'s experiments, divided attention did not reduce cue detection for conditions in which cue detection was claimed to be automatic. Perhaps a more stringent criterion for automatic cue detection would be attentional resources being usurped (as in their divided-attention condition) as well as high effort toward performing the ongoing task. One could easily conduct such an experiment by simultaneously manipulating task emphasis and divided attention (for a model to adapt, see Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). Neither divided attention nor high effort toward the ongoing task should reduce cue detection under conditions of task-inappropriate processing when event-based performance may be truly automatic.

This article and the experiments contained herein were not intended to provide a final analysis of the resource demands placed on the cognitive system by holding an intention and detecting an event-based prospective memory cue. Rather, they were intended to analyze cue detection under conditions that might simulate the natural waxing and waning of attentional allocation policies. In the process of doing so, we found a fairly constant task-interference effect with a categorical intention and an effect of manipulated effort on cue detection. Whether people allocate their attention in the manner speculated herein requires further empirical work, as does integrating the present work with other sorts of intentions that are more specific or have highly integrated cue and target action associations. Nonetheless, the present study has identified components of existing theories that will require some modifications as mainstream cognitive research on prospective memory enters its second decade.

References

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Psychologia, 29,* 545–555.

Cherry, K. E., & LeCompte, D. C. (1999). Age and individual differences influence prospective memory. *Psychology and Aging, 14,* 60–76.

Chism, S. J. (1992). *From A to zotamorf: The dictionary of palindromes*. Morristown, NJ: Word Ways Press.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General, 125,* 159–180.

Duncan, J., Emslie, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: The organization of goal-directed behavior. *Cognitive Psychology, 30,* 257–303.

Einstein, G. O., & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 115–142). Hillsdale, NJ: Erlbaum.

Einstein, G. O., McDaniel, M. A., Smith, R. E., & Shaw, P. (1998). Habitual prospective memory and aging: Remembering intentions and forgetting actions. *Psychological Science, 9,* 284–289.

Einstein, G. O., Smith, R. E., McDaniel, M. A., & Shaw, P. (1997). Aging and prospective memory: The influence of increased task demands at encoding and retrieval. *Psychology and Aging, 12,* 479–488.

Ellis, J., Kvavilashvili, L., & Milne, A. (1999). Experimental tests of prospective remembering: The influence of cue-event frequency on performance. *British Journal of Psychology, 90,* 9–23.

Ellis, J., & Milne, A. (1996). Retrieval cue specificity and the realization of delayed intentions. *Quarterly Journal of Experimental Psychology, 49,* 862–887.

Elvevag, B., Maylor, E. A., & Gilbert, A. L. (2003). Habitual prospective memory in schizophrenia. *BMC Psychiatry,* 3–9.

Hicks, J. L., Marsh, R. L., & Russell, E. J. (2000). The properties of retention intervals and their affect on retaining prospective memories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1160–1169.

Kliegel, M., Martin, M., McDaniel, M. A., & Einstein, G. O. (2001). Varying the importance of a prospective memory task: Differential effects across time- and event-based prospective memory. *Memory, 9,* 1–11.

Kliegel, M., Martin, M., McDaniel, M. A., & Einstein, G. O. (2004). Importance effects on performance in event-based prospective memory tasks. *Memory, 12,* 553–561.

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, R.I: Brown University Press.

Kvavilashvili, L., & Mandler, G. (2004). Out of one's mind: A study of involuntary semantic memories. *Cognitive Psychology, 48,* 47–94.

Marsh, R. L., Hancock, T. W., & Hicks, J. L. (2002). The demands of an ongoing activity influence the success of event-based prospective memory. *Psychonomic Bulletin & Review, 9,* 604–610.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 336–349.

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 861–870.

Marsh, R. L., Hicks, J. L., & Hancock, T. W. (2000). On the interaction of ongoing cognitive activity and the nature of an event-based intention. *Applied Cognitive Psychology, 14,* S29–S42.

Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 652–659.

Maylor, E. A. (1996). Age-related impairment in an event-based prospective memory task. *Psychology and Aging, 11,* 74–79.

Maylor, E. A. (1998). Changes in event-based prospective memory across the adulthood. *Aging, Neuropsychology, and Cognition, 5,* 107–128.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology, 14,* S127–S144.

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 605–614.

McDaniel, M. A., Robinson-Riegler, B., & Einstein, G. O. (1998). Prospective remembering: Perceptually driven or conceptually driven processes? *Memory & Cognition, 26,* 121–134.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16,* 519–533.

Parasuraman, R. (1998). *The attentive brain*. Cambridge, MA: MIT Press.

Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 347–361.

Smith, R. E., & Bayen, U. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 756–777.

Teasdale, J. D. (1989). Daydreaming, depression and distraction. *The Psychologist, 2,* 189–190.

Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I., & Baddeley, A. D. (1995). Stimulus-independent thought depends on central executive resources. *Memory & Cognition, 23,* 551–559.

West, R., & Craik, F. I. M. (1999). Age-related decline in prospective memory: The roles of cue accessibility and cue sensitivity. *Psychology and Aging, 14,* 264–272.

West, R. L., Krompinger, J., & Bowry, R. (in press). Disruptions of preparatory attention contribute to failures of prospective memory. *Psychonomic Bulletin & Review.*

Received December 15, 2003
Revision received June 7, 2004
Accepted June 18, 2004 ■