Interference to Ongoing Activities Covaries With the Characteristics of an Event-Based Intention

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Previous studies of event-based prospective memory have demonstrated that the character of an ongoing task can affect cue detection. By contrast, this study demonstrated that there is a reciprocal relationship insofar as cue-verification and response-retrieval processes interfered with making a response in the ongoing task. The amount of interference was determined by the type of intention, which was manipulated to affect the complexity of verification and retrospective response retrieval. These relationships were true even when the interference caused by cue detection was separated from a more general effect to ongoing-task performance caused by shifts in attentional allocation policies. The results have theoretical implications for models that attempt to specify the cognitive microstructure of event-based prospective memory.

People fulfill a variety of intentions in the course of everyday life. Some examples of different types of prospective-memory tasks include remembering to make a phone call after a certain duration has elapsed (a time-based task), performing an activity right after finishing a different one (an activity-based task), delivering a message to an acquaintance (an event-based task), attending a seminar on changes in health benefits (a novel task), taking vitamins or medication (a habitual intention), and so forth (Brandimonte, Einstein, & McDaniel, 1996). The particular cuing conditions associated with these different intentions vary along many dimensions, such as the amount of self-initiated processing that is required (e.g., Craik, 1986; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Ellis, 1996), how well established in memory the intention is (e.g., Einstein, McDaniel, Smith, & Shaw, 1998), and what social and motivational factors might affect pertinent cognitive processes such as self-remindings (e.g., Hicks, Marsh, & Russell, 2000; Kvavilashvili, 1998; Meacham & Leiman, 1982). Given this variability, most articles have investigated just one type of prospective memory (but for several notable exceptions, see Einstein & McDaniel, 1990; Kliegel, Martin, Mc-Daniel, & Einstein, 2001; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). We have adopted this strategy here by exploring how an ongoing cognitive activity interacts with the identification of different types of event-based prospective cues that are embedded within it.

In a typical event-based laboratory task, participants engage in an ongoing activity that is intended to approximate the demands of everyday life. For example, participants might rate the pleasantness of words, judge the sensibleness of sentences, or name famous faces in the ongoing task (e.g., Ellis, Kvavilashvili, & Milne, 1999; Maylor, 1996). When certain cues or a class of cue words appears (e.g., animal words or faces with beards), participants must make some overt response to indicate that they have remembered the intention. The independent variables that have affected cue detection include cue salience and typically, cue dominance within a category, prior exposure to the cues or the category, the context in which the cue is learned versus retrieved, and so forth (e.g., Einstein, Holland, McDaniel, & Guynn, 1992; Ellis & Milne, 1996; Mäntylä, 1993; McDaniel & Einstein, 1993; McDaniel, Robinson-Riegler, & Einstein, 1998).

To date, only several studies have examined how the ongoing activity and the nature of the intention interact. For example, if the cognitive processing required by the ongoing task highlights a relevant feature of the cues, then detection increases substantially (Darby & Maylor, 1998; Marsh, Hicks, & Hancock, 2000; Maylor, 1998). Several studies have explored whether demanding ongoing tasks can reduce available cognitive resources and concomitantly decrease event-based prospective memory (Einstein, Smith, Mc-Daniel, & Shaw, 1997; Kidder, Park, Hertzog, & Morrell, 1997; Marsh, Hancock, & Hicks, 2002; Marsh & Hicks, 1998). Conversely, Smith (2000, 2001) has shown that having an event-based intention significantly slowed processing in the ongoing task itself. In that work, having an event-based intention slowed overall reaction times in a lexical decision task as compared with having no concurrent intention at all. Thus, the demands of the ongoing task can influence event-based cue detection, and the presence versus absence of an intention can affect the speed with which an ongoing task is performed (cf. Burgess, Quayle, & Frith, 2001).

Building on this work, Marsh, Hicks, and Watson (2002) examined the reaction-time dynamics of the ongoing task at the exact time a prospective cue was encountered. We discovered that suc-

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cessful cue detection severely interfered with the ongoing activity by slowing response latencies as compared with trials when the prospective cue was either absent or overlooked. We reasoned that the observed slowing to the ongoing task from cue detection could be a confluence of several cognitive processes including (a) *recognition* of the cue as relevant to a previously established intention, (b) *verification* that the cue and its surrounding context meet all of the requirements for responding, (c) *retrieval* of the correct response action, and (d) *coordination* of executing both the prospective and ongoing-task responses. Together, the subprocesses of verification (b) and retrieval of the action (c) constitute the retrospective component of event-based memory, whereas recognition (a) is probably best defined as the prospective component.

Absent from our previous work was any direct empirical evidence for the separability of these hypothetical subcomponents. Therefore, the present goal was to examine systematically to what degree retrospective memory processes (i.e., Items b and c) affect cognitive processing of the ongoing task at the exact time a cue was successfully identified. To do so, we manipulated the number and type of prospective cues to examine the cue-verification processes. The relationship between the cues and the response action to be performed was also manipulated to examine the response retrieval processes. We hypothesized that a specific set of cues would require more time to verify if they were semantically unrelated to one another than if they were related. Likewise, we predicted that any given cue would require more verification time if it was part of a larger as compared with a smaller memory set of cues. Therefore, a specific cue (dog) was compared with a categorical cue (animals) in Experiment 1, and both semantic relatedness and memory-set size (four vs. eight cues) were orthogonally crossed in Experiment 2. If prospective memory processes obligatorily interrupt ongoing cognitive processes (e.g., Goschke & Kuhl, 1996; Kvavilashvili, 1998), then we hypothesized that these manipulations of verification processes would slow ongoing-task latencies to different degrees when cues were detected.

Whereas the manipulations in Experiments 1 and 2 were designed to affect verification processes, those in Experiments 3 and 4 were designed to affect retrieval processes associated with the response action. After learning pairs of words, participants were asked to say the second word (target) out loud when they encountered the first word (cue). The relatedness or association of the cue-target word pairs was varied under the rationale that such manipulations should place different retrieval demands on retrospective memory (cf. McDaniel & Einstein, 2000). Highly related cue-target pairings should result in faster retrieval of the target word or response, thereby interfering less with the ongoing task as compared with unrelated cue-target pairings. Together, these manipulations of verification and response retrieval processes examine the complexity of the retrospective content of an event-based intention. As a point of clarification, the prospective cues were generally held constant across the conditions within a particular experiment (except in Experiment 1, as discussed shortly), and therefore, recognition processes are assumed to be constant. In a similar vein, the prospective response was the same across conditions within any particular experiment (i.e., a keypress or a verbalization), thereby holding constant any coordination processes taking place between the prospective and the ongoing tasks. If these two assumptions are correct, then both recognition and

coordination subprocesses are militated against as viable explanations for any differences in reaction times to performing the ongoing task at the time a cue is detected. In this article, complexity refers only to changes in tasks and conditions that affect verification and response retrieval processes.

Theoretically, none of the manipulations performed in this study must necessarily affect the magnitude of interference to the ongoing task when a prospective cue is detected. After all, McDaniel and Einstein (2000) have recently advocated a multiprocess view in which event-based prospective memory is sometimes automatic and sometimes more resource demanding. Because this framework is new, it has been concerned primarily with predicting cue detection as opposed to the reaction-time interference effects that are being studied here. However, the results of the present study will help to inform what cognitive processes cause cue detection to be relatively resource demanding versus more automatically executed.

Unfortunately, different types of intentions specifically designed to affect verification and response retrieval processes might also affect the degree to which participants monitor for the cues (Smith, 2000, 2001). In this case, an overall attentional allocation policy toward or away from the ongoing task that is established at the outset could affect the overall speed at which participants decide to perform the ongoing lexical decision task. Because monitoring effects are not the focus of the present study, control-matched words (for frequency, word length, syllables, etc.) served as the baseline reaction times that were subtracted from the time to complete the ongoing task on trials in which the cue was identified (see Marsh, Hicks, & Watson, 2002). By subtracting reaction times to nonprospective words that are control matched to the prospective cues, any differences in latency to the ongoing task across conditions due to changes in monitoring will be eliminated. In other words, if intention complexity in two different conditions affects both interference and monitoring (and does so differently), eliminating the monitoring effect will isolate differences in the interference effect between those conditions. For this reason, this difference score will constitute the primary dependent variable in the experiments that follow.

Experiment 1

Three conditions were tested in this experiment. Participants in a control condition had no prospective memory task and merely performed the lexical decision task. The two remaining conditions each had an event-based intention. Participants in one condition were asked to respond to a single cue (i.e., the animal word dog), whereas those in the other condition were asked to respond to the category of animals. These conditions were chosen for two reasons. First, we believed that verifying that a prospective cue was a member of a category might interfere more with the ongoing task than verifying that it was the only cue that should receive a prospective response. With a categorical intention such as responding to animal cues, the semantic features of the cue must be mapped onto the semantic features of the intention, which we speculated might take more time and interfere more with the ongoing task than verification processes that involved a more direct one-to-one mapping of a specific cue learned at intention formation (cf. McDaniel & Einstein, 2000). Second, we sought to replicate Smith's (2000) monitoring effect because Brandimonte, Ferrante, Feresin, and Delbello (2001) were unable to obtain it, and further, manipulations of verification or response retrieval processes might affect monitoring, which is an influence that would need to be controlled. Control items in both prospective conditions should be slower than in the no-intention control condition if an overall monitoring effect is obtained. Otherwise, a null outcome in this regard would support Brandimonte et al.'s (2001) results. If monitoring exists and its magnitude is affected by the type of intention, then overall latencies were expected to be slower in the categorical condition as compared with the single-cue condition. Therefore, Experiment 1 will serve to demonstrate that the subtraction technique used throughout will remove any monitoring effects leaving a somewhat purer measure of interference to the ongoing task.

Method

Participants. Undergraduate students from the University of Georgia volunteered in exchange for partial credit toward a course research requirement. Each participant was tested individually in sessions that lasted approximately 25 min. Participants (N = 108) were randomly assigned to one of the three between-subjects conditions (with 36 in each).

Materials and procedure. The parameters of the ongoing lexical decision task were identical to those used by Marsh, Hicks, and Watson (2002). There were 210 trials, with equal numbers of valid English words and pronounceable nonwords. The 105 valid words were chosen from the Kučera and Francis (1967) normative compendium. Every time the software replaced a word in the ongoing task with a prospective cue, it also replaced another valid word with a control-matched word equated on word frequency, number of letters, and syllabic length to the cue. When there was an intention in any experiment in this article, eight prospective cues occurred every 25 trials at trials numbered 25, 50, 75, and so forth, through Trial Number 200. When there was not an intention, the same controlmatched words used in the prospective conditions were nonetheless inserted into the ongoing task so that the appropriate comparisons could be made. In the present experiment, participants in the single-cue condition experienced the prospective cue dog eight times (and its control-matched word buy eight times), whereas the categorical-intention condition encountered eight different words denoting animals and eight different controlmatched words.

At the beginning of the experiment, participants read instructions for the lexical decision task from the computer monitor. The directions explained to the participants that on each trial there would be a "waiting" message indicating that the space bar should be pressed with one of their thumbs to initiate a trial. For each letter string, the participants were instructed to respond as quickly but as accurately as they could by pressing one of two appropriately labeled keys to indicate whether the item was a word or nonword (the home keys were used, respectively). These directions were reiterated by the experimenter who indicated for the two prospective conditions that we were also interested in people's ability to remember to perform an action in the future. The prospective memory instructions clearly specified that the word response to the ongoing lexical decision task should be made first and that the "/" key should be pressed during the subsequent waiting message between trials whenever a cue was detected. These instructions were identical to those that we have used previously (Marsh, Hicks, & Watson, 2002). In the single-cue condition, participants were asked to respond to the cue *dog*, whereas in the category condition, they were asked to respond whenever a word denoting an animal was encountered (the example monkey was given in this condition, which did not ever appear as a prospective cue). When the experimenter was satisfied that participants understood all of the instructions, the computer monitor

was cleared and a 5-min puzzle distractor task was administered. After this short retention interval, the experimenter initiated the ongoing task without making any reference to the prospective memory task.

Results and Discussion

Unless specified otherwise, the probability of a Type I error is .05 throughout this article. Before reporting the critical results, we dispense first with several data-analytic issues that apply to all of the experiments. In almost all cases, prospective memory was generally quite high because specific cues were learned to criterion during intention formation. Consequently, neither the latencies for missed prospective cues nor their control-matched counterparts are reported because they were insufficient to analyze. Marsh, Hicks, and Watson (2002) found an intention-superiority effect on such failed trials, and the interested reader is directed to that earlier article for further details concerning this aspect of performance. In this article, attention is focused on the latencies to ongoing task performance for successfully identified cues and their controlmatched counterpart words. Averages for the latter have been calculated on a participant by participant basis to correspond only to those control words yoked to successfully identified cues. In Table 1, we have classified these control words under the heading of Prospective trials to highlight their yoked status. Finally, a number of trimming techniques were available for eliminating outlying responses (e.g., Marsh & Hicks, 1998; Ratcliff, 1993), but none affected the results in the present experiments. Consequently, only responses that were in error were eliminated, which constituted 3.1% of the ongoing-task trials and less than 0.3% of the prospective trials.

The data are summarized at the top of Table 1. The column labeled Prospective memory summarizes the average proportion of the eight cues that were detected. By this traditional measure, performance was better in the single-cue condition as compared with the category condition, t(70) = 3.16, SEM = 0.05. This aspect of performance is not terribly surprising (e.g., Einstein et al., 1995). As it relates to reaction times for the ongoing task, Table 1 reports five different latency measures. There are three average latencies under the heading Prospective trials corresponding to trials containing detected cues (Success), their controlmatched words that had no intentionality (Control), and the difference score between them. Under the heading Other trials are the average latencies to the remaining words and nonwords in the lexical decision task. For these other nonprospective trials, reaction times were slower to classify the nonwords as compared with the words, t(107) = 12.27, SEM = 11.90. This standard outcome demonstrates that participants were performing the ongoing task as expected. Consequently, this aspect of performance will not be considered in later experiments.

Differences in the allocation of attention between the ongoing and prospective tasks (i.e., monitoring) can be evaluated by analyzing latencies either to control-matched words or to the other neutral words contained in the lexical-decision task. The former will be used because they were specifically included for this reason. Nevertheless, the reader may want to scan down both of these columns of data and note that in this experiment (and those

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Table 1

Experiment and condition	Prospective memory	Prospective trials		Other trials		
		Success	Control	Difference	Words	Nonwords
Experiment 1						
Control			679		665	856
Single cue	.93	888	687	201	688	814
Animal category	.78	916	767	149	752	872
Experiment 2						
4 animals	.91	1025	723	303	718	820
8 animals	.90	1081	767	314	764	886
4 unrelated	.85	1171	737	435	759	853
8 unrelated	.81	1280	848	433	838	872
Experiment 3						
Control			636		631	784
Cues only	.91	1330	884	446	860	918
Cue-target pairs						
Unrelated cues	.84	2305	951	1354	933	942
Related cues	.83	2253	845	1408	847	946
Experiment 4						
Say "now"	.94	1239	817	422	813	856
Say first associate	.92	1890	871	1019	863	892
Cue-target pairs						
Associated	.88	1613	881	733	879	890
Unassociated	.68	2747	884	1863	869	880

Average Prospective Memory Performance and Average Latency (in ms) to Respond to the Ongoing Task as a Function of Trial Type in Experiments 1-4

Note. Difference = success - control. Dashes indicate that data are not available by design.

that follow) both classes of items tell the identical story.¹ Ongoingtask latencies to the control-matched items replicated Smith (2000, 2001) insofar as differences among the three conditions existed, F(2, 105) = 8.99, MSE = 9,533.91. Having a categorical intention slowed overall processing in the ongoing task as compared with having no intention in the control condition, t(70) = 3.52, SEM = 25.15. As Smith argued (2000), this outcome suggests that having an intention can divert attentional resources away from performing the ongoing task. But, having an intention about a single prospective cue did not result in any overall slowing as compared with having no intention at all, t(70) < 1.0, *ns*. This outcome replicated Brandimonte et al. (2001) who also used specific prospective cues (albeit two of them) and found no generalized slowing effect in an ongoing lexical decision task as compared with a no-intention control condition.

Given the conflicting results, all that can be determined at this juncture is that participants in the two different prospective conditions established different attentional allocation policies between the ongoing and prospective tasks. Note, however, that increased monitoring in favor of the prospective task (i.e., slowing of the ongoing task) in the category condition resulted in worse eventbased cue detection as compared with the single-cue condition in which less monitoring was evident. Therefore, a policy of allocating attention away from the ongoing task does not guarantee success at the prospective memory task. More generally, these data suggest strongly that amount of monitoring may be uncorrelated with cue detection. At present, the exact variables affecting monitoring are unknown. However, that point only reinforces our position that the monitoring effect needs to be eliminated when comparing latencies with the ongoing task across different conditions, as discussed next.

The success-minus-control difference score eliminates the significant increase in monitoring that was present in the categorical condition. By this measure, interference to the ongoing task caused by detected cues was the same in the two prospective conditions, t(70) = 1.25, p > .10. We had predicted that verifying a cue was a member of a category would interfere more (i.e., take more time) than verifying it was the only cue that should receive a response. One possibility is that the nominally greater interference effect with the single cue is real, but we simply did not have sufficient power to detect it. Perhaps episodic retrieval of specific cues stored at intention formation interferes more with ongoing cognitive processing than does category classification. After all, simultaneous episodic retrieval appears to be difficult, if not impossible (e.g., Rohrer & Pashler, 2002). Nevertheless, the critical outcome of this experiment was that the amount of interference to the ongoing task that was caused by verifying cues was the same in both the single-cue and category conditions.

¹ All other factors being equal, the reader might assume that nonword latencies would show some evidence of monitoring just like the words in a lexical decision task. One problem in making this prediction is that nonword (negative) decisions in a lexical-decision task may be a function of extra cognitive processes using extralexical information (e.g., Grainger & Jacobs, 1996). These extralexical processes are a function of task demands, speed–accuracy tradeoffs, metacognitive variables, and a host of other factors that we did not attempt to control in this study. Although interesting predictions can be made about the appearance or absence of monitoring effects on nonwords, we will not be considering this issue further because our main interest in this article is in controlling for monitoring differences rather than studying characteristics of this process.

In summary, the results from this experiment highlight two dissociations. First, an attention allocation policy of increased monitoring does not necessarily result in better cue detection because event-based performance was worse in the category condition as compared with the single-cue condition. Second, interference to the ongoing task from cue detection was the same in both event-based conditions; and therefore, the monitoring effect and the interference effect appear to be independent of one another. If there was some natural relationship such as monitoring that was caused by rehearsing the intention in working memory, then less interference should have been observed in the condition with more monitoring, but this did not occur. Theoretically, monitoring may be the consequence of a metacognitive strategy established at the outset of the ongoing task, whereas interference may be a function of the four subcomponent processes of recognition, verification, response retrieval, and coordination. The results of both of these dissociations together highlight the importance of using the difference score measure when attempting to examine the microstructure of event-based prospective memory.²

Experiment 2

In this next experiment, cue-set size was manipulated by having participants learn to criterion either four or eight specific prospective cues. That variable was crossed orthogonally with whether the cues were semantically related (i.e., all animal cues). We hypothesized that either cue-set size or relatedness could affect monitoring, but more important, our critical prediction was that each variable could affect the verification processes that determine whether an environmental cue warrants a prospective response.

Theoretically, cue-set size and cue relatedness were chosen because Homa (1973; see also Juola, Fischler, Wood, & Atkinson, 1971) found that speed of recognition-memory performance was a function of both category membership on a learned list and the number of exemplars in the learned category. Slower latencies were observed with members from larger categories, and rejection of category lures was especially slow. Extrapolating from these results, we predicted the verification associated with a cue-set size of eight rather than four items to interfere more with the ongoing task. By the same token, verifying a specific cue from a set of unrelated items was predicted to interfere more than verifying it from a semantically related set. Because only a keypress response was required for the prospective cues, verification processes are the only ones of the four potential subcomponent processes that could be affected by these manipulations if any differences are found.

Method

provided in a sheet protector, and participants were allowed to study them until they believed that they had them memorized. After removing the list, the experimenter verbally provided the first letter of each cue (which was unique), and the participant had to produce all cues successfully. If recall was not perfect, learning cycled through the same study-test procedure until it was perfect. The identical procedure was followed with the two unrelated cues conditions. A very important feature of the design was that the related and unrelated cues were chosen to have closely (if not identically) matched word frequencies, numbers of syllables, and so forth. In this regard, the two sets of cues were identical. Subsequent to cue learning, the experimenter explained the prospective memory task and provided a distractor activity before commencing the ongoing task. The distractor activity was included to prevent the prospective task from becoming a vigilance task.

In the eight set-size conditions, each cue was experienced once in the ongoing lexical-decision task. In the four set-size conditions, each cue was experienced twice. In these latter conditions, the four cues were chosen to be as comparable as possible with the larger set of eight cues. The relevant control-matched words (which were identical in the related and unrelated conditions) were inserted either once or twice into the ongoing task as was appropriate to the cue set size condition being tested. Therefore, with the exception of learning the cues to criterion, this experiment was identical in all other procedural respects to Experiment 1.

Results and Discussion

We conducted a series of 2 (cue set size) \times 2 (semantic relatedness) fixed factor analysis of variance (ANOVA) models. The data are summarized in Table 1. The proportion of cues detected was quite high, with more semantically related cues identified than unrelated cues, F(1, 140) = 9.78, MSE = 0.02. However, there was neither a main effect of cue set size nor an interaction. Latency on the control-matched items should indicate whether the type of intention affected the attentional allocation policies between the ongoing and prospective tasks (i.e., monitoring). There was an effect of cue-set size, F(1, 140) = 15.92, MSE = 13,679.73, and an effect of cue relatedness, F(1, 140) = 5.89, both of which were obviously a result of much longer latencies in the eight unrelated cues condition as compared with the remaining three conditions. The interaction between cue-set size and cue relatedness was marginal, F(1, 140) = 2.93, p = .09. These impressions were verified by simple contrasts that declared the eight unrelated cues condition different from each of the other three conditions, smallest t(70) = 2.65, but no differences among these three, largest t(70) = 1.67, p > .10. These results suggest

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 four experimental conditions created by crossing cue-set size (four vs. eight) with semantic relatedness of the cues. Volunteers were tested in each condition (n = 36; N = 144).

Materials and procedure. All participants encountered eight specific cues in the ongoing task. In the two related (animal) conditions, participants either learned four or eight cues to criterion. A list of the cues was

² We have anticipated that some readers may be concerned about two points. First, there is the possibility of repetition priming in the single-cue condition that is not present in the category condition. Recall that latencies to control-matched words were virtually identical to other words, and had these nonrepeated words been used as the baseline, the same outcomes would have been observed. In addition, the subsequent experiments are not subject to the same concern. Second, the difference score advocated here is an absolute metric that accounts for overall attentional allocation policies across different event-based conditions. A relative metric such as the latency difference score divided by control latency could lead to different conclusions. However, the simplifying assumption has been made that intention retrieval and its interference on the ongoing task are independent of variables that affect attention allocation policies. Although this assumption may eventually be proven to be incorrect, at this juncture there is neither strong theory nor empirical evidence to contravene it.

that cue-set size has the potential to affect the allocation of attention away from an ongoing task but only with unrelated cues as opposed to the related ones.

The success-minus-control difference score clearly shows more interference to the ongoing task from the unrelated cues as compared with the related cues, F(1, 140) = 9.84, MSE = 57,436.29, with neither an effect of cue-set size nor interaction. These results strongly suggest that numbers of specific cues do not affect verification processes. By contrast, cues that are semantically related to one another are verified faster and interfere less with the ongoing task as compared with unrelated cues. We are not sure why set size of the cues did not affect the magnitude of the interference effect, but the interference effects in this experiment were substantially larger than in the previous one. The difference between verifying one single cue in the previous experiment versus verifying one among several cues in this experiment may pertain to the amount of information that can be kept active in working memory while also performing the ongoing task. Nonetheless, semantic relatedness did matter. The facilitation of verifying one among several related cues as opposed to one among several unrelated cues may be caused by categorical priming in which the category of animals is already activated above baseline.

It is noteworthy that our manipulation of four versus eight unrelated cues changed attentional allocation policies in terms of eliciting a difference in monitoring, whereas the same set-size manipulation with related cues did not. Smith (2000, 2001) demonstrated a monitoring effect both with one and six unrelated cues. In Experiment 1, one specific animal cue did not increase monitoring relative to a no-intention control condition, whereas an animal categorical intention did. Once again, these cross-report discrepancies highlight that the interference that results from cognitive processes occurring at the time a cue is encountered is distinct from attentional allocations that can shift between the prospective and ongoing tasks.

Experiment 3

In the previous two experiments, differences in interference to the ongoing task were investigated as a function of variables believed to involve cue-verification processes. According to our analysis, another form of interference to the ongoing task could arise from retrieving the target response. This aspect of eventbased retrieval was investigated in the next experiment by having participants learn cue-target word pairs (e.g., hit-junk). When they encountered the cue (hit), they were asked to say the target word aloud (iunk). Two different conditions of cue-target pairs were tested: one in which the cues were all unrelated to one another, and one in which the cues were all semantically related to one another. The cues and their corresponding targets to be spoken aloud were unrelated in both of these cue-target pairs conditions. These two conditions were compared with another in which the identical cue words from the unrelated pairs conditions were learned, but the prospective response was to say the cue word aloud (hit). Interference to the ongoing task in this cues-only condition was expected to be comparable in magnitude with that observed in Experiment 2. By contrast, having to retrieve the appropriate target word response in the two cue-target pairs conditions was predicted to have a much greater interference effect as compared with the cues-only condition.

A no-intention control condition was also tested again. If Experiments 1 and 2 are replicated, both a monitoring effect and an interference effect should be observed in comparing the control condition with the cues-only condition. The former effect is a consequence of attentional allocation policies, and the latter effect is a consequence of cue verification and response retrieval processes. We had no a priori prediction of whether greater monitoring would be observed in the cue-target conditions as compared with the cues-only condition. Such changes in attentional allocation policies might depend on whether participants perceived the difficulty of the prospective task as different in the cues-only versus pairs conditions. The two different cue-target conditions that manipulated semantic relatedness of the cues were tested to ascertain whether relatedness among items in the cue set that affected verification processes in Experiment 2 would still exert an interference effect in the presence of having to retrieve a target response.

In summary, the four conditions tested were as follows. The control condition had no event-based prospective memory task. The cues-only condition learned eight specific cue words to be spoken aloud. Both cue–target pairs conditions learned eight word pairs, and participants should have spoken the target response word aloud when the cue word was encountered. The two cue–target conditions differed only in whether the cue words were semantically related to one another.

Method

Participants. University of Georgia undergraduates (N = 100) volunteered in exchange for partial credit toward a course research requirement. Each participant was tested individually in sessions that lasted approximately 30 min. Participants were assigned quasi-randomly to each of the four conditions (n = 25).

Materials and procedure. Participants in the control, cues-only, and unrelated cue-target pairs conditions all learned the same eight cue words: *hit, nice, barn, cutlet, fault, pastor, axe,* and *trunk.* In the unrelated cue-target pairs condition, these cues were paired with eight target responses: *junk, stereo, letter, picture, day, movie, ring,* and *bolt.* All of the words or pairs were learned to criterion by testing and retesting using the first letter of the cue (and target as appropriate) method described previously. In the related cue-target pairs conditions, all of the cues were replaced with animal words, but the target response words were identical to the unrelated cue-target pairs condition. The eight cues used in both cue-target conditions were identical to the eight cues used in Experiment 2 that had been equated previously on all of the important variables affecting lexical decisions and, potentially, event-based performance.

When the experimenter was confident that participants understood that they should say the appropriate responses aloud after making their word judgment in the ongoing lexical-decision task, a 5-min distractor activity was administered to prevent the prospective task from becoming a vigilance task. Because prospective responses were spoken aloud, the experimenter had a computer attached to the participants that indicated when a prospective cue occurred. The experimenter recorded successes and failures so that the appropriate data files could be subsequently updated.

Results and Discussion

Overall prospective memory was quite good, and differences were present among the three conditions that had an intention, F(2,

72) = 3.31, MSE = 0.02. Responding was numerically less frequent in the two cue-target pairs conditions as compared with the cues-only condition, but all three pairwise post hoc tests failed to reach statistical significance. Regarding response latencies, a oneway ANOVA model on the control words to assess monitoring effects declared that differences existed among the four conditions, F(3, 96) = 12.77, MSE = 36,238.53. Simple effects analyses indicated that latencies to the ongoing task were fastest in the control condition as compared with the three prospective-memory conditions, all three ts (48) had associated p values less than .01. Among the three prospective memory conditions, the related cuetarget pairs condition was nominally faster than the unrelated cue-target pairs condition (by over 100 ms) for these neutral items, but this simple difference was only marginally significant, t(48) = 1.59. That monitoring effect conceptually replicated the monitoring effect in Experiment 2 inasmuch as the condition with eight unrelated cues caused a more general slowing in the ongoing task as compared with related cues. Thus, the semantic relatedness variable affects attentional allocation policies similarly across the two experiments.

The success-minus-control interference score in the cues-only condition was comparable in magnitude with the eight unrelated cues condition in Experiment 2. This outcome is reassuring insofar as the only feature that was different between the two experiments was the prospective response: a keypress in Experiment 2 and saying the cue aloud in this experiment. However, the interference effect with a single consistent response was dwarfed by the interference effect caused by having to retrieve a unique target response, omnibus test among the three prospective conditions, F(2, 72) = 9.78, MSE = 747,220.01. Undeniably, the interference effect of recalling the appropriate unique response was approximately four times the size of the interference effect from issuing a more routine target response. Nevertheless, the interference effect to the ongoing task was identical in the two cue–target conditions that differed in semantic relatedness of the cues, t(48) = 1.0, ns.

Two points are noteworthy from this experiment. First, the interference effect related to retrieving a novel target response is so large that it must be an additive effect as compared with the routinized responses tested in the cues-only condition and those conditions tested in Experiments 1 and 2. Second, the unrelated cue–target pairs condition that produced the nominally greatest monitoring effect neither had different cue-detection rates nor exhibited different overall interference because of detection as compared with the related cue–target pairs condition. Thus, as argued earlier, changes in the allocation of attention between the ongoing and prospective tasks probably does not predict event-based success nor the interference to the ongoing task when a cue is detected.

Experiment 4

The interference effects demonstrated in Experiments 1–3 were not necessarily preordained because participants were specifically requested to make their ongoing task response prior to the prospective memory response, and the latter should have been made during the waiting interval before the next trial was initiated. Consequently, both verification and response-retrieval processes could have taken place after the ongoing task response was made. This observation suggests that some subcomponents of eventbased prospective memory may be automatic and obligatory. In this next experiment, we investigated the response retrieval processes in more detail. On the basis of the multiprocess view, target responses that are strongly associated to a cue should be automatically delivered to consciousness (McDaniel & Einstein, 2000). By extension, such strongly associated cue–target pairs should interfere less with ongoing task performance if their retrieval is faster or "more obligatory" as compared with cue–target pairs that lack an association such as those used in Experiment 3.

This prediction was tested in an associated-pairs condition in which the cue-target pairs were all pat phrases (e.g., dog-food, *photo-album*, etc.). When participants encountered the cue (*dog*), they should have responded aloud by saying the target (food); and thus, these pairs had a strong forward association from the cue to the target response. In an unassociated pairs condition, all of the prospective cues were identical, but they were re-paired with the target responses from the other pat phrases (e.g., *dog-album*). These two critical conditions were tested along with two control conditions. In the first, participants merely had to say "now" when cues (e.g., photo) were encountered. This condition should produce interference effects to the ongoing task comparable with saying the cue aloud or pressing a key, because only a single target response needed to be retrieved throughout the experimental sequence (cf. Experiments 1 and 2). In the second control condition, participants responded aloud with their first associate to each cue. We had no a priori prediction of whether retrieving a first associate would interfere more or less than recalling the response term from a well-known pat phrase, but we predicted it would interfere less than retrieving novel responses as tested in the unassociated pairs condition.

Method

Participants. University of Georgia undergraduates volunteered in exchange for partial credit toward a course research requirement. Participants (N = 136) were tested individually in sessions that lasted approximately 30 min. Initially, 34 volunteers were haphazardly assigned to each of the four between-subjects conditions (i.e., say "now," say first associate, associated cue–target pairs, unassociated cue–target pairs). One participant from the say "now" condition was excluded from the analyses on the basis of language fluency criteria.

Materials and procedure. Participants in the two control conditions (say "now" and say the first associate) learned eight specific cues to criterion (i.e., *dog, prison, phone, photo, orange, window, candy,* and *dollar*). We used a recall criterion for learning in this experiment because the first letter of each cue was not unique. In the associated and unassociated cue–target pairs conditions, participants learned eight word pairs (the target responses were *food, term, call, album, juice, sill, wrapper,* and *bill*). The cue and target responses all formed pat phrases for the associated cue–target pairs condition. Learning in these two critical conditions was by cued recall in response to the entire cue word (e.g., *dollar*–). The reader should note that the eight prospective cue words were identical in all four conditions.

Results and Discussion

Overall event-based prospective memory in the say "now" and first-associate control conditions was high and equivalent to one another, t(65) < 1.0, *ns*. However, performance was better in the associated cue–target condition than in the unassociated cue–target condition, t(66) = 4.39, *SEM* = 0.04. That outcome supports the multiprocess view insofar as McDaniel and Einstein (2000) reported an unpublished experiment in which participants more often remembered to respond "sauce" to the cue *spaghetti* than to respond "steeple." Therefore, the present results provide some strong support for the multiprocess view, because when the cue and target are highly associated, the intention to respond appears to be retrieved more obligatorily than when they are not.

Complementing these overall cue-detection results are the response latencies to the ongoing task. The success-minus-control interference score was not equivalent among the four conditions, F(3, 131) = 27.99, MSE = 462,017.30. Interference in the say "now" control condition was comparable with the previous experiments, but interference was greater to retrieve one's first associate than to say "now" in this experiment, t(65) = 5.37, SEM = 111.31. The relative difference in interference probably represents the response being learned at intention encoding in the say "now" condition and then being repeatedly retrieved as compared with no specific response being learned originally in the first-associate condition and therefore requiring unique retrieval to each cue. For the two critical cue-target-pairs conditions, less interference was observed with a strongly associated cue-response pair than a newly learned one, t(66) = 5.52, SEM = 204.75. In fact, the interference in the unassociated cue-target pairs condition was more than double that in the associated cue-target condition.

Although all four conditions required response retrieval of some sort, the first associate condition produced slowing that was middling between the associated and unassociated cue-target pairs conditions, F(2, 99) = 20.24, MSE = 580,510.73. That outcome suggests relatively automatic retrieval of highly associated responses that were primed at intention formation (photo-album) as compared with more effortful retrieval associated with idiosyncratic responses (e.g., photo-picture) that were not primed and had to be generated online at the time a cue occurred. By contrast, episodic retrieval of a truly novel association learned earlier (e.g., photo-sill) appears to be the slowest and most effortful. Faster retrieval and less interference from the associated cue-target pairs as compared with the first associate condition may suggest that intention formation constrains the possible response options (e.g., *dog-food* rather than *dog-bone*, *dog-collar*, etc.). This possibility could have interesting real-world implications. For example, success at any given intention when multiple possible intentions exist related to a single cue (e.g., "deliver messages to a colleague") may be facilitated when episodic retrieval can disambiguate among semantically related responses that might otherwise come to mind (e.g., colleague-meeting, colleague-report, etc.). To our knowledge, competitor responses to a cue have not been studied in event-based prospective memory, but the results of this experiment suggest that this could be an interesting avenue of inquiry.

General Discussion

To date, most studies of event-based prospective memory have investigated properties of the cues, the context, or different populations of individuals as a means of identifying variables that mediate cue detection. Undeniably, this approach has been fruitful. In the present article, however, a slightly different tack was taken in which variables predicted to affect response latency to the ongoing task were examined as opposed to accuracy of cue detection. In all four of the experiments, dissociations were discovered between cue detection and the amount of interference that detection caused to the ongoing task. For example, cue detection was much better in the single-cue condition in Experiment 1 as compared with the categorical condition, but the amount of interference to ongoing processing was statistically equivalent. Similarly, unrelated cues in Experiment 2 produced more interference as compared with related cues, but cue detection was significantly worse for unrelated cues. In both Experiments 3 and 4, cue detection was generally good, but target response retrieval severely interfered with the ongoing task and especially so when the cuetarget relationship was novel and an association was lacking. Had only cue detection been assessed, only relatively meager conclusions could have been drawn from this study.

Instead, we have replicated Smith's (2000, 2001) finding that event-based intentions can change people's attentional allocation policies insofar as they proceed through the ongoing task at relatively faster or slower paces. Presumably, slower paces are indicative of caution or care that would be associated with greater monitoring to identify prospective cues. However, one could imagine that the opposite relationship could also hold. Very demanding portions of an ongoing task that require more attention than other portions may have very slow response latencies and relatively poor event-based cue detection. Therefore, slower overall response latencies may be indicative of greater levels of attentional monitoring, but the relationship between overall latencies and cue detection is neither intuitively obvious nor preordained.

Nevertheless, the results of Experiments 1 and 3 clearly suggest that the amount of monitoring associated with possessing a particular event-based intention has to be removed from the equation to assess properly potential cognitive subprocesses that may be occurring when a cue is detected. Beyond the practical ramifications of eliminating the monitoring effect, the theoretical implication here is that changes in attentional allocation policies also represent a form of response strategy or criterion shift. As in other areas of human-memory research, isolating this component to performance is often important. However, removing differences in overall attentional allocations to study the microstructure of interference effects neither minimizes the importance of monitoring effects nor militates against studying such effects in their own right. For example, intriguing questions concerning such policy changes are whether they are executed more strategically (i.e., consciously) or more automatically and whether they are established at the outset or can change over the course of the ongoing task. Neither Smith's (2000, 2001) previous work nor the present experiments were designed to answer such questions.

At a general level, no interference effect would have been observed if some event-based prospective memory processes did not obligatorily interfere with ongoing task processing. As stated previously, the cues should have received a word response in the lexical decision task before the prospective response was executed. Therefore, all aspects of event-based tasks do not appear to be automatic or "attention free," as might be inferred from an analysis of cue-identification accuracy alone (e.g., McDaniel & Einstein, 2000). Consequently, by exploring the nuances of these interference effects, one can obtain a better understanding of the various cognitive processes that subserve successful event-based prospective memory. Several of these component processes that could be responsible for the observed slowing to ongoing-task performance include cue recognition, verification that the cue is correct in the present context, retrieval of the appropriate response, and coordination of the ongoing response and prospective responses. The manipulations used in this study examined differences in interference as a consequence of verification and response retrieval processes.

We make no claim concerning whether these stages proceed partially in parallel or must be performed more serially. After all, nothing close to a psychological refractory period analysis of component task performance was performed (e.g., Pashler, 1998). Nonetheless, part of the interference effect appears to be associated with cue verification. The unrelated specific prospective cues used in Experiments 2-4 all produced an approximate 430-ms interference to the ongoing task, whereas cues that were related to one another in Experiment 2 resulted in about 115 ms less interference. In standard recognition memory tasks, semantically related cues are retrieved (or identified) more quickly than unrelated items (Homa, 1973; Juola et al., 1971). From that work cue-set size was predicted to have a similar impact on interference, but when it was manipulated as four versus eight cues in Experiment 2, a null outcome was obtained. As speculated earlier, perhaps cue-set size was not large enough, or perhaps criterion learning vitiated any observable differences in the interference effect.

One way to pursue investigations of verification processes would be to manipulate categorical intentions where the preexisting size of categories is large versus small (e.g., Nelson, McEvoy, & Bajo, 1984). Verifying that an item is a member of a small category (e.g., rodents) may interfere less with the ongoing task than verification with a larger category (e.g., buildings or animals). An alternative to category size might be the density of the interconnections among category items as specified in an associative network work model such as PIER 2 (e.g., McEvoy, Nelson, & Komatsu, 1999). Of course, reductions in interference from verification processes include those manipulations already designed to facilitate cue identification such as presenting a colored cue against a monochromatic background or a capitalized cue word against a background of lowercase words (e.g., Einstein, Mc-Daniel, Manzi, Cochran, & Baker, 2000). Although not all cueidentification processes must necessarily cause severe interference to the ongoing task, none have been found yet that are interference free.

Another component process to event-based memory is retrieving the target response. Response items that were novel and had no preexisting association to the cue caused severe interference to ongoing processing in Experiment 3 as compared with those that were highly associated in Experiment 4. Further research may wish to explore whether a graded interference effect could be obtained using forward associates from the cue to target response of various strengths. For example, the cue *draft* produces the response "beer" quite strongly, "army" less so, and "wind" even less so (Nelson, McEvoy, & Schreiber, 1998). These target responses might interfere in a graded manner with the ongoing task if priming from initial criterion learning did not corrupt their natural, relative association values.

In terms of everyday cognitive processing, cue-target associations and response-retrieval processes may dictate how intrusive habitual versus novel intentions are to current tasks. For example, the sight of a pill bottle to someone who takes medication regularly might interfere less with current trains of thought than the identical cue to someone who only needs to take medication infrequently. In a similar vein, one direct implication of the present results is that a momentary delay in processing information in the ongoing task could result from successful cue detection. Under normal circumstances, this effect may not result in any problem whatsoever. In other cases, it could result in small mistakes and blemishes in ongoing-task performance. Perhaps information following the cue will be inadequately attended and processed less efficiently. If that information is needed later as it might, say, in pilot navigation, more serious errors could result. In still other cases, a cue may only serve as a reminder that an intention has gone unfulfilled and the conditions remain incorrect or suboptimal for responding. In these cases a more lingering presence in working memory or extended cognitive processing could take place that has an even more deleterious effect to ongoing task performance than being able to respond immediately as in the present experiments. Therefore, extensions of the present results could have important implications for everyday cognitive performance.

In conclusion, fully understanding event-based prospective memory will require understanding the reciprocal relationship between cue-based intentions and the ongoing task in which they occur. Only recently have investigations been undertaken to determine (a) how characteristics of the ongoing task affect cue detection accuracy and (b) whether the characteristics of an intention (e.g., complexity) affect responding to the ongoing task itself in terms of latency. Clearly, the present study falls into this latter category, albeit at the level of a particular response as opposed to overall differences in response latency. However, even more sophisticated paradigms need to be developed that can assess both accuracy and latency differences. Serendipitously, the associated and unassociated pairs conditions in Experiment 4 resulted in both a detection difference and a latency difference. In that case, lower detection rates were associated with more interference. Of course, the relationship between detection and interference could be very different in other circumstances. Codifying the nature of the relationship between cue detection and its effect on concurrent tasks would seem to be an important interim step in understanding this type of prospective memory task.

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Received August 13, 2002 Revision received February 9, 2003 Accepted March 25, 2003