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Encountering items previously paired with prospective memory target events can serve to reactivate intentions

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Two experiments were conducted to determine whether encountering items that were previously paired with prospective memory (PM) targets would serve as effective reminders and thereby improve PM performance. Experiment 1 showed that PM target detection was facilitated by encountering items (cues) that were paired with PM targets prior to intention formation, and that such facilitation was not dependent upon cues and PM targets being semantically related. Using a categorical intention, Experiment 2 showed that encountering cue items improved PM performance for all intention-related items, not just those previously paired with potential PM targets. However, the benefit of encountering cue items was moderated by the number of intervening trials between cues and targets. Overall, the data suggest that encountering items previously paired with target items induces reactivation of the intention but is only beneficial when the heightened level of activation can be maintained by working memory.

Keywords: Prospective memory; Intentions; Reminders; Priming; Attention.

Throughout the day, we form intentions to complete a task at some point in the future, in which we associate the intended action with some environmental cue. This use of memory is typically referred to as event-based prospective memory (PM). Typically, we are engaged in some other activity at the time intentions are formed. For example, while eating lunch in a restaurant, an individual may form the intention to retrieve their dry cleaning. With the present set of experiments, we sought to determine the influence on PM performance of reencountering items that were paired with PM targets[1] at, or immediately prior to, the formation of intentions. Using the previous example, we were interested in determining if later encountering the restaurant where you formed the intention would act as a reminder to perform the task.

In accordance with Anderson's (1983a) adaptive control of thought (ACT) model there are data to support the idea that intention-related concepts, when compared to the other contents of memory, have a heightened level of activation and that this activation is sustained for longer periods of time (Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998). Within this framework, the total activation available to memory is finite and distributed among various individual memories or concepts. PM failures would occur because of attentional lapses (Smith, 2003, 2008) and failure to maintain the relative activation of

[1] We use the phrase "PM targets" to refer to the environmental stimulus to which some intention-related action should be made.

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intention-related concepts over time (Goschke & Kuhl, 1993). As such, any reactivation of the intention that occurs between encoding and execution should serve to benefit PM performance (Einstein & McDaniel, 1996; Ellis, 1996; Mäntylä, 1996). Additionally, the closer in time the reactivation and the opportunity to fulfil the intention, the more beneficial reactivation should be. Theoretically, such reactivation should occur if some external stimulus is encountered that acts as a reminder either overtly or covertly (Kvavilashvili & Fisher, 2007).

Research into the role of reminders in PM (e.g., Meacham & Leiman, 1982) has been scant even though the use of reminders is prevalent in everyday life (Intons-Peterson & Fournier, 1986; Marsh, Hicks, & Landau, 1998). In this literature, much of the interest has focused mainly on the characteristics of the reminders. Studying overt reminders, Guynn, McDaniel, and Einstein (1998) found that not all reminders have a positive effect on PM performance. In their study, people were told to circle certain words (e.g., school) whenever they were encountered later in the study. In their second and third experiments, reminders were given prior to PM target encounters that sometimes (1) prompted retrieval of the specific targets (i.e., remember the words you studied earlier), (2) prompted retrieval of only the action to be performed (i.e., remember what key you have to press later in the experiment), (3) prompted retrieval of both the target and action (i.e., remember what key to press when encountering words that you studied earlier), or (4) prompted the target, action, and context (i.e., remember what to do when encountering those words in the puzzle task). They found that reminders that referenced the target event only were less effective than the other conditions. Some improvement in PM performance was seen when the reminder referred to the action only; however, the reminders having the largest impact were those that referenced both the target event and the action. In other work on reminders, falsely expecting to receive a reminder shortly before the target event occurs has been shown to impair PM performance (Schaefer & Laing, 2000). Additionally, studying the effectiveness of reminders in performing air traffic controller duties, Vortac, Edwards, Fuller, and Manning (1993) found that reminders that restricted the amount of information available were more effective than more detailed reminders. The authors argued that such results were obtained because reprocessing more restrictive reminders was less cognitively demanding.

More relevant to the present study, two other recent studies have examined the impact of more covert reminders on PM performance. In the first, Meier, Zimmerman, and Perrig (2006) primed PM targets with different types of stimuli (see Mäntylä, 1993, for related work). In a short-term memory task in which a picture of an object and a different word were presented on each slide, people had to name the words, but remember the pictures for a short-term recall test. As an example of the priming manipulation, the PM target word ''piano'' might occur a few trials after semantically related items in either word or picture form (e.g., the word ''conductor'' or a picture of a conductor). The picture primes were more effective in improving PM target detection as compared to a no-prime control condition. However, the word primes did not significantly improve performance. Notably, the improvement caused by picture primes was almost exclusively associated with the subjective report by participants that PM target retrieval was a spontaneous ''pop-up'' type of experience, rather than an experience of actively searching or monitoring for the target. This finding suggests that covert reminders may sometimes influence prospective memory through spontaneous processes (cf. McDaniel & Einstein, 2000).

In the second relevant study, Taylor, Marsh, Hicks, and Hancock (2004) investigated the impact of partial-match cues (see West & Craik, 1999, for related work on PM lures). They gave participants the intention to make an additional response to animal words that began with ''L'' while they were engaged in a pleasantness rating task. They found that presenting semantic (animal words that did not begin with ''L'') and orthographic (nonanimal words that began with ''L'') partial-match cues during the ongoing task resulted in improved PM performance. The authors argued that encountering partial-match cues induced participants to engage in a self-initiated retrieval of the intention in order to determine if the presented stimulus matched the criteria set for intention execution. This was evidenced by increased response latencies to the partial-match cues as compared to other nonprospective trials.

Unlike Taylor et al. (2004), who sought to determine the effect on PM performance of encountering items that partially matched the

criteria for intention completion, we designed the present set of experiments to determine whether intention completion can be facilitated by encountering associated items that did not even partially meet the conditions for intention execution. More specifically, we were interested in whether the presence of external cues that were previously paired with target events can serve as effective reminders to fulfil the intention. Recall our example of encountering a restaurant where one had created an intention to pick up dry cleaning. Might that encounter covertly produce a reminder? And how long might such an effect last? Our laboratory analogue was to engage participants in a paired associate learning task prior to the PM task (e.g., CAR–ENGINE, PAPER–CLOCK) and then present these items in an ongoing task during which PM responses should be made. The cues in these pairs represent the restaurant in our ecological example. The target words in the pairs represent encountering the dry cleaning store itself. Both the cue and the target have a chance to reactivate the intention and prompt prospective memory retrieval, but only the target event should prompt the action in order to fulfil the intention. The issue at hand is whether processing the paired-associate cue word would enhance performance once a PM target is eventually encountered.

We tested three between-subject conditions in our first experiment. Everyone in the study learned three semantically related cue–target pairs (e.g., CAR–ENGINE) and three unrelated pairs (e.g., PAPER–CLOCK). The six target words in these pairs were used as PM targets in an ongoing lexical decision task (LDT). In the paired condition, the cue word previously paired with each target was presented three trials prior to each target item in the LDT. In the mixed condition, the cue–target pairings were reformed such that previously learned cues were presented three trials prior to a different target in the LDT (e.g., CAR–CLOCK). In the no-cue condition, no primes (i.e., paired-associate cues) were presented in the LDT, only PM targets.

If PM performance is facilitated by encountering cue items, it may be the result of more automatic processes such as spreading activation resulting in target item activation and thus the intention also becoming reactivated prior to the actual processing of the target item (cf. Anderson, 1983a, 1983b; Collins & Loftus, 1975; McNamara, 1992). Theoretically, this activation may not cause the intention to reach conscious awareness, but could lower the threshold required for a PM target to prompt a PM response. Alternatively, such facilitation could be the result of a process that results in retrieval of the intention into conscious awareness. Previous research has shown that the amount of monitoring by participants can wax and wane throughout the experiment (Marsh, Hicks, & Cook, 2006); therefore, retrieval of the intention into the focus of attention may cause a relative increase in the amount of monitoring thereby facilitating target detection. Examination of responses latencies can help to distinguish between these two alternative processes. If increased monitoring results from encountering cue items then slowing on the cue trials and the trials immediately following cues should be seen. Alternatively, a spreading activation account would not predict such slowing due to the implicit nature of its underlying mechanisms. It is important to note that given the paradigms used in the current research, some degree of environmental monitoring by participants is likely (Einstein et al., 2005). Therefore, our examination of response latencies is not meant to speak to the monitoring versus spontaneous retrieval debate but rather is aimed at measuring the relative amount of monitoring. If response latencies increase significantly after encountering cue items, this could be indicative of *increased* monitoring.

EXPERIMENT 1

Method

Participants. A total of 81 undergraduate students from the University of Georgia participated in exchange for partial credit towards a course research requirement. Each participant was tested individually in sessions that lasted approximately 20 minutes. Twenty-seven participants were randomly assigned to each of the three between-subject conditions.

Materials and procedure. Prior to the prospective memory task all participants performed a paired-associate learning task, during which they were presented with six pairs of items. Three of the pairs were semantically related items (e.g., CAR–ENGINE) and three were unrelated both semantically and orthographically (e.g., PAPER–CLOCK). Other than the six items that formed the related pairs no other items were semantically

related. Participants were presented with the word pairs for 2 s each. Immediately after the study phase participants completed a cued recall task in which they were presented with the item that was presented on the left side of the screen and asked to type the word that was paired with it. Participants completed the learning and test phases twice after which they were instructed to engage in a 5 minute distractor task (performing multiplication problems). Perfect cued recall was obtained by the end of the second test cycle for all participants.

Participants next engaged in a standard prospective memory experiment in which the ongoing task was a 200-item lexical decision task (LDT). After being given the directions for completing the LDT, participants were instructed to make an additional response (''/'' keypress) after making the word/nonword judgement if the item presented during the LDT was one of the six PM targets. It was made clear to participants that these items were the target words from the paired associate learning phase. PM target words were presented every 30 trials beginning on the 30th trial. The order in which the PM targets were presented was randomised anew for each participant. After receiving the instructions, participants were again engaged in the distractor task for 5 minutes before beginning the ongoing task. To ensure that any PM errors were not due to failures of retrospective memory, the experimenter asked each participant to list orally the six items they were to make the additional response to both prior to the distractor task and after the completion of the LDT. None of the participants showed a retrospective memory failure for PM target items.

In the no-cue condition none of the words that were previously paired with the PM targets occurred during the lexical decision task. In the paired condition the items previously paired with the PM targets were presented during the lexical decision task three trials before its matched target word occurred. Therefore, for three PM target trials its semantically related cue word from the paired associate phase was presented three trials beforehand; and three PM targets were preceded three trials beforehand by their unrelated, paired cue word. In the mixed condition one of the previously learned cue words was presented three trials before each of the PM targets; however, none of the cue words appeared directly before its paired target word. So each PM target was preceded by one of the other five cue words. This manipulation had an effect of making each PM target item unrelated to the PA cue that directly preceded it. The PA cue word that occurred before a given target word was determined randomly.

Results

One participant in the paired condition erroneously made the PM keypress on cue trials as well as target trials. As a result these data were removed from all subsequent analyses.

Performance on all dependent measures did not show significant differences between the paired and mixed conditions[2]; nor was there an effect of relatedness in the paired condition. Therefore, in the following analyses we have collapsed over these two conditions. Furthermore, to facilitate comparison with the subsequent experiment we will refer to this condition as the 3-away condition (a reference to the distance between the cue and target).

As can be seen in Table 1, better PM performance was seen in the 3-away condition compared to that of the no-cue condition. A direct comparison of PM performance, as measured by proportion of PM targets correctly responded to, revealed significantly better performance in the 3-away condition as compared to the no-cue condition, $t(80) = 4.35$, $p < .001$, $d = 0.97$.

Table 2 presents the response times for three different types of trials: correct word trials, cue word trials, and word trials occurring between cues and targets (interword trials). Additionally,

TABLE 1
Mean (*SE*) proportion of PM targets detected

Experiment and condition	*Studied PM targets*	*Unstudied PM targets*
Experiment 1		
3-away	.88 (.02)	
No cue	.64 (.07)	
Experiment 2		
3-away	.78 (.04)	.79 (.04)
6-away	.71 (.04)	.57 (.05)
9-away	.72 (.03)	.64 (.04)
No cue	.75 (.04)	.60 (.05)

[2] Overall performance in the paired condition was .89 (.03) and .87 (.02) in the mixed condition. The difference in response latencies on cue word trials was marginally significant with slower responses in the mixed condition, $t(51) = 1.91$, $p = .06$, $d = 0.53$

TABLE 2
Mean (*SE*) response latencies on word trials, cue-word trials, and word trials that occurred between cues and targets

Experiment and condition	*Word trials*	*Cue trials*	*Interword trials*
Experiment 1			
3-away	900 (20)	1307 (69)	1057 (47)
No cue	909 (26)	872 (55)	827 (41)
Experiment 2			
3-away	807 (16)	737 (17)	934 (29)
6-away	781 (13)	731 (17)	881 (19)*
9-away	791 (18)	750 (24)	875 (24)*
No cue	801 (16)	749 (18)	743 (23)

*Only include RTs from the first two trials after a cue item.

RTs to target words were excluded from the analyses, as were response times greater than 2.5 *SD*s above or below the group mean. Direct comparisons revealed no significant differences in RT on word trials, $t(80) < 1$, $p = .91$, $d = 0.02$. RTs on cue trials, however, were significantly slower in the 3-away condition than those for the noncue words on the corresponding trials in the no-cue condition, $t(80) = 4.31$, $p < .001$, $d = 0.96$.

In order to further examine the effect of encountering cue items, RTs to words that occurred between the cues and PM targets (or the corresponding trials in the no-cue condition) were compared and showed that participants in the 3-away condition responded to these items more slowly than those in the no-cue condition, $t(80) = 3.25$, $p < .01$, $d = 0.73$. Within-group comparisons of RTs on word trials and RTs on word trials that occurred between cues and targets also reveal significant slowing in the 3-away condition, $t(53) = 3.40$, $p = .001$, $d = 0.93$. In order to confirm that our measure of relative slowing was related to target detection, a correlational analysis was conducted and revealed a significant relationship between overall PM performance and interword RTs[3], $r = .29$, $p < .01$.

Discussion

The data from Experiment 1 revealed that processing a cue word during the LDT which had previously been paired with a PM target resulted in better overall PM performance. Additionally, encountering cue items caused participants to slow down considerably on the next couple of trials. Such increases in RTs are indicative of increased levels of monitoring following the presentation of items that were previously paired with a PM target. This increase in monitoring is likely the cause of better PM performance following the presentation of a cue item.

The benefit shown here, however, may be due to the nature of the intention. Encountering a cue item from the paired associate phase may not have acted as a reminder of the intention, per se, but rather just created the expectation of being presented one of the previously learned target items. Therefore, in Experiment 2 we sought to address this issue by giving people a categorical intention (responding to animal words) and manipulating whether the animal words presented during the ongoing task were items previously studied during the paired associate phase.

Additionally, one feature of the first experiment was that cue and target items occurred in close proximity during the LDT. Prior research examining the effects of when reminders occur in reference to target events has shown mixed results, with some showing improved PM when reminders and targets occur in close proximity and others suggesting little change due to reminder placement. An example of the former effect is from an air traffic control task simulation (Vortac, Edwards, & Manning, 1995). In their experiments, having reminder cues available seconds before and during the opportunity to change an aeroplane's destination route were more effective than either having no reminder at all or having the reminder disappear more than 10 s prior to the PM retrieval opportunity. Thus, timely reminders were more effective during that cognitively demanding task. In contrast, Guynn et al. (1998) found no impact of delay between reminders and target events in their second experiment. The time between reminders and PM targets was either about 1 minute or about 6 minutes in that study (and about 3.5 minutes in their standard conditions). An obvious difference between these studies is the timescale: a matter of seconds in the Vortac et al. study versus minutes in the Guynn et al. study. Therefore, in Experiment 2, in addition to examining the effects of prior learning, we investigated the effect of manipulating the distance between cues and targets that varied between roughly 3 s and roughly 10–12 s.

[3] We thank an anonymous reviewer for suggesting this analysis.

EXPERIMENT 2

Method

Participants. A total of 168 undergraduate students from the University of Georgia participated in exchange for partial credit towards a course research requirement. Forty-two participants were randomly assigned to each of the four between-subject conditions and were tested individually in sessions that lasted approximately 20 minutes.

Materials and procedure. In Experiment 2 the procedure was virtually identical to Experiment 1, except that the materials and the instructions were modified for a categorical intention. Participants were given the intention to make the additional keypress to animal words. A list of nine common animals was compiled, from which six would serve as PM targets during the LDT. Before the distractor task, participants underwent a paired-associate learning phase in which six animal words served as the to-be-recalled target words. The six animal words were each paired with semantically unrelated cues. Again, cue–target pairs were studied for 2 s each followed by a cued recall test. The study–test phase was completed twice.

Following the paired-associate learning phase and a 7 min distractor task (multiplication problems), participants were given instructions for the lexical decision task and the intention to make the additional keypress to animal words. The LDT included 245 trials during which six PM targets occurred every 40 trials, starting with the 40th trial. The order in which the PM cues were presented was randomised. Unlike Experiment 1, only three of the animal words that were studied during the paired-associate learning were used as PM targets. The other three PM targets were animals not previously studied. The assignment of which animal words were used during the learning phase and which were then replaced by unstudied items during the LDT was determined randomly for each participant.

As in the previous experiment, we tested a no-cue condition in which none of the paired-associate cues were presented during the LDT. In the 3-away condition, a cue was randomly presented three trials before the occurrence of each animal word such that no cue was paired with its previously associated target. The 6-away and 9-away conditions were similar, except that the cue was presented either six or nine trials before a PM target. Because only three of the PM targets were previously studied, three of the studied cues preceded animal words that were not previously studied.

Results

PM accuracy is presented at the bottom of Table 1. A 2 (item type: studied vs. unstudied) × 4 (cue distance) ANOVA revealed a main effect of item type, $F(1, 164) = 14.56$, $p < .001$, $\eta_p^2 = .08$ a main effect of cue distance, $F(3, 164) = 2.96$, $p < .05$, $\eta_p^2 = .05$, and a significant interaction, $F(3, 164) = 2.68$, $p < .05$, $\eta_p^2 = .05$. There were no significant differences in PM performance on studied and unstudied targets in the 3-away condition, $t(41) < 1.00$, $p = .73$, $d = 0.11$. However, PM performance on unstudied items was significantly lower than studied items in the no-cue condition, $t(41) = 3.13$, $p < .01$, $d = 0.98$, and the 6-away condition, $t(41) = 2.96$, $p < .01$, $d = 0.92$. In the 9-away condition, the difference in studied versus unstudied performance was marginally significant, $t(41) = 1.88$, $p < .07$, $d = 0.59$.

To best explore the between-subject effects, planned contrasts were conducted comparing the control condition to each of the experimental conditions for the dependent variables. Compared to the control condition, overall PM detection was only significantly better in the 3-away condition, $t(164) = 2.14$, $p < .05$, $d = 0.33$. There were no differences in performance on studied items, $ts(164) < 1.00$, $ps > .48$, $ds < 0.15$. However, performance in the 3-away condition was significantly better than in the control condition for unstudied items, $t(164) = 2.94$, $p < .01$, $d = 0.46$. None of the other conditions differed significantly from the control for unstudied items, $ts(164) < 1.00$, $ps > .54$, $ds < 0.15$. Therefore, with a more categorical intention, the benefit conferred on PM performance of encountering a cue item was restricted to unstudied items.

To further explore the effects of cue presence and distance from target items, one-way ANOVAs were conducted on nontarget item response times, which are shown at the bottom of Table 2. There were no effects of condition on RTs to word trials, $F(3, 164) = 0.53$, $p = .66$, $\eta_p^2 = .01$, or on RTs to cue trials (or control matched words), $F(3, 164) < 1.00$, $p = .88$, $\eta_p^2 = .004$. However, there was an effect of condition on word trials that occurred

between cues and targets[4], $F(3, 164) = 11.53$, $p < .001$, $\eta_p^2 = .17$. RTs on these trials were significantly slower in the three experimental conditions compared with the no-cue condition, $ts(82) > 3.98$, $ps < .001$, $ds > 0.88$. Within-group comparisons of RTs on word trials and word trials that occurred between cues and targets showed significant slowing in each of the conditions where cues were encountered, $ts(41) > 5.08$, $ps < .001$, $ds > 1.59$. In contrast, in the no-cue condition RTs on interword trials were significantly faster than on other word trials, $t(41) = 2.5$, $p < .01$, $d = 0.78$.

Interestingly, in the 9-away condition, comparison of RTs to words that occurred on the first two trials after a cue and those on the last two trials before the target ($M = 802$, $SD = 23$) reveal that the amount of slowing was significantly reduced as distance from the cue increased, $t(41) = 2.76$, $p < .01$, $d = 0.86$. Similarly, in the 6-away condition there was a numerical, but not significant, difference in RTs on the last two trials before the target ($M = 852$, $SD = 22$) and those on the first two trials following a cue with slower responses on the latter, $t(41) = 1.50$, $p = .14$, $d = 0.47$. As in Experiment 1, a significant relationship was seen between overall PM performance and RTs to word trials that occurred between cues and targets, $r = .156$, $p < .05$.

As in the previous experiment, encountering cue items prior to targets facilitated intention completion. However, any significant benefit was only seen when the cue–target pairs were in relatively close proximity (two intervening trials). When cue–target pairs were separated by either five or eight intervening trials, PM performance was similar to that in the no-cue condition. A numerical superiority in PM performance for the 3-away condition was seen over the no-cue condition for both studied and unstudied items; however, this improvement was only statistically significant for unstudied items. Like Experiment 1, the response time data indicate that encountering cue items caused participants to more vigilantly monitor for potential target items, at least on the next several trials. This is likely the reason PM performance benefited from encountering cue items in the 3-away condition. Additionally, the rapid decrease in the amount of monitoring seen in the 6- and 9-away conditions helps explain why PM performance in these conditions was similar to that in the no-cue condition.

[4] For better comparison across conditions only RTs on the first two trials that occurred after cues (or corresponding trials in no-cue condition) were used to calculate interword trial RTs.

GENERAL DISCUSSION

The purpose of the current set of experiments was to determine if encountering items that were previously paired with PM target events could serve as reminders of the to-be-completed task, thereby increasing the probability of intention completion. Using six specific targets, in Experiment 1 we showed that when given an item that was previously learned in association with the PM targets shortly before the onset of the target event, PM performance improved. Increased performance was not reliant on semantic relatedness between the cue and target items and was not dependent on the match of cue–target pairs. That is, the improvement in performance was also seen if cue words did not directly precede their paired associate but rather preceded any of the other target events.

Experiment 2 explored the generality of the findings from Experiment 1 and showed that the facilitation of PM performance from paired associate cues was not limited to specific intentions. The studied versus unstudied manipulation in Experiment 2 showed that detection of unstudied items substantially benefited from encountering cue items shortly before target events. This result suggests that cue items served to reactivate the overall intention and did not just bring to mind the intention-related items that were previously studied. A small numerical benefit was also seen for studied items in the 3-away condition. The lack of significant effects for studied items may have been due to ceiling effects and the nature of the categorical intention. When the categorical intention was used performance on studied items was similar across conditions and had an overall mean near 75%. Given that only three studied target items occurred and 82% of participants across conditions responded to at least two of the targets, it is likely that an effective ceiling on performance had been reached and that the effect of encountering cue items was at point of diminishing returns.

The effect of distance between cues and targets was also examined in Experiment 2, and the data suggest that the effect of cue item reminders is limited by either time or by the amount of intervening processing. Improved performance was seen, as in the first experiment, if the cue

preceded the target event by three trials; however, when the cue items were either six or nine trials before the target, performance was similar to that in the no-cue condition. These results differ from previous findings by Guynn et al. (1998) who, using more overt reminders, found that the delay between reminders and target events had no effect on PM performance. However, they used overt reminders that did not necessitate the retrieval of the intention. Therefore, an important distinction should be made between reminders that do not require retrieval of the intention and those that do. However, the rapid loss of any beneficial effects of encountering the cue items in the current experiments is similar to previous findings using a delayed execution paradigm. Research has found that when there is a delay between target events and the opportunity for execution, PM performance declines substantially if attention is divided during delay periods as short as 5 s (Einstein, McDaniel, Willford, Pagan, & Dismukes, 2003; McDaniel, Einstein, Graham, & Rall, 2004). The quick loss of any beneficial effects when the number of intervening trials increases from two to five accords well with Marsh et al.'s (1998) suggestion that activation and deactivation of intentions occurs routinely throughout our day so that current processing is not subject to interference from future intentions. They suggested that such reactivation occurred through mechanisms that allowed intention-related items to be reprocessed more quickly or efficiently than nonintention-related items.

How cue items serve to facilitate intention completion is of theoretical importance and can be informed by examination of response latencies. One interpretation comes from the associative priming literature. Processing an item that was previously paired with an intention-related item may cause activation of the intended action through the target item similar to mediated priming effects (McNamara, 1992, 1994). Priming effects have been shown to be dependent on the short temporal lag between primes and targets (Ratcliff & McKoon, 1988; see McKone, 1995, for a review); therefore, such a spreading activation model would account for the very brief window in which cue items serve as effective reminders. The implicit nature of such a mechanism, however, would not account for the slowing of response latencies after encountering a cue item. In both experiments response times to words that occurred on the two trials following a cue showed significant amounts of slowing.

More likely is that cue items facilitated retrieval of the intention into conscious awareness. Having sufficiently associated cues with intention-related items, encountering cues may have caused a search of memory and retrieval of the target event and action. This account of the current effects is in accord with the latency data. Such relative slowing on items after encountering cues would be expected if participants were consciously searching for and retrieving information from memory. These results are similar to those found by Scullin, McDaniel, and Einstein (2010), who showed that cueing participants to an upcoming target event caused an increase in monitoring when the target events were nonfocal to ongoing task processing.

One inconsistency between the results of the two experiments needs to be addressed. In Experiment 1 response latencies on cue trials in the 3-away condition were significantly slower than those on the same trials in the no-cue condition. However, no slowing was seen on cue trials in Experiment 2. This discrepancy is likely due to the nature of the intentions. Slowing on cue trials in Experiment 1 may have been the result of participants needing to decide if the cue items met the criteria for intention completion. That is, participants likely needed additional processing time to determine if the previously studied cue item was one of the six specific items requiring a response. However, in Experiment 2, which used an animal word intention, cue items could quickly be dismissed as not meeting the criteria for PM execution.

The current results, taken together with the findings of Einstein et al. (2003) and McDaniel et al. (2004) that showed rapid forgetting in delayed execution tasks, suggest that retrieval of intentions prior to when the intention can be executed is only beneficial when the intention can be actively maintained in working memory. The benefit of encountering cue items when there are two intervening LDT trials before the target occurs, and a lack of beneficial effects when there were either five or eight intervening trials, accords well with current theories of working memory that suggest a capacity limit of between three and five items (Cowan, 2000; Usher, Cohen, Haarmann & Horn, 2001). When an intention becomes reactivated by encountering a cue item it is brought into working memory; however, the heightened level of activation cannot be maintained because of continuous information processing related to the ongoing task. This view is

consistent with the activation buffer in some neurocomputational models (Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann, & Usher, 2005; Usher et al., 2001), which suggest that due to processing constraints only a limited number of units can be actively maintained at one time. Further supporting this interpretation, Kliegel and Jäger (2006) showed that performance on a measure of inhibitory control was a significant predictor of performance on a delay–execute PM task. That is, the ability to inhibit distracting thoughts during the delay period was critical to delay–execute PM performance. We are not suggesting that intentions must be actively maintained in working memory from intention formation to completion; rather, we are arguing that any retrieval of the intention prior to when the intention can be fulfilled is only beneficial if the heightened activation caused by retrieval can be maintained by working memory. The role of working memory in limiting the effects of encountering cue items is further supported by the fact that, in the 9-away condition, RTs to word trials that occurred between cues and targets decreased as distance from the cue increased (nonsignificant numerical decreases were also seen in the 6-away condition). This result indicates that the increased monitoring resulting from having encountered cue items diminishes rapidly likely causing the similarly rapid loss of cue–item facilitation on PM performance. Within this framework, it is not necessary for the level of reactivation to be sufficiently strong as to bring the intention into the focus of attention; however, we believe that the slowing of response times after encountering a cue item is indicative of the intention reaching awareness.

In summary, the current experiments have shown that items paired with intention-related material can serve as covert reminders of the intention. However, the results indicate the benefit to intention completion is moderated by the amount of time or processing that occurs between cues and targets, possibly implicating working memory's ability to actively maintain only a limited number of items. Furthermore, the pattern of response latencies indicates that encountering cue items benefits PM by encouraging retrieval of the intention at a conscious level at the cost of interference to the ongoing task.

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