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The Dynamics of Intention Retrieval and Coordination of Action in Event-Based Prospective Memory

Richard L. Marsh
University of Georgia

Jason L. Hicks
Louisiana State University

Valerie Watson
University of Georgia

Event-based prospective memory requires responding to cues in the environment that are associated with a previously established intention. Some researchers believe that intentions reside in memory with an above baseline level of activation, a phenomenon called the intention superiority effect. The authors of this study predicted that intention superiority would be masked by additional cognitive processes associated with successful event-based prospective memory. These additional processes include noticing the cue, retrieving the intention, and coordinating intention execution with the ongoing activity. In 3 experiments, intention superiority was demonstrated by faster latencies to the ongoing activity on failed prospective trials and the existence of the additional processes was demonstrated by slower latencies on successful trials. This study demonstrates the importance of investigating the microstructure of the cognitive components involved with processing and responding to an event-based prospective memory cue.

In the course of everyday life people often encounter cues in their environment that cause them to recollect events that occurred in the past. For example, a sheaf of papers collected at a conference may evoke memories of a recent trip, or the sight of a particular pen may cause us to remember the party at which it was received as a gift. Cues such as these engage retrospective memory processes for experiences that were recorded in the past. However, environmental cues can also serve effectively to remind us of intentions that we want to fulfill in the future. The sheaf of papers could also remind us of a previously established intention to send out reprints to colleagues who have requested them. In this case, the cue draws to mind a prospective memory in which an unfulfilled intention reaches consciousness. Cues such as these have been labeled *event-based prospective memory cues*, and they will serve as very strong triggers to completing an intention if the conditions surrounding noticing the cue are appropriate (e.g., Einstein, Holland, McDaniel, & Guynn, 1992; Einstein & McDaniel, 1990). For example, seeing the stack of papers will only lead to fulfilling the intention if one has the requisite number of reprints already copied and enough time to mail them all out at that moment. Otherwise, the intention goes unfulfilled and the papers will presumably serve as an effective event-based cue on another occasion.

Much is already known about the characteristics of event-based cues that lead to remembering an intention. For example, cues that are particularly salient will be noticed more frequently (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Marsh, Hicks, & Hancock, 2000). Cues that are distinct from the background context or are unusual in their own right tend to be noticed more frequently as well (McDaniel & Einstein, 1993). When an intention has been formed to respond to a particular category of cues, highly typical category members evoke the intention more often as compared with less typical exemplars (Ellis & Milne, 1996). Older adults will miss more event-based cues than younger adults unless the retrieval context supports cue identification (e.g., Cherry & LeCompte, 1999; Einstein, Smith, McDaniel, & Shaw, 1997; Maylor, 1993, 1996; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; West & Craik, 1999). In terms of processing resources, different event-based tasks probably lie along a continuum in which the conditions surrounding retrieval may range from being relatively more automatic to requiring some substantial capacity to identify the cue. For this reason, McDaniel and Einstein (2000) have proposed a multiprocess view of event-based prospective memory that specifies some (but not all) of the conditions that are likely to lead to relatively automatic versus more effortful identification of an environmental cue and subsequent retrieval of the intention.

In this study of event-based prospective memory, our goal was to explore a topic that has hitherto received very little attention. In the vast majority of published articles, the standard Einstein–

Richard L. Marsh and Valerie Watson, Department of Psychology, University of Georgia; Jason L. Hicks, Department of Psychology, Louisiana State University.

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

McDaniel paradigm has been used in which cues are embedded in an ongoing activity, such as pleasantness ratings of words, judging the sensibleness of sentences, or naming famous faces (e.g., Ellis, Kvavilashvili, & Milne, 1999; Maylor, 1996). Participants are told to press a key on a computer or perform some other action when certain cues or a class of cue words appears (e.g., animal words or faces with beards). The average proportion of times they do respond to prospective cues has been considered to be their metric of success. Although this measure is likely to be quite informative in many future explorations of prospective memory, it does not capture the microstructure of certain aspects of event-based performance, such as (a) noticing the cue, (b) retrieving the intention itself, and (c) coordinating a response with the task demands of the ongoing activity. Rather, the average proportion metric captures all three aspects together without any detailed consideration for their potentially separable contributions to performance. Our goal in conducting this study was to open a window on some of these issues by measuring reaction times to successful versus failed event-based trials that occurred during the ongoing activity. We hoped that using a different dependent variable would be informative about the cognitive processes that take place when event-based cues are noticed versus when they are not. Our theoretical rationale was as follows.

Some of us have argued that after an intention is formed, it may reside in memory with a special status (Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998; Marsh, Hicks, & Bryan, 1999; Maylor, Darby, & Della Sala, 2000). That status may be a relatively higher activation level compared with neutral memories or a quicker than average revival rate when being retrieved. This argument and the data supporting it have been labeled the *intention superiority* effect. Such a simple "*activation*" account would predict that if we embed prospective cues in a lexical decision task, then responses to them should be faster than to control words matched on all of the relevant variables that affect response speed in this task (see also Goschke & Kuhl, 1996, on perceptual readiness of intention-related materials). (For an extended discussion of the logic of using lexical decision to measure latent activation levels, see Marsh et al., 1998.) However, that prediction may be naive because heightened activation may only affect one aspect of the process, namely, noticing the cue. Heightened activation may affect neither the simple retrieval of the intention itself nor the coordination of executing the prospective task with the processing requirements of the ongoing activities. If one makes the reasonable assumption that each of these three cognitive activities requires processing time to complete, then response time to cues that are successfully noticed in a lexical decision task may be slower than response time to control-matched words that have no associated intentionality. Of course, one might quibble that heightened activation could affect retrieval of the intention, but this only reinforces our point that the contribution to event-based prospective memory of these three potentially separable activities needs to be more thoroughly investigated. Therefore, our first research question concerned whether successfully identified cues were responded to more quickly or more slowly because of the associated intention to respond.

As just argued, if items or materials associated with an unfulfilled intention do enjoy a benefit of heightened activation, then the additional retrieval and coordination activities associated with event-based prospective memory are likely to mask any reaction-time facilitation associated with the cognitive mechanisms that result in the intention superiority effect. However, intention retrieval and coordination of the prospective and ongoing activities will only occur after noticing the event-based cue. They will not occur if the cue goes unnoticed (i.e., on failed prospective trials). By this logic, an intention superiority effect may be found in which reaction times to failed trials are faster than reaction times to control-matched words in an event-based prospective task. If the intention superiority effect is limited to the script-based paradigms in which that phenomenon was found originally, then no reaction-time differences should exist between failed and control-matched words in the lexical decision task. Therefore, our second research question concerned whether failed trials that did not evoke a prospective response would display an intention superiority effect in event-based prospective memory paradigms.

On the assumption that successful identification of an event-based cue leads to the decision to respond, the coordination of the prospective and ongoing activities should also take some finite amount of time to complete. In many of the published articles, participants were working at a computer pressing various keys, and the prospective response was usually (but not always) to press a special key on the keyboard. Any slowing that might be found could be at the level of two production rules firing, one for the prospective task and one for the ongoing task. These two activities would then be competing for similar motoric responses, or more generally, the same pool of limited attentional resources (see the General Discussion section of Marsh & Hicks, 1998). To investigate this issue, we changed how participants made their prospective memory responses by varying the modality of the response. Therefore, our third research question concerned whether any latency differences reflected costs associated with coordinating the cognitive processes of responding to both the prospective and ongoing tasks.

As the reader will notice, we have launched our investigation from the theoretical vantage point that an intention superiority effect (faster reaction times to event-based cues) will probably be masked by three (potentially separable) aspects of successful prospective memory processes. These include noticing the target as relevant to a previously established intention, retrieving the intention itself, and coordinating ongoing activity with the activity required to fulfill the intention. We freely admit that we have labeled these *aspects* of event-based prospective memory because we are not prepared to label them as steps or stages. In other words, we do not make any claim about the order in which they occur or whether they must be done serially or can be done in part simultaneously. Moreover, we also admit that the three aspects of event-based performance that have been identified here will need to be revised and refined by future investigations. Our present goal is simply to explore for the first time the microstructure of cognitive processing that takes place when an event-based target is noticed versus when it is not.

Experiment 1

We conducted Experiment 1 to assess whether an intention superiority effect would be found in an event-based prospective memory paradigm. On the one hand, heightened activation of intention-related materials should cause these cues to be identified more quickly in a lexical decision task. On the other hand, the processes involved with noticing and retrieving an intention, and then coordinating the prospective and ongoing activities, may slow responses instead. Obtaining a slowing effect on successfully identified cues would be strong evidence in favor of these prospective processes taking place when a cue is noticed. By contrast, when a cue is missed (i.e., fails to be noticed) the reaction time to identify the cue as a word may be a relatively pure measure of whether an intention superiority effect exists. If it does exist, then identification times should be faster because task-relevant material has accrued activation from its intentional status (or because the cue can be revived more quickly).

Method

Participants. Undergraduate students from the University of Georgia volunteered in exchange for partial credit toward a course requirement. Forty participants were tested individually in sessions that lasted approximately 25 min. In this experiment, half of the participants were assigned to a condition involving the intention to respond to animals whereas the other half were asked to respond to articles of clothing. The two conditions were merely conceptual replications of one another.

Materials and procedure. The lexical decision task consisted of 210 trials during which participants were asked to decide whether letter strings formed valid English words or did not. Half of the trials presented valid words (an affirmative response) and half presented nonwords (a negative response). Conforming to our standard practice, the 110 valid words were medium- and high-frequency words selected from the Kučera and Francis (1967) compendium. The nonwords were formed from a separate pool of words matched for word frequency, letter length, and syllabic length. One or two consonants were changed to make the word a nonword under the constraint that the nonword was still pronounceable (see Shoben, 1982). Except as later noted, words and nonwords were randomly intermixed anew for each participant by the software written for this experiment.

Event-based prospective cues occurred every 25 trials beginning on Trial 25, then Trial 50, and so on, through Trial 200. In other words, a total of eight event-based prospective cues were embedded in the lexical decision task. The 10 extra trials at the end of the sequence were included to capture any late prospective responses. For half of the participants, these cues were the names of animals, whereas for the other half, they were names of articles of clothing. Both sets of cues were selected from the Battig and Montague (1969) category norms. When animal cues were tested, eight of the valid English words were specifically matched on word frequency, letter length, and syllabic length to the prospective cues as control-matched words. These control-matched words were semantically unrelated to the intention. The same was true when the intention was to respond to articles of clothing. This composition meant that of the 110 valid English words for a given participant, 16 were fixed and 94 were simply other words that were unrelated to either animals or clothing (just like the control-matched words).

Participants read instructions for the lexical decision task from the computer monitor and the experimenter reiterated them verbally. The instructions described the experiment as investigating how quickly different kinds of words could be identified. After participants understood the instructions, the experimenter explained that we were also interested in their ability to remember to perform an action in the future. They were asked to press the *?/* key after making their “word” response to either animals or clothing, depending on the condition to which they were assigned. An example of the category was also given that would not be encountered later (e.g., *monkey* or *shirt*). The experimenter was clear and unambiguous that the word response should precede the prospective response and that the latter response could be made in the waiting period following each trial. After the instructions were delivered, the computer monitor was cleared and participants were asked to solve mazes for 4 min as a distractor activity before commencing the lexical decision (ongoing) task.

Consistent with other lexical decision experiments conducted in our laboratory, word and nonword responses were made by pressing labeled keys placed on the *F* and *J* (home) keys. The lexical decision task was self-paced insofar as each trial began with a “waiting” message. Participants were instructed to press the *space bar* with one of their thumbs to initiate the trial. Doing so caused a short warning tone to occur, a fixation point (an asterisk) appeared for 250 ms, and then the letter string itself appeared. After making a word–nonword response, the waiting message appeared in the same location in the center of the monitor as the letter string had occupied. The software was written to accept prospective responses whenever they occurred, but they should have occurred during the waiting period.

Results and Discussion

Unless specified otherwise by a *p* value, statistical significance does not exceed chance by the conventional .05 alpha level throughout this article. Four preliminary issues are discussed before presenting the data of interest. First, responses to the prospective memory task occurring a trial or two later were infrequent, and when they did occur, we counted them as failed event-based trials. We did so for two reasons. Doing so has been our standard practice, but more important, we were interested in the cognitive processes that occur at the exact time an event-based cue is encountered. If a participant realized a trial or two later that a prospective response was missed, then this realization does not inform the cognitive processing that occurred previously when the cue was presented. Although analyzing these late responses might have been interesting in their own right, they occurred too infrequently across the participants (1.4%) to obtain stable latency measures of performance. Second, trials on which a lexical decision error was made were not included in the analyses (about 2.6% of all trials), and fortunately, errors did not occur on prospective trials or control-matched trials. Third, we could have reported the data trimmed such that outliers were identified and removed that were greater than three standard deviations above a given participant’s average latency (e.g., Marsh et al., 1998), but the conclusions reached would have been identical to analyzing the untrimmed data. The latter approach was taken here. Fourth and finally, the results from the animal versus clothing conditions were virtually identical (e.g., .67 vs. .70 average prospective memory), and we have pooled over these conditions in reporting the results. In fact, we eliminated this factor in all subsequent experiments in this article.

The data are summarized in Table 1. The column labeled *prospective memory* corresponds to the standard measure of event-based performance, namely, the average proportion of cues that received a prospective response. In this experiment, that was .68, which indicated that almost 70% of the cues successfully elicited a response. The remaining columns summarize the average reaction times on the various types of trials in the lexical decision task. The four columns labeled *prospective trials* report reaction times to making the word response on successful and failed trials, as well as the control-matched words that were semantically unrelated to the intention. For the two control-word columns, these average reaction times reflect the control-matched trials corresponding to the items contributing to the successful or failed trials, respectively. For example, if a participant successfully identified five

Table 1
Proportion of Successful Event-Based Identifications and Average Reaction Times to Trial Types in Experiments 1–3

		Prospective trials				Other trials	
Exp.	Prospective memory	Success	Success control	Fail	Fail control	Words	Nonwords
Exp. 1	.68 (.03)	1128 (83)	771 (25)	690 (25)	786 (46)	785 (16)	885 (27)
Exp. 2	.60 (.04)	1148 (80)	848 (44)	683 (21)	782 (44)	774 (22)	866 (40)
Exp. 3	.69 (.04)	885 (56)	758 (29)	681 (35)	790 (47)	703 (15)	NA

Note. Standard errors are in parentheses. Exp. = Experiment; NA = not available in naming task.

prospective cues, then the *success control* measure was the average reaction time to the five corresponding control-matched words. Likewise, the "fail control" measure was the average reaction time to the control-matched words corresponding to the three prospective cues that were missed. These measures were computed on an individual participant basis because which items a particular participant identified (or failed to respond to) was idiosyncratic to that individual. Because prospective memory was generally better than 50%, fewer trials contribute to analyses of failed trials. In addition, the degrees of freedom in the inferential tests will vary slightly depending on the number of participants contributing to an analysis. No pattern of effect was changed by this issue and it is the only approach that assures that item selection effects are not affecting the conclusions.

The last two columns labeled *other trials* summarize reaction times to the remaining words and nonwords. Concerning those data, nonwords were identified as such more slowly than words were identified, $t(39) = 5.40$. This outcome is a standard finding in almost all lexical decision tasks, and it reassures us that participants were responding in a standard fashion.

The two types of prospective trials (successes and failures) were analyzed together with their yoked control-matched trials in a 2 (success vs. failure) $\times$ 2 (prospective vs. control) within-subjects analysis of variance (ANOVA) model, which was followed up with simple effects analyses. For the present purposes, all that matters is that the two-way interaction of the omnibus test was statistically significant, $F(1, 39) = 17.32$. Because the interaction is disordinal in nature and identifiable as a crossover variety, the main effects are uninterpretable anyway. Words were processed much more slowly when they were successfully identified as a prospective cue as compared with control-matched words that had no such intentionality associated with them, $t(39) = 4.13$. As argued earlier, the 357-ms slowing represents some combination of cue identification, intention retrieval, or coordination activities between the prospective and ongoing tasks. The overarching point is that these event-based prospective memory processes obscure any potential intention superiority effect when cue identification is successful. On average, only 32% of the event-based trials were missed, and so as argued before, there were less data contributing to average latencies for failed trials. Nevertheless, words that did not elicit a prospective response were identified faster than control-matched words, $t(39) = 1.85$, $p < .07$. Although this two-tailed statistical test failed to meet conventional significance, it does meet that criterion as a one-tailed test ($p < .04$). Thus, this 96-ms facilitation effect is consistent with the intention superiority effect insofar as intention-related material may be identified more quickly (or revived faster) as compared with material that has no associated intentionality.

At this juncture, it is unclear exactly to what process(es) to attribute the slowing on successful trials. Any one (or all) of the three aspects of event-based memory previously identified could account for the slowing. A prime candidate to examine further is the coordination of the two manual key presses required in this experiment, namely, the word response and the prospective response. Such response competition would occur after the cue has been identified and after the intention to press the *?/* key has been retrieved. If one assumes that separate pools of attentional resources exist (e.g., Pashler & Johnston, 1998), then changing the modality of the prospective response may eliminate some or all of the slowing observed on successful trials in this experiment. This hypothesis was evaluated in the next experiment.

Experiment 2

We conducted this next experiment to determine whether a portion of the slowing observed on successful trials was due to coordination or response selection processes involved in the ongoing versus prospective tasks. Because manual responses were required for the lexical decision task, we changed the prospective response to articulating the word *now* whenever a prospective cue was encountered. If the ongoing task and the prospective task were competing for limited resources in Experiment 1, then the amount of slowing should be attenuated (i.e., less slowing) when the prospective response is made in another modality. However, if the bottleneck is a more centrally mediated one, such as at the level of executive processes that we have claimed previously are needed for event-based memory (Marsh & Hicks, 1998), then perhaps the magnitude of the slowing will be equivalent to that observed in Experiment 1.

Method

Participants. Thirty-six University of Georgia undergraduates volunteered in exchange for partial credit toward a course requirement. Each participant was tested individually in sessions that lasted approximately 25 min. None had participated previously and none had taken part in other studies of prospective memory.

Materials and procedure. The procedural details of this experiment were virtually identical to Experiment 1, except in two respects. First, the instructions were modified to reflect that the word *now* was to be spoken aloud to the experimenter when a cue was encountered. Consistent with

Experiment 1, participants were asked to say this after they had pressed the word key in the ongoing task. To ensure the experimenter knew when to expect a response, the participant's computer was linked to a second computer behind the participant that indicated to the experimenter the trial number and the actual event-based cue that appeared in the lexical decision task. The experimenter recorded the cue and whether an oral response was made. After the experiment was conducted, the experimenter updated the lexical decision data files to reflect successful and failed prospective responses in a manner consistent with how the computer had recorded them in Experiment 1. Second, as mentioned earlier, we eliminated the clothing category because of the virtually identical results obtained in Experiment 1. Therefore, all participants had the intention to respond to animal cues. In all other respects pertaining to the lexical decision task and the distractor period, the procedure was identical to that used in Experiment 1.

Results and Discussion

As shown in the last two columns of Table 1, nonwords were identified more slowly than nonprospective words, $t(35) = 3.20$. This standard outcome was expected. Overall prospective memory was slightly lower in this experiment, with 60% of the cues successfully identified. However, this outcome was ultimately beneficial because relatively more failed trials will be available to be analyzed in the reaction-time data to assess the existence of an intention superiority effect in event-based paradigms. The omnibus ANOVA verified that the 2×2 interaction term was statistically significant $F(1, 35) = 21.45$. Moreover, the pattern of latencies was virtually identical to those obtained in Experiment 1. Successful trials on which event-based cues were recognized elicited much slower response latencies than their control-matched words, $t(35) = 4.63$. Although we do not statistically compare the data from this experiment with Experiment 1, it is obvious that the magnitude of the slowing effect was comparable (300 ms). The same was true of failed trials that elicited word identification responses much more quickly (by 99 ms) than control-matched words by a standard two-tailed test, $t(35) = 2.17$.

Despite using a different prospective response, the outcome of this experiment replicated the previous one in all of its essential properties. As indicated by latency to the failed trials, having an intention about a class of objects facilitates identification of those objects. Of importance, this facilitation was not due to some long-term semantic priming effect from the categorical intention, because semantic priming in a lexical decision task does not usually survive even one or two intervening items (e.g., Meyer & Schvaneneldt, 1971). Moreover, long-term semantic priming has only been obtained under the very specific conditions of using nonwords that were pseudohomophones (e.g., *phrog*), and never was the effect obtained after a maximum of eight intervening trials (Joordens & Becker, 1997). The facilitation also cannot be a consequence of repetition priming because we used a categorical intention and each prospective cue was unique. The slowing on the successful trials implies that event-based prospective memory processes are occurring quite early in word identification, at least with the lexical decision task used here. We thought that some of the slowing observed in Experiment 1 might be due to coordinating the key presses required by the prospective and ongoing tasks. Because we obtained similar amounts of slowing in this experiment with a prospective response made in a different modality, the cost of coordination may be at the level of more centrally mediated processes (i.e., not response specific).

Experiment 3

This last experiment was conducted to address an important issue concerning the preceding experiments, namely, the nature of the ongoing task. Making lexical decisions requires retrospective semantic matching of the letter string, and it requires the decision of which response button to press (Neely, 1991). Everyday tasks such as reading, taking a walk, or taking a short break from other activities may require action of some sort, but these activities may not require making overt decisions as is required in lexical decision. Perhaps the effects that were observed in the previous experiments are somehow context bound to the particular ongoing task because it required semantic matching and/or an overt decision. If this assertion were true, then it would limit the generalizability of the claims that could be made about the microstructure of event-based prospective memory processes. Consequently, we believed that it was very important to investigate the slowing effect on successful trials and the intention superiority effect on failed trials using an entirely different ongoing activity to determine the generality of these findings.

A number of promising alternative ongoing tasks presented themselves because they have been used in past research as alternatives to lexical decision. For example, perceptual identification or word naming are two tasks that would also provide latencies to the ongoing activity. We chose naming (i.e., pronunciation) because the task does not require a decision component, because reading aloud is a relative automatic and well-practiced task, and because we had the necessary equipment and software readily available to conduct this experiment. Theoretically, lexical decisions versus naming are carried out by fundamentally different cognitive processes (Ratcliff & McKoon, 1988). Although both require access to the mental lexicon (i.e., retrieval), lexical decisions contain a discrimination component (of words from nonwords) and require binary responses. These features are not present in naming because participants are simply reading words aloud into a microphone. If these additional features of lexical decision somehow contributed to coordination difficulties, then perhaps the slowing effect that we have found is a consequence of these components of the ongoing task. To assess this possibility, we changed the ongoing task to simple naming. If the three hypothetical processes involved in event-based prospective memory behave similarly regardless of the ongoing task, then we should still observe the slowing and the heightened activation effects on successful and failed trials, respectively. If the naming task is a relatively better or somehow purer measure of activation because there is no decision component, then the effects observed in the previous experiments, especially the slowing effect, may vanish.

Method

Participants. Fifty-seven 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 20 min. The larger sample size in this experiment was an accident owing to Richard L. Marsh's failure to monitor how many participants were tested (i.e., it was not by design to collect such a large sample size).

Materials and procedure. The stimulus materials were virtually identical to the previous experiments except that nonwords were replaced with medium-frequency words found in the Kučera and Francis (1967) compendium. This change meant that all stimuli were valid English words. The software was updated to remove the lexical decision component and to add collection of voice-activated response latencies. A Lafayette Instruments (Lafayette, IN) voice-activated relay was triggered whenever the participants spoke into a microphone. To increase the sensitivity of our equipment, we preamplified the sound received from the microphone through a Realistic stereo amplifier (Tandy Corp., Forthworth, TX) into the voice-activated relay. In turn, the relay was wired to the serial port of the computer and reaction times were taken from the onset of the word on the screen until the computer received information from the voice key. In our experience, the preamplification of the microphone greatly reduces mistriggers of the voice key. We used a boom microphone on its own stand that could be adjusted to the size of the participant and their desired seating position. The microphone was approximately 2 in. from the left side of their mouth, and it did not obstruct viewing the computer monitor.

As in the previous experiments, each trial was self-paced. Participants saw a waiting prompt at the beginning of each trial. They pressed the *N* key with their right index finger to see the next word. A 300-ms delay occurred before the word appeared. Participants had been instructed to speak the word loudly and clearly into the microphone because the computer was recording how quickly they could pronounce various words (this was also our new cover story for what was being measured in the experiment). When the voice key was triggered, the word was replaced with the waiting prompt. Activation of the voice key between trials had no effect on timing because this information was discarded right up until the moment the to-be-read word appeared. As in the previous experiments, participants had been instructed to press the *?/* key when an animal word appeared. They were instructed to do so after pronouncing the animal name and during the waiting period following that trial. During the retention interval, mazes were solved and the voice key was calibrated to an optimal level of sensitivity for each participant by having them read the numbers 15 down to 1 on individual trials. Because this took a slightly different amount of time for each participant, the retention interval was only approximately 4 min as compared with the preceding experiments.

Results and Discussion

Before turning to the results, we first mention one data analytic issue. We eliminated any latency that was less than 300 ms on the assumption that it was a mistrigger of the voice key. We also eliminated all trials over 5,000 ms because we could not fathom that reading a word would take that long. This trimming procedure resulted in the loss of 2.1% of all of the nonprospective trials and 0.3% of the prospective trials. We considered this an acceptable level of data loss. The results are summarized at the bottom of Table 1. The reader will note the absence of a latency to nonwords because those stimuli did not appear in this experiment that used the naming ongoing task. Pronunciation latencies showed the same pattern as did the lexical decision task used in Experiments 1 and 2. The omnibus ANOVA on prospective trials yielded a significant two-way interaction, $F(1, 30) = 6.19$. Latency was slower on trials when participants remembered to fulfill the intention as compared with control-matched words, $t(50) = 2.19$. The average slowing was 127 ms. Thus, the slowing effect is not a consequence of the extra decision component in lexical decision. Rather, that effect appears to be a more general result. In addition, when a prospective response was omitted in the waiting period following an animal word, the animal on that trial was named faster than words on control-matched trials, $t(34) = 1.84$, $p < .07$, by an average of 109 ms. That outcome shows that an intention superiority effect can be obtained with a naming task as well. As in Experiment 1, the simple effect analysis is only statistically significant by convention with a one-tailed test ($p < .04$). As argued earlier, the documented existence of the intention superiority effect in previous research justifies the use of this test because there is no theoretical reason to predict that the opposite outcome would occur.[1]

The outcomes from this experiment are reassuring insofar as they demonstrate that the results from Experiments 1 and 2 are not context bound or somehow a consequence of our choice of using a lexical decision task. The intention superiority effect on failed trials and the slowing on successful trials can be obtained using either lexical decision or naming latency. Because naming latencies are often somewhat shorter than lexical decision latencies, these data reinforce the notion that successful prospective memory processes are operating quite early in processing the prospective cue and do not appear to be an afterthought in processing related to the requirements of the particular cover task. Rather, having an intention related to a class of items facilitates processing them when the cue goes undetected (failed trials) but interferes with the ongoing task, as evidenced by slowed responses when the cue is detected (successful trials). We turn now to consider more generally what these experiments demonstrate about event-based prospective memory and the cognitive processes that are likely to be subserving it.

General Discussion

We began this study with three interrelated research questions concerning event-based prospective memory. The first question pertained to whether event-based cues would be responded to more quickly or more slowly than control-matched words that had no associated intentionality. The answer in all three experiments was that successfully noticed cues were processed more slowly. According to our analysis, this outcome occurred because successfully performing an event-based intention requires cognitive processes involved in noticing the cue, retrieving the intention, and coordinating its execution with the ongoing activity. Under the assumption that these processes take time, the slowing effect was predicted and then verified. Our second research question addressed whether the intention superiority effect could be demonstrated in an event-based paradigm. We hypothesized that the processes of noticing, retrieving, and coordination would mask the effect even if it was operative in this paradigm. However, we did find in Experiments 1–3 that cues that went unnoticed (i.e., failed prospective trials) enjoyed somewhat faster response latencies in the ongoing task. Our interpretation of this outcome is that it represents additional, strong evidence that material associated with intentions to perform an activity either reside in memory with an above baseline level of activation or that such memories are simply able to be revived more quickly.

[1] The reader may have noticed that the degrees of freedom for the omnibus two-way ANOVA do not match the degrees of freedom for the pairwise comparisons. This occurred because a small number of people never recognized a prospective memory cue, and therefore had no successful trials. Regarding the failed trial analysis, a larger number of participants recognized all eight prospective memory cues, and therefore had no failed trials. When the pairwise comparisons were conducted including only those that were involved in the two-way ANOVA, the patterns were no different than as reported.

Our third research question concerned whether we could find evidence of the costs of coordinating the prospective response with the processing required in the ongoing activity. The manual versus oral responding in Experiments 1 versus 2 did not appear to change the magnitude of the slowing effect. However, any time two tasks must be executed in the same window of time there is likely to be a cost of concurrence, as Norman and Bobrow (1975) labeled it. When framed in this fashion, there is more than a passing resemblance of successful event-based memory to standard divided attention tasks in which two concurrent tasks must be coordinated. From this perspective, the coordination involved when a prospective cue is noticed will likely place some minimal demands on executive control processes (Baddeley, 1996). Thus, although we did not obtain a grasp on manipulating coordination activities, we nevertheless feel that it is an important aspect of event-based memory that warrants further study.

As a package, we admit to readers that these experiments have only begun to scratch the surface in exploring the component processes of noticing, retrieval, and coordination in event-based memory. As it relates to noticing, a highly salient cue could be tested in order to assess whether this manipulation would attenuate the slowing. The idea here is that easier identification is likely to be performed more quickly. By contrast, cues that blend into their context and are not distinctive (McDaniel & Einstein, 1993) may increase the magnitude of the slowing effect because their detection requires substantially more conscious processing. Of course, these manipulations would most assuredly affect the overall level of event-based performance. As such, issues relating to the microstructure of processing as a function of frequency of success might also be fruitful avenues of inquiry in their own right.

As it relates to retrieval, we have used the standard Einstein–McDaniel paradigm in which a single prospective action (e.g., press a key) is issued to every distinct cue that is encountered. There were good reasons for doing so, including the most basic assumption underlying the majority of event-based prospective memory experiments: We know that when participants identify a cue, they will undoubtedly have retrospective memory for the intended action because it is so simple. However, retrieval could be made more difficult by having different intended actions associated with different cues. Although such an idea presents some interpretative difficulties with memorization of the to-be-performed activities and different initial amounts of processing of the cues, presumably more difficult retrieval would take more time and increase the magnitude of the slowing effect that was found in this study. Another retrieval manipulation that might affect latency to targets would be manipulating how frequently various cues occur (e.g., Ellis et al., 1999) on the assumption that in the limit case a habitual response is retrieved quite automatically.

This last point dovetails quite nicely with McDaniel and Einstein's (2000) claims that event-based memory is sometimes automatic and other times requires more conscious resources (i.e., their multiprocess view). Examination of the microstructure of event-based responding (as we have done here) of two such different conditions is likely to be quite informative. Of course, the automatic versus controlled distinction may represent an amalgam or confluence of differences in the noticing, retrieval, and coordination aspects that we have discussed here. We have used a categorical intention that has been labeled *general instructions* as opposed to *specific instructions* to respond, say, when the cue *tiger* appears (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). If categorical instructions require some optimal level of central executive resources (Marsh & Hicks, 1998), then perhaps with specific instructions the slowing effect on successful trials would not be as pronounced. However, the microstructural components of event-based responding being investigated here do raise the possibility that automatic event-based responding is never really automatic at all. For example, if highly salient cues make noticing automatic, then retrieval and coordination may still demand significant resources. Consequently, perhaps immunity to divided attention does not demonstrate automaticity unless performance is measured on all tasks and there is no cost of concurrence to be found in any of them. For this reason, researchers may want to hold in abeyance labeling an event-based task as automatic until further research on this question has been conducted.

As it relates to coordination, a number of avenues for inquiry exist, including manipulating the complexity of the ongoing task or the complexity of the prospective response. In the latter case, such manipulations would have to control for retrieval complexity to assess accurately only the effects of coordination. However, combining manipulations that are likely to affect two or more of the components of event-based memory as identified here should also be a worthwhile endeavor. The consequences of doing so might show subadditivity if there are fixed costs to these stages or if there are fixed costs to coordinating the subprocesses involved in event-based memory. By contrast, perhaps superadditivity could be found if there is synergy in facilitation effects to each subcomponent individually. Whatever the outcomes of the many Gedanken experiments we have suggested, the overarching point is that examining the microstructure of the cognitive processing that takes place when event-based cue is encountered is likely to be an important and profitable endeavor. As we lamented earlier, the present study should be considered only an initial exploration into these issues.

More generally, the intention superiority effect has been demonstrated with script-based materials (Goschke & Kuhl, 1993; Marsh et al., 1998), with unrelated materials (Marsh et al., 1999), and with naturally occurring intentions (Maylor et al., 2000). In this article, that effect has now been extended to the conditions tested in this particular event-based paradigm. Although it might not be found in every variation of event-based memory (see previous discussion on automatic vs. controlled tasks), researchers need to be mindful that the three aspects of noticing, retrieval, and coordination might mask the existence of an intention superiority effect. In other words, the microprocesses of successful event-based memory may hide what is also there, namely, a facilitation effect. As prospective memory paradigms become increasingly refined, we will be able to understand better the intention superiority effect and why it arises. However, shades of that effect can be found in other paradigms that have little to do with priming or activation as well.

For example, in tests of source monitoring, memories comprised primarily of cognitive operations revive more quickly than memories comprised primarily of perceptual details (Johnson, Kounios, & Reeder, 1994). Before an intention is fulfilled it too must be represented in memory as primarily comprised of cognitive operations (i.e., details of planning and elaboration). However, after it is fulfilled, records of perceptual detail become associated with having carried out the task. We have demonstrated in the same experiment that material associated with an intention revives more quickly before it is performed and more slowly after it is performed (Marsh et al., 1998) and that result maps on directly to latency measures for cognitive operations and perceptual details, respectively. Thus, there is at least one strong parallel between findings in the source-monitoring literature and those obtained in the event-based prospective memory literature. Although we cannot develop these ideas more fully here, this observation may attest to the existence of many, as yet undiscovered, cross-fertilizations that will help us to understand better the cognitive processes involved in event-based prospective memory.

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