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Associating a Time-Based Prospective Memory Task with an Expected Context Can Improve or Impair Intention Completion

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SUMMARY

Three experiments investigated time-based prospective memory defined here as remembering to fulfil an intention during a later window of time. When people associated the response window with a future context, time-based responding was better if that context expectation was correct as compared with having no context expectation at all. By contrast, if the response window occurred in a context that preceded the expected context, time-based performance was worse than having no context expectation at all. An explicit reminder about the intention was sufficient to ameliorate the decrement found with an incorrect context association. However, successfully completing a different, event-based prospective memory intention was not sufficient to overcome the incorrect context association. The authors assert that possessing such associations alters normal monitoring of the passage of time which in turn leads to the pattern of results obtained. Copyright © 2004 John Wiley & Sons, Ltd.

Human memory is studied in controlled laboratory settings, in part, because the principles that are acquired can be applied to improve everyday cognitive functioning. One area of memory that has the potential for direct and immediate application is understanding how people successfully remember to complete their intentions; and that is the focus of this article. Generally speaking, when an activity cannot be carried out immediately, the intention to perform it later is stored as a declarative representation in memory (e.g. Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998). Either through self-initiated retrieval or in response to cues in the environment, the intention is eventually recollected at an appropriate time when the activity can be performed. Scientific inquiry on remembering to complete intentions has been labelled prospective memory and this research domain has gained increasing prominence in the last decade. Nevertheless, given its central importance in our everyday lives, the topic still remains vastly under-studied today. Consequently, only event-based and time-based intentions have been explored in any detail and the latter type of memory has received short shrift as compared with the former type.

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Event-based intentions are those in which an environmental cue triggers recollection such as when an overdue library book reminds one of the intention to return it (e.g. Einstein, Holland, McDaniel, & Guynn, 1992; Ellis, Kvavilashvili, & Milne, 1999; Maylor, 1996, 1998; McDaniel, Robinson-Riegler, & Einstein, 1998). Most event-based studies ask participants to respond overtly to a cue (or class of cues) when they occur in some ongoing activity such as making pleasantness ratings on items, identifying faces, answering trivia questions, and so forth. The ongoing activity simulates the cognitive demands of everyday life during which cues about intentions need to be recognized. By contrast, time-based intentions are activities that one must complete at a specific time such as attending a meeting or that must be performed after some amount of time has elapsed such as removing food from the oven or stove (Einstein & McDaniel, 1990; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Similar to event-based prospective memory tasks, studies of time-based intentions also engage participants in an ongoing task and ask them to perform some action after a specified duration has elapsed.

The present inquiry focuses on time-based prospective memory because very little empirical work currently exists about such intentions. Most studies of time-based performance address the question of how performance compares to event-based tasks. Ostensibly, such intentions are somewhat more difficult to complete successfully as compared with event-based tasks (e.g. Craik, 1986; Einstein et al., 1995). The alleged increase in difficulty stems from the fact that the environment usually does not provide retrieval cues for time-based intentions (perhaps with the exception of clocks), and therefore, people must rely mainly on their own self-initiated monitoring of the perceived passage of time. There is mixed evidence for the difference in difficulty insofar as older adults have reduced self-initiated processing and consequently should exhibit decrements on time-based tasks. Such evidence has been found in some studies (e.g. Einstein et al., 1995; Martin & Schumann-Hengsteler, 2001) but the absence of a difference or even better performance by older adults on a time-based task has also been reported (e.g. d'Ydewalle, Bouckaert, & Brunfaut, 2001; d'Ydewalle, Luwel, & Brunfaut, 1999). Unfortunately, there is no existing theory about how time-based intentions are successfully completed, except one slightly dated theory based mainly on intuition (Miller, Galanter, & Pribram, 1960). That theory, called the test-wait-test-exit (TWTE) model, simply asserts that people cycle through stages of testing to see if an appropriate amount of time has elapsed to initiate intention completion (Harris & Wilkins, 1982). If it has not, then they wait an additional period of time before testing again. Eventually, the time criterion will be reached and they can exit the cyclical test-wait process to fulfil the intention.

Although the TWTE model has intuitive appeal, it does not specify the underlying cognitive constructs that cause time-checking (i.e. testing) behaviour. That model also does not explain subtle performance differences between different types of time-based intentions such as pulses and steps (Ellis, 1988). Time-based pulses are intentions to perform an activity at a specific time (e.g. meet a friend for lunch at 12:15) whereas time-based steps are intentions that can be completed within a larger window of time (e.g. visit a relative some time on Saturday afternoon). Often times pulses are completed more frequently than steps, perhaps because of perceived or real differences in importance between the two types of intentions. Regardless, our goal is not to supplant the TWTE model, rather our goal is to collect additional empirical evidence concerning time-based intentions that will inform what variables may mediate laboratory-based (and real-world) testing of elapsed time. After all, the critical component of the TWTE model is the time checking that either leads to additional waiting or exiting to intention completion.

We hypothesized that when many intentions about activities that are to be performed on any given day are encoded into memory, people make an association between the intention and a future context in which the activity will likely be carried out. This hypothesis is probably equally true for event-based as well as time-based intentions. For example, intending to give a colleague a message (an event-based task) is probably associated with the next time one plans on being at work, despite the fact that one could easily run into the person at the supermarket. In the same way, intending to call a friend may be associated with a future context such as being at home some evening after dinner. One recent study delivered the intention in the context of explaining one of two different ongoing activities that would be performed later (Nowinski & Dismukes, in press). The second ongoing task was explained later. Event-based cues occurred in both ongoing tasks, but people remembered to respond more often in the context associated with the intention at learning. Nowinski and Dismukes argued that the expected context cued the prospective memory task, thereby increasing performance. Based on this work we predicted that if either a cue or a time-window occurs in an unexpected context, intention completion may suffer relative to (1) its occurrence in the correct context, or (2) as compared with an intention that lacks any particular context expectation.

With respect to time-based intentions that are the focus of this study, the occurrence of an expected context may cue the intention which in turn causes clock-checking behaviour. The absence of the expected context having occurred yet may indicate that clock checking is not yet needed. These predictions also can be derived directly from the automatic association theory of event-based prospective memory (Guynn, McDaniel, & Einstein, 2001; McDaniel et al., 1998). That theory merely predicts that with enough activation accruing to the intention, it will eventually reach consciousness; and in the present case, we have merely assumed further that this will cause clock checking (i.e. time testing that would be needed in the TWTE model). As an everyday example, many cooks will not set a timer to remove something from the oven if they expect to be in the kitchen when the appropriate time has passed. If, however, they are in another room the activation level of the intention may wane without support from the kitchen context, and consequently, the intention may get fulfilled late (or worse the food may be ruined).

An alternative possibility to the activation account is that entering the expected context explicitly cues recollection of the intention and that in turn causes clock-checking behaviour (and intention fulfilment). In this case, the rememberer would basically be relying on the context to cue the intention in much the same way people must rely on a cue to evoke an intention in studies of event-based prospective memory. Determining which of these two mechanisms is operative will be difficult because, as just noted, increased activation would also support the intention eventually reaching consciousness. Nevertheless, the purpose of the study is to examine whether associating a time-based intention with being in a future context affects intention completion, regardless of whether the underlying theory can be specified unambiguously at this time.

By way of overview, in the first experiment we asked people to make a time-based step response after 6 min but before 7 min had elapsed in the experiment. We divided the ongoing task into three distinct phases. Some people were told to expect the 6–7 min response window to occur in the third phase when they were performing a particular task (making syllable ratings). In fact, this was correct for some participants and incorrect for other participants for whom the response window actually occurred during the first phase (when making pleasantness ratings). This latter condition simulates real-world conditions in which one anticipates being able to complete an intention at a particular time and in a particular context but the prior activities take longer than expected. For example, one may need to make a phone call or obtain something from one's secretary after a meeting, but if the meeting runs long, the time window may have expired or the secretary may have already left for the day. As comparison conditions, we also tested people who did not associate the time-based intention with any phase in the experiment which we assume simulates those real-world intentions that lack any expected context association. To foreshadow, Experiments 2 and 3 address potential ways to ameliorate the performance deficit observed in Experiment 1.

EXPERIMENT 1

Participants in two conditions were asked to form the intention to respond with a special key press during a 6–7 min window. They were further told that they could expect this window to occur in the third phase of the experiment when they were making syllable ratings on words. The instructions, however, were clear that they could nevertheless check the computer's clock whenever they wished to assess how much time had elapsed in order to successfully complete the time-based intention. In one of these two conditions, the first and second phases were rather short, and the response window occurred in the third phase as expected. In the other condition, the first phase was protracted and actually ended at the end of the response window. Thus, in this latter case, the response window did not occur in the context in which it was expected but occurred in a context that preceded it. If the expected context serves as a cue to check the elapsed time, then we predicted much better time-based prospective memory performance in the former condition as compared with the latter one. In such cases, the expected context comes too late and it would have been advantageous to monitor the passage of time in order to interrupt the current activity. As comparison conditions, we also tested these same two conditions but did not suggest anything to participants about when the response window might occur.

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. One-hundred and twenty-seven participants were quasi-randomly assigned to one of the four between-subjects conditions. Cell *N*s are specified in Table 1 and they are slightly unequal because two different experimenters were testing participants under all conditions cotemporaneously.

Materials and procedure

Regardless of assigned condition, all participants experienced three distinct phases in the experiment. In the first phase, they made pleasantness ratings using a 5-point Likert scale of words presented in the centre of the computer monitor. In the second phase, they orally answered a series of demographic questions asked by the experimenter. In the third phase, they counted the number of syllables in a different set of words from that used in the first phase. The words came from a pool of 210 medium frequency words selected from the

Table 1. Average prospective memory performance and average number of clock checks for each condition in Experiments 1–3

Experiment and condition	Cell *N*	Prospective memory	Number of clock checks: Total	Phase 1	Phase 2
Experiment 1					
Expected context (Phase 3)					
Short-first	35	0.71	2.31	0.34	1.97
Long-first	36	0.28	2.78	1.53	1.25
No context expectation					
Short-first	29	0.48	3.34	0.83	2.52
Long-first	27	0.56	3.11	3.04	0.07
Average	56	0.52	3.23	—	—
Experiment 2					
No reminder	32	0.25	2.34	1.06	1.28
Reminder at 1 min	27	0.52	3.93	3.70	0.22
Reminder at 5 min	26	0.54	3.35	3.00	0.35
Experiment 3					
No reminder	34	0.29	2.06	1.56	0.50
EB cue at 1 min	37	0.13	1.94	1.05	0.89
EB cue at 5 min	37	0.05	1.46	0.35	1.11

Note: EB = Event-based; — = not meaningful.

Kučera and Francis (1967) compendium. All of these words were randomly assigned anew to trials for each participant tested. The demographics questionnaire was made in-house and it asked innocuous questions about the participants' class year, intended focus in school, etc.

Two prospective memory conditions were tested that differed only in the timing of the three phases which is depicted in Figure 1 for clarity. In what will be referred to as the long-first condition, there were 140 pleasantness ratings (Phase 1) and 70 syllable counting judgments (Phase 3), for a total of 210 judgments. By contrast, in what we have named the

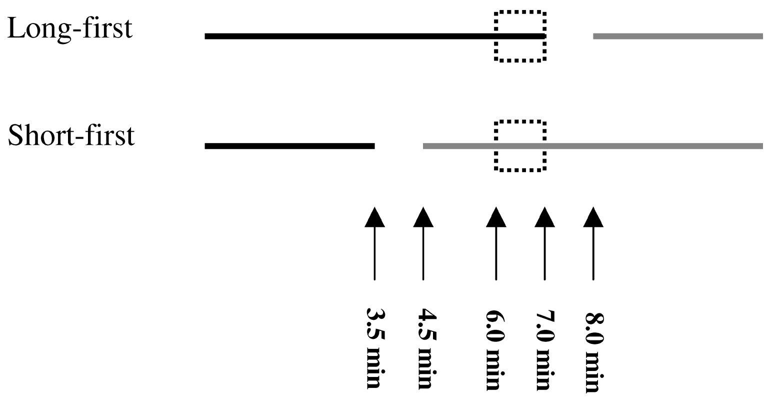

Figure 1. The timing of the three phases in Experiment 1. The black line denotes the duration of Phase 1 (pleasantness ratings), the gap between lines denotes the 1 min demographic questionnaire, and the grey bar denotes the duration of Phase 3 (syllable ratings). The box encapsulates the window when the time-based prospective memory response should have been made (6–7 min). Key time points are specified with arrows

short-first condition, there were 70 pleasantness judgments and 140 syllable counting judgments. Each trial lasted 3 s, so the pleasantness rating task took 7 min in the long-first condition, and 3.5 min in the short-first condition. Both conditions were given a time-based step intention to respond by pressing the /-key after 6 min but before 7 min had elapsed. They were further informed that because the computer was pacing each trial, they should anticipate that the 6–7 min window would occur during the syllable counting task after the demographics questionnaire had been administered. However, all participants were told that they should check the computer's clock by pressing the Z key whenever they wanted to know how much time had elapsed from the first pleasantness rating trial. Doing so brought up a small clock in the upper right-hand corner of the computer monitor in the form 4:23 which indicated that 4 min and 23 s had elapsed.

Obviously, the association of the appropriate response window occurring in the syllable counting task was incorrect for the long-first condition, but was correct for the short-first condition. In the long-first condition, the syllable counting task began 8 min into the experiment after both pleasantness ratings (7 min) and the demographic questionnaire (1 min). In the short-first condition, the syllable task began 4.5 min into the experiment after pleasantness ratings (3.5 min) and the questionnaire. As comparison conditions, another two conditions were given the same intention to respond in the 6–7 min window, but expectation of the syllable counting context was omitted from the instructions. These two comparison conditions conformed to the timing of the phases for the long-first and short-first conditions, respectively. In this fashion, the four conditions differed insofar as two were expecting the window to occur during the third, syllable counting phase and two conditions had no such expectation of when the appropriate window would occur.

All instructions for the experiment were initially read from the computer monitor. When the participant had finished reading them, the screen was cleared and the experimenter verbally reiterated all of the instructions. Any questions were answered at this time and all participants were asked to remove any time-keeping devices such as watches and cell phones. A 5-min distractor task of working on mazes was administered before the ongoing task was commenced without any mention of the tasks that were to be performed. The experimenter timed the entire experiment with a hand-held stop watch and used this to pace the demographic questionnaire to exactly 1 min. At the end of the experiment, a short post-experimental questionnaire was administered to verify that all volunteers understood all of the tasks that we had asked them to perform.

Results and discussion

Unless specified otherwise with a p value, the probability of a Type I error does not exceed 5%. The data are summarized in the top portion of Table 1. We first discuss the average time-based prospective memory performance, and then consider the average number of clock checks. Because the prospective memory dependent measure was binary (participants made the time-based response or they did not), some readers may rightfully question using standard inferential statistical techniques. Therefore, we report comparisons both with standard approaches and chi-square analyses. Time-based performance was scored as correct if the response occurred in the 6–7 min window and incorrect if it was omitted or the response occurred outside this window.

Prospective memory was statistically equivalent in the two comparison conditions where the response window was not associated with any particular context, $t(54) < 1$, ns. Consequently, performance in these conditions was pooled and compared to the short-first and long-first condition (see the row in Table 1 labelled average). Time-based prospective memory was significantly different among the three conditions, $F(2, 124) = 7.44$, $\chi^2(2) = 13.60$. In addition, expecting the response window to occur in the correct context (short-first condition) improved performance relative to the comparison conditions that held no context expectation, albeit just shy of conventional significance, $t(89) = 1.91$, $\chi^2(1) = 3.44$, $p = 0.06$. The opposite result was obtained in the long-first condition. When the first phase subsumed the response window which was expected to occur in the third phase, performance was much worse than the comparison condition, $t(90) = 2.32$, $\chi^2(1) = 5.17$. Therefore, the data indicate that associating a time-based intention with a future context improved performance when the expected context was correct, but that association was quite detrimental to performance if the expected context was incorrect and the response window actually occurred in an earlier context.

Of course, the reader will note that the design of the long-first and short-first conditions confounds time and number of context changes prior to the arrival of the response window. More specifically, there are two context changes in short-first condition and none in the long-first condition. The number of intervening tasks has been shown to affect event-based prospective memory, with more intervening tasks improving prospective memory (Hicks, Marsh, & Russell, 2000). This outcome was obtained in the two conditions with a context expectation, but the opposite pattern can be seen numerically in the two comparison conditions (i.e. two context changes resulted in nominally worse prospective memory). If number of context changes were reliably affecting performance, the pattern of effects should have been the same in the context expectation conditions as compared with the comparison conditions, but it was not. Therefore, context expectation appears to be driving the performance differences and the number of context changes, *per se*, preceding the response window does not consistently affect time-based prospective memory.

The total number of clock checks reflects checking behaviour prior to actually making the /-key response or through minute 7. Thus, only a very few clock checks were excluded from analysis in which a participant checked after successfully making the /-key response. We have also provided the average number of clock checks in each phase of the experiment to provide additional insight into clock-checking behaviour. The total number of clock checks did not differ between the two conditions that lacked an expectation about when the response window would occur. Consequently, we pooled these two conditions together as we did for the prospective memory accuracy analysis. The omnibus test among the three conditions revealed no overall difference in total clock checks, $F(2, 124) = 1.87$, ns. However, examining the distribution across the two phases suggests that people in the short-first condition checked mainly in the correct context (Phase 3), $t(34) = 9.61$. Of course, participants in this condition had a shorter Phase 1 than Phase 3 whereas the long-first condition had more time to check in Phase 1 than in Phase 3. Nevertheless, the long-first condition had an equal number of clock checks in each phase, $t(35) < 1$. Therefore, people who expected the response window to occur later simply waited to check the clock until the expected context arrived, by which time it was literally too late to respond.

Finer grained analysis of the clock-checking data is consistent with the idea that an incorrect context association is an impediment to checking prior to the critical window. First, more clock checking occurred during Phase 1 in the long-first condition without an associated context (3.04) as compared to when there was an association to Phase 3 in the long-first experimental condition (1.53), $t(61) = 2.39$. Second, all of the Phase 3 clock checking in the long-first condition (1.25) comes from the 72% of the participants who missed the response window in Phase 1 and failed to make their time-based response.

Third, if one examines clock checking in the critical 1.5 min prior to the beginning of the 6–7 min response window, there is substantially more clock checking in the short-first (1.91) as compared with the long-first condition (1.05), $t(69) = 2.52$. Clearly this last comparison indicates that people who entered the expected context (short-first) checked the clock more because they were in the expected context (i.e. the context cues them to check). Fourth, and finally, we correlated time-based performance with clock checking. Because our sample sizes are small, these correlations should be interpreted with caution. There was a small and nonsignificant positive correlation pooling over all conditions of 0.13. Finer grained analyses of each condition alone revealed the clock checking in Phase 1 was positively correlated only for the long-first condition, 0.77, and negatively correlated with Phase 3 clock checking, −0.35. Thus, participants in the incorrect context expectation condition who checked the clock during the first phase overcame the incorrect association whereas those who relied on the association did not. In sum, the appearance of the Phase 3 context increased clock checking for both the short-first and long-first conditions, but it helped only the short-first condition because the response window occurred in that phase. Participants in the long-first condition did not check as much until the expected Phase 3 context, and as stated before, by which time it was too late to respond successfully.

The outcomes from this experiment very clearly demonstrate that a correct expectation of the context one will be in during the response window improves time-based prospective memory performance. Moreover the locus of the improvement appears to be that the correct association causes clock checking at an appropriate time. By contrast, when the response window opens (and closes) prior to the arrival of an expected context, people have not adequately monitored the passage of time and they miss their opportunity to fulfil the intention. The remaining two experiments investigated whether the poor prospective memory performance accruing from an incorrect context association could be ameliorated.

EXPERIMENT 2

In looking for mechanisms that might overcome the incorrect association between the response window and the expected context we turned to other studies of prospective memory. With event-based prospective memory, reminders are sometimes effective at improving intention completion (e.g. Einstein & McDaniel, 1990; Guynn, McDaniel, & Einstein, 1998; McDaniel, Einstein, Graham, & Rall, 2004). The most effective reminders are ones that convey information about the cue and the target action to be performed. To our knowledge, there have been no laboratory investigations of reminders influencing time-based prospective memory. Nevertheless, receiving a reminder in the first phase of the experiment should activate the intention and perhaps cause people to monitor the clock when otherwise they may have waited until the third phase. We also manipulated when the explicit reminder occurred. In one condition, the reminder appeared 1 min into Phase 1 (5 min prior to the response window) and in another condition it appeared 5 min into the first phase (1 min prior to the response window). Should a difference manifest itself between the two different placements of the reminders, we predicted that the reminder closer to the response window (5 min into Phase 1) might produce better performance. This prediction stems from the fact that we expected people to check the clock soon after the reminder, and if the time to respond was closer, we expected that might cause people to abandon the strategy of relying on the context change to remind them of their intention. We also tested the long-first condition again without any reminder for purposes of replication and to provide a baseline against which the two conditions that received a reminder could be compared.

Method

Participants
Undergraduates from the University of Georgia volunteered in exchange for partial credit toward a course requirement. Each participant was tested individually and none had participated in Experiment 1. Participants were quasi-randomly assigned to the three experimental conditions. The distribution of the 85 participants to the three conditions can be found in Table 1.

Procedure
All three conditions were tested using the methodology specified for the long-first condition in Experiment 1. That is, all participants were asked to respond during the 6–7 min window, were told that this would likely occur during the third phase of the experiment, and were asked to check the passage of time whenever they wanted to do so. The two reminder conditions received an unexpected 5 s message either 1 or 5 min into the Phase 1 pleasantness rating task. The message read 'Please remember to press the /-key between 6 and 7 minutes.' After 5 s the screen was cleared and the next word in the pleasantness rating task appeared. In all other respects the procedure was identical to that used in Experiment 1.

Results and discussion

The data are summarized in the middle portion of Table 1. The poor performance that results from expecting the response window to occur in a different, later context was replicated (see the row labelled no reminder). By contrast, the explicit reminders dramatically improved performance, omnibus $F(2, 82) = 3.31$, $\chi^2(2) = 6.35$. In addition, performance in each of the two reminder conditions was higher than the no reminder control condition, smaller of the two statistics: $t(57) = 2.17$, $\chi^2(1) = 4.52$. Although there was nominally (2%) better performance when the reminder occurred closer to the response window (at 5 min), performance in the two conditions receiving reminders did not differ statistically from one another, $t(51) < 1$, ns. That null outcome is consistent in spirit with the claim that multiple reminders do not serve to further increase event-based prospective memory (Ellis et al., 1999). Rather than frequency or location of the reminder, whether one receives a single reminder at all appears to be the critical variable. Consequently, the results from this experiment demonstrate that time-based intentions benefit from reminders as event-based prospective memory tasks can sometimes benefit. Although some readers might not find that result surprising, the outcome is important for several reasons. First, reminders have never been tested with a time-based task, and certainly not when they significantly precede the time in which an activity must be carried out. Second, reminders do not always improve prospective memory such as when they are ever-present and people habituate to them within several minutes (Vortac, Edwards, & Manning, 1995).

The clock-checking data are informative about the underlying mechanism of improvement. More specifically, the average total number of clock checks prior to the response window was greater in the two reminder conditions as compared with the no reminder control condition, albeit just at the cusp of traditional significance, $F(2, 82) = 2.90$, $p = 0.06$. This outcome strongly suggests that the reminder served to prompt clock checking which in turn increased the probability of fulfilling the intention. This interpretation can be verified in a number of different ways, but it is observed most strongly by examining the Phase 1 clock checking alone (see Table 1). The number of checks in this phase alone was approximately three times higher in both reminder conditions as compared with the no reminder control, $F(2, 82) = 8.89$. As in Experiment 1, participants who did not receive a reminder split their clock checking evenly between the two stages, $t(31) < 1$, whereas those in the reminder conditions confined their clock checks to the appropriate Phase 1 despite their expectation of the response window occurring in Phase 3, smaller of the two $t(26)$'s $= 5.14$. In addition, pooling over both reminders conditions, more clock checking occurred in the 1 min following the reminders (1.52) as compared to not receiving any reminder at all (0.42), $t(83) = 2.44$. Finally, we correlated clock checking with time-based prospective memory performance. Clock checking in Phase 1 was positively correlated with performance (0.42) whereas checking in Phase 3 was negatively correlated (-0.40). Moreover, these correlations were found in each condition separately which suggests that overcoming the wrong contextual association requires that one check the clock early (in Phase 1). In summary, like an expected context, the reminders increased clock checking and they helped to overcome the incorrect context association.

If we are permitted to make the cross-experimental comparison to Experiment 1, a reminder was only effective in increasing time-based performance to the level of having no context expectation at all. The reminder did not increase performance to the level in Experiment 1 where the response window actually occurred in the expected context. From this perspective, a reminder ameliorated performance deficits from associating an incorrect context during intention formation, but it did not fully undo the detrimental impact of possessing the wrong context association. Nevertheless, the reminder had its effect by causing people to check the clock more often prior to the occurrence of the critical time window.

EXPERIMENT 3

Because the reminders were partially effective at overcoming an incorrect context association to when the response window would occur, we tried a different type of reminder in Experiment 3. All participants were given both the time-based intention used in the previous two experiments and an additional event-based intention. The event-based task was to press the same response key (/) when a particular word appeared. That word appeared exactly 1 min or 5 min into the Phase 1 pleasantness rating task (i.e. exactly when the explicit reminders were delivered in Experiment 2). We hypothesized that completing the event-based intention might cue the time-based intention in much the same way that giving a reminder did in Experiment 2. In addition, these conditions also test performance under dual-intention conditions. To our knowledge, no published study exists in which participants are given both a time-based and an event-based intention simultaneously. Having two intentions may improve performance on the time-based task more generally (independent of responding to the event-based task) because people who have greater numbers of intentions tend to complete a higher percentage of them as compared with those who have fewer intentions (see Park et al., 1997). In addition, there is real-world evidence that people tend to think about other intentions after completing an intention (Sellen, Louie, Harris, & Wilkins, 1997). As a baseline measure of performance, the long-first condition was tested again without the extra event-based intention.

Method

Participants

The 108 participants were University of Georgia undergraduates who volunteered in exchange for partial credit toward a course research requirement. Each participant was tested individually and none had participated previously in any study concerning prospective memory. The quasi-random assignment of participants to the three conditions resulted in the cell sizes given in Table 1.

Procedure

As in Experiment 2, the methodology of the long-first condition was used for all participants in this experiment. After delivering the time-based intention, the instructions added that participants should press the / response key whenever they encountered the word *tiger*. The word appeared on Trial 20 (1 min into Phase 1) or Trial 100 (5 min into Phase 1), and it occurred just that one time. No event-based prospective memory task was given to the baseline long-first condition, and so these participants had only the one (time-based) intention. As in Experiments 1 and 2, there was a 5 min distractor task of working on mazes after the instructions and prior to commencing the Phase 1 pleasantness rating task.

Results and discussion

We begin by considering performance on the event-based task in the two dual-intention conditions. Performance was better when the cue word appeared 1 min ($M = 95\%$, $SE = 3.77$) into Phase 1 as compared with 5 min ($M = 54\%$, $SE = 8.33$), $t(72) = 4.45$. Event-based prospective memory is usually good with a specific cue word, and the lower performance in the 5 min condition most likely reflects more forgetting that had occurred since forming the intention 10 min earlier. The critical outcome, as can be seen at the bottom of Table 1, was that time-based prospective memory was not improved by simultaneously holding the event-based intention. However, there were significant differences in time-based performance, $F(2, 103) = 4.15$, $\chi^2(2) = 7.91$. Contrary to our expectation, possessing the event-based intention decreased time-based performance even further. Performance was nominally lower when the event-based cue occurred at 1 min as compared with the long-first control condition, $t(69) = 1.65$, $\chi^2(1) = 2.68$, $p = 0.10$, and statistically lower when it occurred at 5 min, $t(69) = 2.81$, $\chi^2(1) = 7.27$. Because so few participants responded in the two dual-intention conditions, conditionalized analyses based on successfully detecting the event-based cue yielded virtually the identical story just described.

The overall number of clock checks did not differ among the three conditions, $F(2, 105) = 1.49$, ns. However, the distributions of that checking between Phases 1 and 3 was not the same in the three groups. More specifically, the number of clock checks in Phase 1 differed significantly among the conditions, $F(2, 105) = 6.02$. More clock checking occurred in Phase 1 prior to the expected context than in Phase 3 for the control condition that exhibited the highest time-based performance in this experiment, $t(33) = 3.04$. By contrast, the same number of checks or significantly fewer of them occurred in Phase 1 as compared with Phase 3 for the two dual-intention conditions, $t(36)$'s < 1 and $= 3.11$, respectively. Therefore, once again, increased clock-checking behaviour in the appropriate phase predicts successful time-based performance even at this low end of the response scale. Unfortunately, simultaneously possessing event-based and time-based intentions appears to have caused participants to rely more on the context association for the time-based intention and they checked less frequently in Phase 1 when they believed the response window would not occur. The correlations between time-based responding and clocking replicated Experiment 2 insofar as there was significant positive correlation with Phase 1 checking (0.40) and a significant negative correlation with Phase 3 checking (−0.43). This result suggests that checking prior to the expected context is an effective strategy to overcome the incorrect association. Pooling over all participants in all conditions of the three experiments replicates statistically significant positive and negative correlations with Phase 1 and Phase 3 checking (0.32, −0.20, respectively), but also reveals a significant positive correlation with overall clock checking (0.21, $p < 0.001$). Thus, as might be expected, with sufficient power, we can demonstrate the obvious fact that more checking increases the probability of successful responding.

Although there are a number of plausible explanations for the deleterious effect on time-based performance from concurrently possessing an event-based intention, we briefly describe two accounts. According to some theories, detecting an event-based cue places a load on working memory which reduces the amount of resources for performing other tasks (e.g. Marsh & Hicks, 1998; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003). By this account, monitoring the passage of time was disrupted by having to perform both the ongoing pleasantness task and detecting the event-based cue. As in many other arenas of memory research, when a larger load is placed on working memory, more automatic associations often dominate performance. We believe that this may have occurred in this experiment. Whether participants were consciously aware they were more reliant on the association of time-based intention to the context of the response window occurring in Phase 3 is debatable. But the data suggest that they do rely on the association more. Another account of the decrement in time-based performance would assert that participants' time monitoring is disrupted from attentional allocation strategies made at the time they formed both intentions (Marsh, Hicks, & Cook, in press). By this account, participants realize that they are being asked to perform essentially three concurrent tasks and they settle on an approach to the entire task set that gives short shrift to the time-based intention. These two accounts are similar to one another and differ mainly in whether or not the deficit is caused by more versus less strategic processing on the participants' part. Regardless of which account is correct, the results from this experiment clearly demonstrate a case in which possessing dual intentions can disrupt prospective memory performance.

GENERAL DISCUSSION

This study examined associating the expected completion of a time-based intention with being performed in a future context. When the time to respond coincided with the expected context, performance was better than having no associated context expectation at all (Experiment 1). Consequently, accurately predicting when a time-based intention is likely to be fulfilled has beneficial effects on intention completion. However, the results from Experiment 1 also demonstrated that expecting to be in a particular context can have deleterious consequences if the prior activities take longer than expected. One way to account for these results is to assume that the association between the activity and the expected context becomes stored at intention formation and becomes part of the declarative representation of the intention. When that context occurs, it can serve as a backward retrieval cue to the intention itself. Because the intention is receiving some activation from the context, it has a higher probability of coming to mind and causing time checking behaviour, which in turn leads to more frequently fulfilling the intention.

These results and this theoretical account bear some resemblance to environmental context effects that have been reported for many years (e.g. Baddeley, 1982; Rutherford, 2000; Smith & Vela, 2001; Wickens, 1987). In those studies, recollection of information is best when the environmental context is reinstated during retrieval. The main difference between those studies and the present one on prospective memory is that participants never experienced the Phase 3 syllable counting task. Rather, they had to rely on their imagination for what that context would be like based on the verbal description given in the instructions. Given that true environmental context effects are often quite small, the magnitude of the improvement (and decline when the wrong context is expected) is somewhat impressive with a time-based intention. Although we did not test an event-based intention, the theoretical analysis offered here would predict that expecting to encounter environmental cues in a particular context should affect performance in a similar manner (cf. McDaniel et al., 1998). Of course, one difference between event-based and time-based intentions is that the former rely on environmental cues much like the context association being studied here. Therefore, the magnitude of the expected context effects may be smaller with event-based intentions, but of course, this conjecture remains to be tested.

The current study suggests that a careful consideration of when an intention can be carried out has the potential to greatly improve everyday prospective memory. To use an example given in the introduction, if one forms the intention to phone a friend that evening, it could be beneficial to associate it with being in a particular context such as one's living room or den. Unfortunately, the down-side of doing so would be if one ultimately spends the evening working on a hobby in one's basement then the intention may have a higher probability of going unfulfilled. According to this analysis, the current study may also hold some explanatory power for why Gollwitzer's (1999) implementation intentions have a higher probability of being completed (also see Gollwitzer & Schaal, 1998). Implementation intentions are prospective memories that are formed with a very specific plan for completing them. For example, if one wishes to purchase milk on the way home from work, then mentally planning the route deviation to the store at intention formation improves the probability of actually doing it. To date, such intentions have mainly been claimed to be more elaborate and hence more durable (e.g. Chasteen, Park, & Schwarz, 2001). However, another explanation of the efficacy of implementation intentions can be derived directly from the theory put forth here, namely, the future context associated with the intention backwardly cues the intention when that context is actually encountered. Once again, we make no claims about whether this only increases the activation level of the intention or whether it also causes the intention to be explicitly retrieved. By either means, clock checking is increased and time-based prospective memory performance is commensurately improved.

Experiments 2 and 3 in this study examined what factors may improve prospective memory when the wrong future context is expected. We found that only an explicit reminder about the intention increased clock checking and eventual intention completion. Completing a different, event-based intention had no beneficial effect on time-based prospective memory, but rather, had deleterious consequences instead. Although we were somewhat surprised that the dual-intention conditions did not increase time-based performance in Experiment 3, the explicit reminders used in Experiment 2 are nevertheless consoling. Those data suggest that an explicit reminder from an external source can overcome the initial context association. Perhaps it is for this reason that some people feel the need to set alarms on wristwatches and PDAs to remind them to complete their time-based intentions. However, as noted earlier, alarms differ from the reminders in Experiment 2 insofar as alarms are usually set for the exact time when an activity needs to be completed (e.g. removing food from the oven).

In conclusion, this study suggests that associating a future context with a time-based intention can improve responding if the response window occurs in the expected context. By the same token, if the response window occurs before that expected context is encountered, then time-based performance is dramatically reduced. We suspect that context associations are most beneficial with routine time-based intentions or with associations to contexts that occur routinely. For example, if one needs to complete an activity by 1 pm the following day, one might associate it with a routine morning meeting or associate it with a routine lunch date with a friend. Because both occur prior to the 1 pm deadline, everyday intention completion should be more successful. By contrast, if the morning routine or habitual lunch date is disrupted for some reason, the current study suggests that the context association established at intention formation may result in the intention going unfulfilled in a timely manner. More generally, this study does demonstrate the utility of examining how intention completion is affected by expectations about the future context one will be in when an activity is predicted to be carried out. We are quite optimistic that this work can be extended in the laboratory to other sorts of intentions and also extended to understanding and improving fulfilment of real-world intentions formed outside the laboratory.

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