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Task interference from prospective memories covaries with contextual associations of fulfilling them

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One of the current issues in the field of prospective memory concerns whether having an intention produces a cost to other ongoing activities (called task interference). The evidence to date suggests that certain intentions held over the shorter term do interfere with other tasks. Because the cumulative effect of such costs would be prohibitively expensive in everyday life, the present study examined one means by which that interference may be reduced. Participants who formed a specific association to fulfilling an intention in a future context did not exhibit task interference over the intervening period until that context was encountered. This outcome was observed with both an event-based and a time-based prospective memory task. The results suggest that associating intention fulfillment with a specific context can eliminate task interference, and they emphasize the importance of studying intentions that are linked to future contexts versus those that are not.

One of the many important functions of memory is to store intentions about future plans, goals, and activities. Intending to refill a prescription, planning a trip to the grocery store, setting aside a future time to write, read, or work on a hobby, or forming the intention to give someone a piece of information are everyday examples of what has been termed prospective memory in the scientific literature. The label connotes a forward-looking component to the memory, and it was intended to contrast directly with retrospective memory, for activities and events that occurred in the past. Although people form a vast array of prospective memories that vary along many dimensions (see Kvavilashvili & Ellis, 1996), perhaps the most often cited distinction contrasts event-based with time-based prospective memory (see, e.g., Einstein & McDaniel, 1990; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). In event-based prospective memory, people allow an environmental cue to remind them to complete an intention. For example, the sight of a convenience store might bring to mind the intention to replenish milk, or the sight of a friend might trigger t he intention to relate a novel story. In time-based prospective memory, people plan to execute an activity either at a predetermined time, such as attending a meeting at work, or after a specific period of time has elapsed, such as taking food out of the oven before it is overcooked. Despite the fact that neither type of intention is more or less important than the other, event-based prospective memory has received much more scientific scrutiny than time-based memory (see Cook, Marsh, & Hicks, 2005). Consequently, the theories concerning event-based memory are more developed, as are the various laboratory techniques used to study it.

The present study explores a timely issue in the field of prospective memory—namely, the degree to which possessing a prospective memory interferes with an ongoing activity. In standard laboratory instantiations of event-based tasks, people are engaged in a cognitive activity such as rating words on various dimensions, naming pictures of famous faces, performing a lexical decision task, reading a passage, and so forth (see, e.g., Ellis, Kvavilashvili, & Milne, 1999; Marsh, Hicks, & Watson, 2002; Maylor, 1996, 1998; McDaniel, Robinson-Riegler, & Einstein, 1998). Prior to commencing the task, they are asked to respond to a cue, such as a specific word or a class of items (e.g., words denoting animals), with a special action that indicates they remembered their intention. This laboratory paradigm is intended to simulate real-world situations in

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which people are engaged in an activity such as driving and the cue appears in the environment (Einstein, Holland, McDaniel, & Guynn, 1992). Recently, Smith (2003) has argued that event-based prospective memory requires preparatory attention that can usurp resources from the ongoing activity. For example, among her demonstrations is the simple case of measuring reaction time in a lexical decision task for a condition that has an active event-based intention versus a condition that does not. Participants in the condition that has the active intention perform the lexical decision task much more slowly (see Marsh, Hicks, Cook, Hansen, & Pallos, 2003). (For a more comprehensive demonstration and explanation of the *preparatory attention and memory* [PAM] model, see Smith & Bayen, 2004.) The idea that event-based prospective memory might require resources is consistent with our own claims that certain forms of event-based prospective memory might require an optimal level of central executive resources (Marsh & Hicks, 1998).

McDaniel and Einstein (2000) concur that event-based tasks can require resources when detecting the cue requires cue-focused cognitive processes. However, they also propose that some event-based intentions require no resources, and that cue detection can occur automatically (McDaniel, Guynn, Einstein, & Breneiser, 2004). The basis of their *multiprocess view* (MPV) is that the conditions surrounding the event-based task will determine whether resources will need to be recruited from the ongoing task and allocated to the prospective task. More specifically, salient cues, ongoing tasks that focus people on the relevant features of the cue, and a high association between the cue and the action to be performed all create optimal conditions for automatic cue detection. Although the present study was not designed to disambiguate between the PAM and MPV theories, it does appeal to the notion that prospective memory tasks can usurp resources from an ongoing task, as evidenced by slower reaction times on that task. The cost associated with possessing a prospective memory has been labeled *monitoring*, but we will use the term *task interference* because it is theoretically neutral and does not connote that people are actively looking for event-based cues. (For a discussion of this issue, see Marsh et al., 2003.)

Although we favor the view that task interference arises from attentional-allocation strategies, it is not the only explanation for the cost. The dual-task literature is replete with an alternative explanation—namely, that participants must make a decision on every trial about the prospective task and the ongoing task. By this account, vigilance processes related to both tasks occur on each trial, thereby causing the observed slowing. There are a number of reasons to believe that this alternative is not favored in many prospective memory studies. First, the empirical evidence shows that participants are not actively thinking about the prospective memory task. Reese and Cherry (2002) stopped participants and asked them to report what they were thinking about; only 5% of the time was the intention mentioned. Our own data on explicitly recording self-initiated reminders converges on this number; the intention was reported to be in mind on only 4% of the trials (see Hicks, Marsh, & Russell, 2000). Second, if the intention were always in mind, performance should be on ceiling in virtually all studies of prospective memory, but it is not. Third, participants do not need to make an intention-related decision on every word in a time-based task, but as the results of this study will bear out, task interference is nevertheless obtained. Fourth, if adding an intention always produced a dual-task situation, then older adults who have cognitive deficits should consistently show reductions in intention completion relative to younger adults, which they do not. For these, and several other reasons not listed in this paragraph, we prefer an attentional-allocation explanation to a decision and response interference explanation. However, our preference should not dissuade readers from considering and exploring this alternative explanation for task interference.

To date, task interference has been depicted as a Boolean event, insofar as it occurs or it does not (e.g., West, Krompinger, & Bowry, 2005). That view is likely to be somewhat shortsighted, because if many intentions created a cost to ongoing tasks in everyday life, their collective effect on the cognitive performance of busy people would be to quickly grind it to a halt. As stated recently, a constant cost from holding an intention would be prohibitively expensive in everyday life (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003). This observation raises the important question of how people may suspend any task interference effects in everyday life. Einstein et al. have claimed that perhaps the intention wafts in and out of consciousness over the retention interval from intention formation to cue detection (cf. Hicks, Marsh, & Cook, 2005; Marsh, Hicks, & Cook, 2005). By this account, intending to purchase milk on the way home from work will cause one to think about that intention periodically throughout the workday. Although this is plausible, there may be another means by which to reduce the task interference effect and obviate having to think about the intention at all. We hypothesized that people sometimes associate fulfilling an intention with a future context. Using the milk example, people will associate the intention to perform the activity with the drive home from work. The context of driving home may activate the intention and create task interference, but little or no task interference may be evidenced prior to experiencing that context.

Two recent studies support the idea that a contextual association to when the intention will be fulfilled can affect performance. Nowinski and Dismukes (2005) conducted an event-based task and had participants form the intention while learning the instructions for one of two ongoing activities that would later be interleaved with each other. The instructions for the second activity were delayed well past intention formation. They discovered much better cue detection in the task associated with the intention than in the one that was not. This outcome suggests that associating an intention with a particular context can benefit prospective memory. Cook et al. (2005) associated a time-based intention with a future context as well. Participants were asked to respond after 6 min had elapsed but before

7 min had elapsed. The experiment was split into three distinct phases (pleasantness ratings, a questionnaire, and syllable counting). Participants in the experimental conditions were told that the window of opportunity would occur in the third and final phase of the experiment. This was true for some participants when Phase 1 was quite short, and the contextual association helped these participants when compared with the participants in the control condition who did not associate the response window with any context. By contrast, when Phase 1 ran long enough to include the critical response window (but participants had the intention to respond in the third phase), time-based performance suffered markedly. Those outcomes suggest that people who link intentions to future contexts may rarely think about those intentions until the context occurs. Moreover, the context may actually cue the intention, either directly or indirectly.

The foregoing analysis implies that participants who link an event-based intention with a future context may not begin to show evidence of task interference until they enter that context. Experiment 1 investigated this issue by testing two conditions. Participants in one condition were given the event-based task of detecting words that denoted animals. This categorical intention is known to provide robust task interference on all occasions in which it has been examined (i.e., Marsh et al., 2005; Marsh et al., 2003). The group given the intention was told to expect the animal words during Phase 3 of the experiment, whereas participants in the other (control) condition were not given an intention at all. Reaction times were taken only during Phases 1 and 3, both of which consisted of making lexical decisions. If our intuitions are correct that associating an intention with a future context affects task interference, then reaction times in the control condition would remain equal across Phases 1 and 3. By contrast, in the intention condition, we expected no task interference during Phase 1, because the correct context had not yet arrived; but when that context did arrive in Phase 3, we predicted that a task interference effect would manifest itself. Experiment 2 tests these same ideas about associating an intention with a future context, but using a time-based intention. Because the predictions are more complicated for a time-based task, we will discuss them in the introduction to that experiment.

EXPERIMENT 1

The purpose of this experiment was to demonstrate that when an intention is associated with a future context, minimal or no task interference may occur until that context is reached. If these results are obtained, then it would suggest one mechanism that people can use to avoid the prohibitively expensive cost that task interference would cause in everyday cognitive processing (Einstein et al., 2003).

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. Sixty-one participants were randomly assigned to either the control condition, which had no intention ($n = 32$) or the intention condition ($n = 29$). Three additional participants were tested but were not included in the final sample. One person in each of the two conditions had aberrantly high error rates (above 25%), and another in the intention condition had inordinately long reaction times (above 1,300 msec).

Materials and Procedure. The general parameters of the ongoing lexical decision task were identical to those used by Marsh et al. (2003; Marsh et al., 2002). There were a total of 210 trials, with equal numbers of valid English words and pronounceable nonwords. The 105 valid words were chosen from the Kučera and Francis (1967) word-frequency norms. The nonwords were taken from the same source, but had one or two letters changed to form pronounceable nonwords. We used software that randomly assigned words and nonwords to trials (anew for each participant tested) under the following constraints. Phase 1 of the experiment consisted of the first 105 trials. During this phase, there were 52 word and 53 nonword trials. Phase 3 had 52 nonwords, 49 words that were not event-based cues, and 4 animal words that should have received an event-based response in the intention condition. This randomization procedure ensured that particular words and nonwords would be observed randomly in both Phase 1 and Phase 3, across the participants tested. We made up a questionnaire that asked participants about their year in school, their residence, their academic interests, and so forth. This questionnaire was administered as the second phase, which was sandwiched by the critical Phase 1 and Phase 3 lexical decision tasks.

The participants read instructions for the experiment from the computer monitor. When they were finished, the experimenter cleared the screen and reiterated the instructions verbally. The participants in both conditions were instructed on how to use the home keys to make their word versus nonword responses using both index fingers. The lexical decision task was paced by the software, in that after the participants responded to a trial, a "waiting" message indicated that the next trial would appear in a moment. In fact, the interstimulus interval between fixation points on consecutive trials was fixed at 3 sec, to facilitate conceptual comparisons with Experiment 2, herein. The participants in both conditions were also informed that the experiment had three distinct phases. They would be doing lexical decisions during Phase 1, answering questions and interacting with the experimenter during Phase 2, and then resuming the lexical decision task during Phase 3. When the experimenter reiterated the instructions, he or she also asked the participants to restate what constituted the three phases.

The participants in the event-based condition were also told that we were interested in their ability to remember to perform an activity in the future. They were asked to respond to animal words, and were given the example *monkey*. If they found such a word, they were asked to make their word response first, and then press the "/" key during the waiting message. Moreover, they were told correctly that the animal words would appear during the third and final stage, and not during Phases 1 or 2. When the experimenter was convinced that the participant understood the instructions, a 4-min distractor task was administered, during which time the participant attempted to solve mazes. No further mention was made of the prospective memory task after the maze task commenced. As in the Cook et al. (2005) study, the Phase 2 questionnaire lasted exactly 1 min and was timed with a handheld stopwatch.

Results and Discussion

Unless otherwise noted with a specific p value, the probability of a Type I error in any statistical test does not exceed 5%. Event-based prospective memory was scored as the proportion of animal words that received a "/" key response. Late responses were too infrequent to influence the interpretation of the results, and as in our past work, they were counted as incorrect. The average reaction time for words in the lexical decision task was our primary dependent measure, as it has been in some of our previous work (e.g., Marsh et al., 2003; Marsh et al., 2002). Accordingly, the data were trimmed in an identical fashion—namely, all responses greater than 2.5 standard deviations from a participant's mean were removed, as were all errors. A total of 4.6% of all trials were removed prior to final averaging.

The average reaction times to Phase 1 and Phase 3 are presented in Figure 1 for both conditions. Bars represent one standard error of the mean. A 2 (condition: control vs. intention) × 2 (phase: 1 vs. 3) mixed model ANOVA was conducted. Consistent with the impression drawn from Figure 1, condition and phase produced a significant interaction [$F(1,59) = 6.01$]. That interaction is attributable to stable reaction times across the two phases in the control condition [$t(31) < 1$, n.s.] but a marked task interference effect for the intention condition upon reaching Phase 3 [$t(28) = 3.77$]. Needless to say, those participants who held the event-based intention did not show the robust task interference effect during Phase 1, despite having an intention to respond to animal words. Therefore, the data confirm our prediction that associating an event-based task with a future context can eliminate task interference until that context is reached. Moreover, cue detection averaged 93% in the intention condition. This rate of detection is phenomenally high compared with other categorical intentions in our published studies, in which cue detection of animals has averaged about 73%. As in the Nowinski and Dismukes (2005) study, associating an event-based task with a future context actually appears to benefit performance.

We should note that Smith (2003) tested two conditions in her Experiments 1 and 2. Participants in both conditions were given the event-based task, but participants in the delayed condition were told that they would have to respond to cues after the lexical decision task was over (the control condition); participants in the other condition were told to respond during the lexical decision task. Her control condition bears some resemblance to our condition in which participants associated the intention with a future context. One main difference between the two studies is that her control participants formed an association to an ill-specified context of "later on," whereas ours formed the association to a very specific context. Another main difference is that our participants actually experienced the context and carried out their intention, whereas hers did not. Nevertheless, the present study, as well as the studies of Smith, Cook et al. (2005), and Nowinski and Dismukes (2005), converge on the idea that there are everyday intentions for which individuals can predict a specific, future context for fulfilling the intention. The present results demonstrate that intentions associated with a future context should not be prohibitively expensive because they do not create any task interference until the predicted context is reached (cf. Einstein et al., 2003).

One potential issue with the approach we have taken is that it does not specify how participants recognize that the appropriate context has arrived and that the intention is now relevant. Some might argue that recognition of that arrival is a prospective memory task just like recognizing animal words, and therefore, should require resources in much the way that recognizing animal words usurped attention from the ongoing task. Our response to such a criticism is that recognizing the arrival of Phase 3 is very much like detecting a very specific (and salient) cue. In our other work with

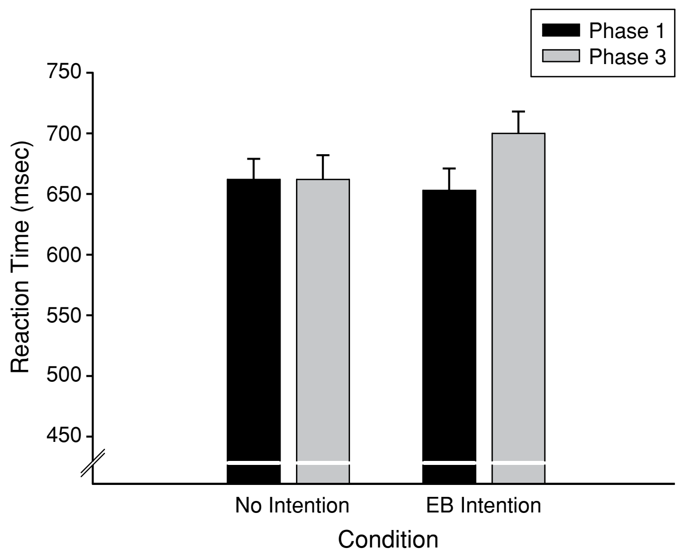

Figure 1. Reaction times in Experiment 1 for the no-intention control condition and the event-based condition, in which the intention was associated with Phase 3. Black bars denote Phase 1 and gray bars denote Phase 3. Bars are standard errors. EB, event based.

specific cues (e.g., asking participants to respond to *dog* rather than to *animals*), we often find that there is virtually no cost to the ongoing activity (see, e.g., Hicks et al., 2005; Marsh et al., 2003). By this account, detecting a specific and salient cue (arrival of the third phase) itself requires no resources, but rather triggers the intention, which in turn changes the attentional-allocation policy to be attentive to the potential detection of prospective memory cues. In this sense, no new theory of prospective memory is needed to account for the fact that task interference does not appear until the correct phase of the experiment. Nevertheless, we acknowledge that we did not measure costs during Phase 2, and it is possible that a cost would have been observed had we used a task that allowed measurement of costs.

EXPERIMENT 2

One logical question is whether similar results will be found with a time-based intention. To our knowledge, there are no published studies examining whether time-based intentions create task interference in the same way that some event-based tasks reliably do (but see Hicks et al., 2005). On the one hand, words in a lexical decision task are relevant to the intention, and the locus of the task interference effect in event-based tasks may be a consequence of slowing on intention-relevant material. By contrast, the words in the lexical decision task are irrelevant to a time-based intention. By this argument, perhaps no task interference will be found with a time-based intention. On the other hand, time-based tasks have been argued to require more self-initiated resources than event-based tasks (Craik, 1986; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). If this is true, then task interference should be found in this next experiment using a time-based intention. Therefore, the first goal of this experiment was to investigate task interference with a time-based task.

Another goal was to ascertain whether associating a time-based intention with a future context would reduce any task interference prior to reaching that context. To do so, we used a new control condition, in which participants were not given any contextual association about when the response window would occur. This goal was identical to the rationale for conducting Experiment 1. The main difference is that task interference has not hitherto been demonstrated for a time-based task, thereby necessitating running a third condition, in which participants have no contextual association about when the intention can be carried out. The third and final goal of this experiment was to explore a major difference between time-based and event-based tasks—namely, that after the time-based intention has been carried out (or the response window closes) task interference should spontaneously disappear. In event-based tasks, the intention is still operative until the final trial of the experiment. If task interference is found in the next experiment, it should be reduced or eliminated after participants realize that the response window has expired (whether or not the intention has been fulfilled).

To explore these issues, we gave participants the intention to respond after 8 min had elapsed but before 10 min had elapsed (cf. Cook et al., 2005). Two conditions were analogous to those tested in Experiment 1: a no-intention control condition and a time-based condition, in which participants were correctly informed that the response window would occur during Phase 3. The additional condition consisted of participants who were not given the association that the intention would be carried out during Phase 3. (This condition was obviated in Experiment 1 by the numerous prior demonstrations of task interference with event-based tasks.)

Method

Participants. Undergraduates from the University of Georgia volunteered in exchange for partial credit toward a course requirement. Each participant was tested individually, in sessions that lasted approximately 25 min. The participants were quasirandomly assigned to the three experimental conditions that we have labeled *no intention*, *uncertain*, and *certain*. The last two labels denote the absence of an association between the future context and intention fulfillment, and a certain association to Phase 3, respectively. Four participants were excluded from analysis: three for aberrantly long reaction times, and one for excessive errors. In the final sample, the control condition consisted of 29 volunteers, whereas the uncertain and certain conditions had 41 volunteers each.

Materials and Procedure. The basic experimental design was modeled after Experiment 1, and thus, the experiment had three distinct phases created in an identical manner, as before. The main difference was that the participants in the uncertain and certain conditions formed an intention to respond with a "/" key response between min 8 and min 10. The software was updated to provide the participants with a means of monitoring the passage of time. The participants were informed that the clock would begin at the onset of the first lexical decision trial in Phase 1 and would run continuously through Phases 2 and 3. They were told that they could check the passage of time whenever they wanted to by pressing the Z key, which would bring up a clock with the format 2:17 in the upper right-hand corner of the computer monitor. In the example given, 2 min and 17 sec had elapsed. The participants in the uncertain condition were not told when the response window would appear, whereas those in the certain condition were told that it would appear during the third and final phase of the experiment when they were making lexical decisions for the second time. Timekeeping devices such as watches and cell phones were removed from view and then returned to the participants during debriefing.

Because each trial lasted 3 sec, the duration of Phase 1 was 5 min 15 sec and the duration of Phase 2 was 1 min. Thus, Phase 3 commenced 6 min and 15 sec into the experiment. Accordingly, the response window (at 8 min) opened 1 min 45 sec into Phase 3 and closed 2 min later.

Results and Discussion

Prospective memory and clock checking. Time-based performance was counted as accurate if the "/" key was pressed in the response window. Responses occurring outside this window did not differ in the uncertain and certain conditions [$t(80) = 1.38$, $p > .15$], probably because the late responses averaged only 4.8%. Correct responding was equivalent in the two conditions, with 63% remembering in the uncertain condition and 59% remembering in the certain condition [$t(80) < 1$, n.s.; chi-square analyses confirmed this null result as well]. These data suggest that unlike event-based prospective memory, associating a time-based intention with a future context does not necessarily improve overall performance.[1] The average number of times participants in the uncertain condition checked the clock was 1.97 in Phase 1 and 2.49 in Phase 3, whereas in the certain condition, these average checks were 0.51 and 2.90, respectively. In the omnibus ANOVA, there was a main effect of phase showing that participants checked more in Phase 3 than in Phase 1 [$F(1,80) = 24.79$], there was no main effect of condition [$F(1,80) = 2.25$, n.s.], and the interaction between phase and condition was significant [$F(1,80) = 10.60$]. Whereas there was an equal amount of checking in each phase in the uncertain condition [$t(40) = 1.34$, n.s.], associating the intention and its fulfillment to Phase 3 almost completely eliminated checking in Phase 1 and localized most checking to Phase 3 [$t(40) = 5.13$].

These clock-checking data are consistent with the test–wait–test–exit model (Harris, 1984; Harris & Wilkins, 1982). In that model, people cycle through time checks and waiting periods before a final check indicates that it is time to exit the test–wait loops. Because the participants in the uncertain condition did not know that the response window would appear in Phase 3, their test–wait cycles included checks in Phase 1, whereas those in the certain condition largely did not. However, both groups tended to check the clock during the minute and a half preceding the opening of the response window, and half of the total number of checks occurred in that time period for both groups. That outcome is consistent with the fact that clock checking increases just prior to the time when a response is needed (see, e.g., Ceci & Bronfenbrenner, 1985). As evidenced by checking behavior, the association to Phase 3 in the certain condition allowed people to avoid checking the clock until Phase 3, which may indicate that they temporarily suspended the intention during Phase 1. This conjecture would be corroborated by the absence of any task interference in Phase 1 for the certain condition, as we consider next.

Task interference. The reaction time data are displayed in Figure 2, grouped by condition and then phase within each condition. The black bar summarizes reaction time during Phase 1, the light gray bar summarizes performance during Phase 3 up until the end of min 10, when the response window closed, and the darker gray bar summarizes performance from after the response window closed until the end of Phase 3. After examining the data in many ways, such as only including people who responded on time as opposed to those who did not, we discovered that finer grained analyses revealed a story identical to the one shown by Figure 2, and furthermore, that additional analyses added virtually nothing to the message that the data conveyed. Consequently, we have summarized and analyzed the data in the most straightforward fashion, which places all participants in all conditions on an equal footing (i.e., Figure 2). We conducted a 3 (condition: no intention, uncertain, and certain) $\times$ 3 (stage: Phase 1, Phase 3 through response window, and Phase 3 after response window) mixed model ANOVA, which indicated that phase and condition significantly interacted [$F(4,216) = 2.56$]. There was also a main effect of condition [$F(2,108) = 3.45$] and a marginal effect of stage [$F(2,216) = 2.79$, $p = .06$].

To analyze the significant interaction, we conducted repeated measures ANOVAs on each condition separately, and followed these up with t tests, for clarity. In the control condition, the average reaction times were not sensitive to the three phases [$F(2,56) < 1$]. As seen in Figure 2, only random fluctuation appears to affect latency. Com-

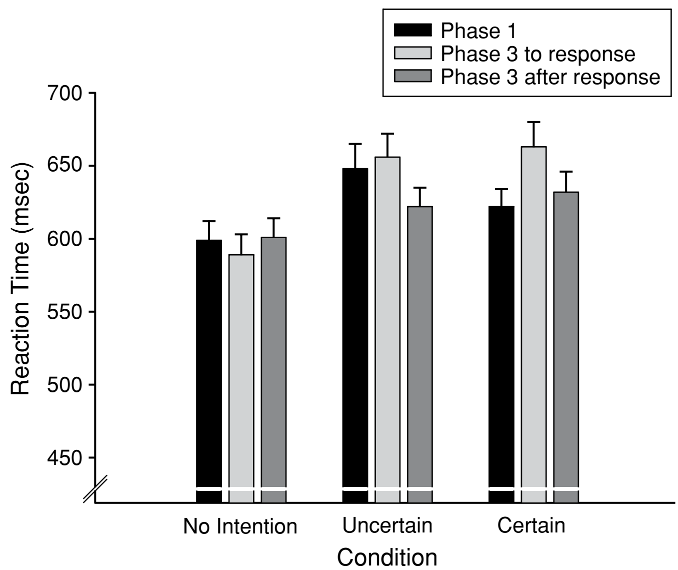

Figure 2. Reaction times in Experiment 2 for the no-intention control, uncertain, and certain conditions. Black bars denote Phase 1, light gray bars denote Phase 3 until the response window closed, and medium gray bars denote Phase 3 after the response window closed. Bars are standard errors.

paring the uncertain with the control condition, reaction times in Phase 1 were significantly slower in the uncertain condition, thereby indicating that a time-based intention causes task interference [$t(68) = 2.07$]. The same was true in Phase 3 up to the end of the response window [$t(68) = 3.03$]. To our knowledge, this is one of the first demonstrations that time-based intentions cause task interference (but see Hicks et al., 2005). For the omnibus repeated measures ANOVA on the uncertain condition, reaction times did differ across the three phases [$F(2,80) = 3.72$]. Phase 1 and the beginning of Phase 3 did not differ [$t(40) = 1.13$, n.s.], indicating that with an uncertain intention, there were equivalent amounts of task interference in both phases. The locus of the significant main effect is that task interference declined almost to the level of the control condition after the response window had closed [$t(40) = 2.59$; i.e., comparing up to the response vs. after the response]. The omnibus ANOVA on the certain condition indicated that reaction times were different across the three phases [$F(2,80) = 3.96$]. However, as seen in Figure 2, the pattern of performance is very different from the one observed in the uncertain condition. When the intention to respond is linked to Phase 3, there is a distinct absence of task interference during Phase 1 as compared with Phase 3, in which strong task interference occurs [$t(40) = 2.37$]. As in the uncertain condition, task interference declines after the response window has closed, albeit just shy of conventional significance [$t(40) = 1.94$, $p = .06$].[2] Finally, when the Phase 1 latencies in the certain condition are compared directly with the Phase 1 latencies in the control condition, they are statistically equivalent [$t(68) = 1.28$, n.s.].

Summary. This experiment has demonstrated a significant effect of task interference with a time-based intention. In addition, linking that intention to a specific future context eliminated any task interference in the context that intervened before the expected context. The same was not true for participants in the uncertain condition, who exhibited a constant interference effect right up until the response window closed. Participants in both conditions that were given an intention, however, showed evidence that task interference declines significantly after the time to respond has ended. Had we made the lexical decision task longer and analyzed only the last 50–60 latencies, perhaps we would have observed the complete elimination of task interference after the response window had passed. The important point is that as in Experiment 1, task interference can be eliminated over an intervening interval in either an event-based or a time-based prospective memory task if the intention is associated with a specific future context.

GENERAL DISCUSSION

The locus of the task interference effect has been characterized as an attentional-allocation policy that must divide a limited pool of resources between the ongoing activity and the prospective memory task (Marsh et al., 2005; Smith, 2003). As McDaniel et al. (2004; see also McDaniel & Einstein, 2000) have noted, maintaining an intention in an active state of readiness over the longer term would seem to be prohibitively expensive in terms of its deleterious effect on ongoing activities. We hypothesized that one way to off-load this cost would be to form a very specific intention and consider the future contexts that one might be in when the next opportunity to fulfill the intention would arise. Doing so would mean that an attentional-allocation policy toward an ongoing activity would not have to be modified until a context was reached that was linked to an intention. The data from the two experiments reported here are consistent with that hypothesis. With both an event-based and a time-based intention, linking the fulfillment to a specific context eliminated the task interference in a context that preceded the expected context. Consequently, this association may be one way that everyday intentions do not interfere, say, throughout one's workday.

The results from Experiment 2 suggest that ill-specified intentions will carry greater costs until they can be fulfilled. That is, uncertain conditions may cause task interference in contexts in which interference might otherwise be avoided. For example, if one is about to attend a meeting and then realizes that an exam being given tomorrow needs to be photocopied, it may be less efficient to form the intention to do it "later today" than to form a more specific intention to take it to one's secretary just before going to lunch. In this way, perhaps less task interference will be observed over the course of the meeting. The results of Cook et al. (2005) also suggest a higher probability of remembering to perform the task (as do those of Nowinski & Dismukes, 2005). Perhaps this is why implementation intentions have been found to increase performance (Chasteen, Park, & Schwarz, 2001; Gollwitzer, 1999; Gollwitzer & Schaal, 1998). When forming the intention to, say, take medication every day, people have a lower rate of adherence if they simply form a very general intention to do so. Adherence is higher if they formulate a very specific plan that includes a context, such as taking the medicine right after brushing their teeth in the morning.

Only a very small number of studies have examined how linking an intention to a future context affects prospective memory. The present results suggest several tangible benefits, including optimizing one's attentional-allocation policies and improving ultimate performance. The downside, of course, has been demonstrated by Cook et al. (2005)—namely, if the expected context at intention formation is wrong, then fulfillment can suffer. With time-based intentions, the response opportunity may pass before the expected context is reached, which will happen when intervening activities take longer than expected. With event-based intentions, a cue may not appear in the expected context, such as when a friend does not stop by or a colleague is home sick and does not come in to work. Under what circumstances the benefits outweigh the potential pitfalls of associating an intention with a future context is unclear. Further work will be needed to clarify these relations.

Another understudied aspect of prospective memory concerns the habitual intentions that people form. We have never solved the problem of how to study a preexisting habitual intention in our laboratory, and we speculate that others have faced the same hurdle (but see Einstein, McDaniel, Smith, & Shaw, 1998). As it relates to the present study, we suspect that habitual intentions cause no task interference at all. Rather, being in a particular context may cue the intention and support fulfilling it. For example, being in the bathroom in the morning may cue the intention to take vitamins, but being in the same location in the evening should not. Instead, it may cue other habitual intentions, such as brushing one's teeth or checking to see that an outside door has been secured for the evening. Our point is that habitual intentions may represent the quintessential class of intentions that are linked to specific contexts. If researchers in this field can overcome the obstacles to testing habitual intentions in the laboratory, they could have a preestablished set of intentions already linked to specific contexts.

Beyond the practical implications of this study, the results do inform theories of prospective memory. The PAM theory may only apply when people enter a context in which they expect to find event-based cues. No mechanism in PAM specifies when preparatory attention will be exhibited and when it will not. In Experiment 1, had an event-based cue been embedded in Phase 1, presumably it would have been detected poorly, because preparatory attention was not activated until Phase 3 context began. To the extent that it was detected, it would have been detected automatically, without the benefit of preparatory attention. Consequently, the present results suggest that PAM is a good start on a theory of event-based memory, but it may only represent the more cue-focused processes, as described in the MPV theory. In MPV, detection is either cue focused, and requires resources, or it is automatic. Which type of detection occurs depends on the particular circumstances of the prospective memory task. Neither theory informs the results found in Experiment 2, with a time-based intention (and neither was intended for time-based tasks). Nevertheless, we have demonstrated that task interference, the hallmark footprint of a more conscious attentional-allocation policy, applies equally well to both time-based and event-based tasks. Thus, both PAM and MPV will need to accommodate the fact that either kind of prospective memory that is linked to a future context eliminates task interference until that context is reached.

One residual sticking point for PAM is that we observed no cost prior to Phase 3 when the intention was linked to that context. The central tenet of PAM is that preparatory attention is necessary in order to realize that an intention can be fulfilled. Given that no preparatory attention was observed prior to Phase 3, by what mechanism(s) does the intention come to mind? In the discussion of Experiment 1, we suggested that the occurrence of Phase 3 acted like a salient reminder of the intention, and that the intention can be recognized without preparatory attention. Of course, that assumption is antithetical to the central tenet of PAM. Any modification to PAM suggesting that bringing an intention to mind can be automatic undercuts that particular theory, and tips the balance in favor of MPV, which does allow for intentions to come to mind automatically.

Perhaps a good accommodation for PAM may be our own arguments that different attentional-allocation policies are set at the outset of each new task (Marsh et al., 2005). When one is contemplating beginning a new task, an intention may come to mind if it is to be completed during that time frame. As mentioned earlier, this could occur because the new task explicitly reminds one of the intention or because it simply increases the activation level of the intention in memory. When one is allocating an overall amount of attention to the new task—or allocating attention to different components of task performance—whether tasks or subtasks require some degree of attentiveness toward an intention is factored into those policies. If the intention is associated with a different context (or task), then the attentional-allocation policy is made without regard to the intention. Support for this approach is found in work by Sellen, Louie, Harris, and Wilkins (1997), who showed that people tend to think about intentions in between tasks and prior to commencing new tasks. Moreover, Hicks et al. (2000) have shown that increasing the number of breaks in an ongoing task increases prospective memory performance. We propose that breaks and starting new tasks serve to reset attentional-allocation policies, which is why task interference does not occur when an intention is linked to a different context. In sum, much remains to be learned about intentions associated with specific contexts versus those that are not. The present study suggests that this aspect of prospective memory is worthy of further, careful scrutiny.

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NOTES

1. Cook et al. (2005) found that associating a time-based intention to a specific phase of the experiment improved time-based prospective memory, which does not replicate the equivalent performance found here. However, there are marked differences in procedures between the two studies, not the least of which is that in the present study, the window to respond came very much later in the task and the response window was twice as long (2 min in the present study and 1 min in the other study). Thus, ample opportunity to respond and a leisurely window of opportunity, as in the present study, can overcome the benefit to knowing when a response is required.

2. Readers may note that the reaction time data for the period after the response window closes reflects an average of those participants who made a time-based response and those who did not. Technically, the decline in task interference should be most pronounced for those who actually made their time-based response on time. The data were analyzed by adding a between-subjects factor of whether a successful response was made. As would be expected, the pattern in Figure 2 was accentuated for those who made their response, but it was attenuated for those who did not. Success at responding did not interact with any other variable, suggesting a decline in task interference for those who responded and those who did not, but we report this analysis cautiously, because the power to detect these effects is somewhat small when the data are analyzed in this fashion.

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