The fate of completed intentions

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Prospective memory (PM) refers to the ability to remember to complete a task at some point in the future, such as picking up eggs on the way home or filling up the gas tank before a long trip. PM, which is a critical aspect of daily functioning and goal-directed behavior (Gardner & Ascoli, 2015), presents a special retrieval challenge for memory (Craik, 1986). Specifically, in contrast to typical retrospverse memory tasks like cued recall, PM tasks require a large degree of self-initiated retrieval. For example, when having the PM intention to give a friend a message, there is usually no one there to prompt you to search for the intention when you later see your friend.

Research on PM has focused primarily on understanding the processes that support event-based PM (remembering to perform an intended action in the context of a specific event or cue). Researchers have demonstrated that PM retrieval can be accomplished through top-down monitoring processes that maintain activation of the intention and/or search the environment for the target event (e.g., Burgess, Quayle, & Frith, 2001; Smith, 2003). There is now also convincing evidence for the existence of spontaneous retrieval processes. According to the multiprocess theory (Einstein & McDaniel, 2005; McDaniel & Einstein, 2000, 2007) spontaneous retrieval occurs when a cue or target event that is associated with the intention causes retrieval of the intention in the absence of monitoring (sometimes experienced as the intention “popping into mind”). Spontaneous retrieval is thought to be a bottom-up and relatively automatic retrieval process that is initiated by the processing of a relevant cue.

Support for the existence of spontaneous retrieval comes from studies showing that successful PM can occur when monitoring is discouraged. For example, Scullin, McDaniel, Shelton, and Lee (2010) described their PM task as being of secondary interest, emphasized the importance of the ongoing lexical decision task, and did not present the one target word until the 501st trial. Under these conditions, there was no evidence of monitoring, and yet focal PM performance was high (78%). Further evidence that cues can trigger the retrieval of intentions in the absence of monitoring comes from research using a suspended phase paradigm. In Scullin, Einstein, and McDaniel (2009), for example, participants performed a PM task while performing an ongoing image rating task (Phase 1). The experimenters then suspended the PM intention (telling participants they would continue the task at a later point in the experiment), after which the participants were instructed to perform a series of lexical decision trials as quickly as possible (Phase 2). Critically, target words from Phase 1 were presented in Phase 2, and the results indicated slowed lexical decision response times to target words (relative to control words), presumably from...
retrieving the PM intention upon seeing the target words (see also, Cohen, Dixon, & Lindsay, 2005; Einstein et al., 2005; Knight et al., 2011; Mullet et al., 2013; Rummel, Einstein, & Rampey, 2012). Research shows that participants do not monitor during a suspended phase (e.g., Marsh, Hicks, & Cook, 2006) and thus the slowed response times must have been due to the cue triggering some type of cognitive reaction – perhaps full retrieval of the intention or a discrepancy or noticing response (McDaniel, Guynn, Einstein, & Breneiser, 2004).

Although spontaneous retrieval is beneficial in that it provides another mechanism for PM retrieval besides monitoring, there may be a dark side to spontaneous retrieval. Specifically, cues may continue to trigger retrieval of intentions even after they have been completed. If previously completed PM intentions are not successfully deactivated, they have the potential to interfere with current task goals (Mayr & Keeler, 2000; Walser, Fischer, & Goschke, 2012), and possibly to produce commission errors, in which the completed intention is performed an additional time. Researchers have begun investigating the consequences of completed intentions, and two general theoretical positions have been proposed. According to the deactivation view (Marsh, Hicks, & Bink, 1998; Scullin, Bugg, McDaniel, & Einstein, 2011; Scullin et al., 2009), completed PM intentions become less accessible after completion and are less likely to invade one’s thoughts, even in the presence of a strong cue. According to the persisting activation view (Walser et al., 2012), however, completed PM intentions are not so neatly deactivated and will continue to be spontaneously retrieved (Bugg, Scullin, & McDaniel, 2013; Scullin & Bugg, 2013; Scullin, Bugg, & McDaniel, 2012; Walser, Fischer, Goschke, Kirschbaum, & Plessow, 2013; Walser, Goschke, & Fischer, 2014; Walser, Plessow, Goschke, & Fischer, 2014).

In support of the deactivation view, Scullin et al. (2009) found evidence for spontaneous retrieval (i.e., slowing to target events) when the target events occurred during a suspended phase (i.e., participants had been told not to perform the PM task during the next phase, but that they would return to that task later), but no evidence for spontaneous retrieval (i.e., no slowing) when the target events occurred during a completed phase (i.e., participants had been told that the PM task was finished). Older adults, by contrast, continued to show evidence for spontaneous retrieval in the completed phase (see also, Scullin et al., 2011). These results suggest that young, but not older, adults can quickly deactivate intentions, which can potentially be explained by compromised cognitive inhibition in older adults (Hasher, Stoltzfus, Zacks, & Rypma, 1991). Additionally, Förster, Liberman, and Higgins (2005) found that when the PM task and an unrelated lexical decision task were alternated, words related to the PM target showed heightened activation before the execution of the PM task, and this activation disappeared after its completion.

Much of the recent research, however, has shown that spontaneous retrieval is not easily deactivated (Bugg et al., 2013; Penningroth, 2011; Scullin & Bugg, 2013; Scullin et al., 2012; Walser et al., 2012). Scullin and Bugg (2013), for example, showed that when spontaneous retrieval is made particularly likely (with the use of highly salient cues – presenting the target items on a vivid red or blue background), young adults occasionally made commission errors. Specifically, in the first phase of the experiment, participants were instructed to complete a lexical decision task with an embedded PM task (e.g., press the Q key to the word corn). After the first phase, they were instructed that the PM task was finished, but in the second phase of the experiment the target word appeared again. Because young adults made commission errors (pressing the Q key in the second phase) to these salient target items, this research appears to contradict the conclusion of Scullin et al. (2011) that only older adults have difficulty deactivating intentions. These results, as well as those found by Walser et al. (2012), in which numerous PM intentions all showed residual activation over long periods of time, suggest that PM intentions are not fully and neatly deactivated after completion, at least under certain circumstances.

Given the evidence for both views, the issue of whether or not the completion of a PM intention results in the deactivation or residual activation of that intention, and if so, under what conditions, has not been clearly settled. Instead, it is likely that observation of the phenomenon is dependent on the specific methodology used to test residual activation, and replications and extensions are needed to tease apart potential relationships. In addition to the variables mentioned thus far (cue salience, age), it appears that a change in the retrieval context may affect the extent to which intentions continue to be retrieved after they have been completed. Scullin et al. (2009, 2011) found evidence for deactivation in young adults (i.e., no slowing) when the retrieval context (i.e., the ongoing task) task changed from the performance phase (image rating task) to the completion phase (lexical decision task). Walser et al. (2012), on the other hand, found evidence for persisting activation when the retrieval context remained constant (see also, Scullin et al., 2012 for evidence of fewer commission errors when the context changed). In the present research, we used the same task during the performance (Phase 1) and suspended or completion (Phase 2) phases, as our goal was to explore factors that could lead to the deactivation of intentions under conditions that are often representative of the real world. For example, after fulfilling our intention to give a co-worker a message at the office, we are likely to later see that co-worker again in that same context.

It also appears that performance of the intended action contributes to deactivating the intention. Bugg and Scullin (2013) found that participants who were never presented the PM target in Phase 1 (as opposed to participants who were presented the PM target four times) were later more likely to make commission errors in Phase 2 (after being told that the PM task was completed). Bugg and
Scullin concluded that performing an intention, rather than simply being informed of its completion, aids in its deactivation and offered two possible explanations. First, it is possible that prior performance of PM intentions increases the number of episodic traces an individual has of having encountered the target words, thereby allowing participants to associate a stop-tag to targets with a concrete episodic experience, rather than an abstract projection of what such an experience would be like. Within this view, processing the target after the PM intention has been completed will still activate the intention, but its retrieval will also include a stop-tag (and thus low or no commission errors). They also propose the possibility that performing the PM task could facilitate deactivation of the task (perhaps unconsciously), such that the target words become disassociated with the intention to press the key, potentially through a reconsolidation mechanism that updates current task goals (Chan & LaPaglia, 2013). The idea here is that completion instructions in general (Scullin et al., 2009), but especially when combined with performance of the action, may help people dissociate the cue-action link. Within this view, processing of the target after the intention has been completed will no longer lead to retrieval of the intention.

At present, there is evidence for both persisting activation and for deactivation of PM intentions following their completion. There is also evidence that performing an intention aids in deactivation. In addition to testing for persisting activation under a variety of conditions, a goal of this research was to use a thought probe procedure, adapted from Plimpton, Patel, and Kvavilashvili (2015) and Reese and Cherry (2002), along with measures of response times and commission errors to develop a better understanding of the conditions in which intentions remain active or are deactivated as well as the specific mechanisms that underlie these effects.

The thought probe procedure, which involved asking participants to report their current thoughts on trials following target and control items, was designed to determine how persisting activation manifests itself. For example, slowing to target words may or may not reflect conscious retrieval of the PM task in the form of specific thoughts about the completed intention. Or, slowing during a suspended phase may represent qualitatively different levels of retrieval of the intention (perhaps full retrieval of the intention) relative to slowing during a completed phase (perhaps a discrepancy or noticing response). Moreover, commission error levels might not be the most accurate reflection of persisting activation if participants are successful in inhibiting the PM action (i.e., retrieval could go unnoticed).

In the first experiment, we examined persisting activation for participants who had their task suspended (in which intentions should remain active; Einstein et al., 2005) and for those who were told the task was complete. To foreshadow, all of our measures suggested that completed intentions remain active after completion. Therefore, in the second experiment we manipulated conditions that we believed would facilitate the deactivation of the PM task.

**Experiment 1**

In Experiment 1 we manipulated whether participants received suspended or completed instructions after Phase 1 as well as performance of the intention in that phase (only one of two PM targets was presented and thus only one had the opportunity to be performed). During Phase 2, however, both target words were presented. In addition to measuring slowing to target words (relative to matched control words) and commission errors to target events, we probed the thoughts of participants following the presentation of target words in Phase 2.

A possible concern with comparing target words to matched control words in a suspended or completed intention paradigm is that greater slowing to PM targets could simply reflect slowing to items that are learned more thoroughly than their controls. It is possible that familiarity, rather than persisting activation, could be driving the results, and including a control condition, where control items are also rehearsed, would address this concern. Previous research using such a control condition, however, has consistently shown strong effects for PM or intention-related information, and thus the persisting activation effects are unlikely to be due to familiarity. Specifically, in a suspended intention paradigm, studies have demonstrated persisting activation of suspended intentions relative to suspended instructions. The primary motivation of this research was to determine if completion instructions mitigate this activation (i.e., whether activation is attenuated with completed instructions relative to suspended instructions).

If completed intentions remain active, then slowing to target words (relative to control words) should be similar in the suspended and completed instruction conditions. If intentions are deactivated after they have been completed, however, then there should be reduced slowing to target events in the completed condition (relative to the suspended condition), low to no commission errors, and no or few reported thoughts about the PM task after the presentation of target words. Further, if the
performance of an intention aids in deactivation, then these effects should be more pronounced for the performed target relative to the non-performed target. Moreover, our multiple dependent measures enabled us to evaluate the possible mechanism of deactivation. Specifically, a pattern of comparable slowing for both performed and non-performed targets, but reduced commission errors for the performed items, would provide support for the stop-tag theory. The thought probe procedure should provide further insight into the specific mechanisms underlying the deactivation of performed targets, because assigning a stop-tag to targets should result in participants reporting thoughts about the previous PM task. By contrast, if the intention is disassociated after retrieval, then there should be relatively few thoughts about the PM task and reduced slowing to performed target words relative to non-performed targets.

Method

Participants and design

Young adult participants (N = 64) were Furman University undergraduates (M age = 20.19, SD = 1.22) who either received $8.00 compensation or course credit. This experiment was a 2 x 2 x 2 mixed factorial that included the between-subjects variable of instructional condition (suspended, completed; 32 participants in each condition), and the within-subjects variables word type (target, control) and prior PM performance (performed, non-performed) during Phase 1.

Procedure

Phase 1

All participants were tested either individually or in groups of up to three on computers separated by blinders and in a quiet environment. Participants were initially told that the research goal was to study people’s performance on a variety of computer-based tasks as well as their thoughts while performing those tasks. They then received instructions for performing the lexical decision task (LDT), which involved pressing a key on the number pad (5) labelled Yes for a word and a key (6) labelled No for a non-word (see Figure 1 for an overview of the procedure). After 10 practice trials with feedback on their accuracy and response time, they received instructions for the PM task. Specifically, participants were asked to press the Q key when either of the target words (e.g., corn or dancer) appeared within the context of the LDT instead of making a lexical decision, but that they could still make the response a couple of trials later if they remembered. All items were presented in white, Arial, 16-point font on a black background following a 300 ms fixation cross. Following Bugg and Scullin’s (2013) procedure, we asked participants to write the instructions and then repeat them to the experimenter in order to demonstrate that they understood the instructions. Repeating instructions out-loud when some participants were tested in groups could be distracting, but steps were taken to minimize these effects. For example, although most participants arrived at repetition points in the experiment at the same time, if some participants were marginally quicker than others then they were asked to wait briefly until the other participants in the room were also ready to repeat instructions. Additionally, participants tested in a group were always in the same condition, and thus heard the same instructions.

Participants were not discouraged from monitoring during the PM task, and the PM task was described as being equally important as the LDT. This was done because successful PM execution during Phase 1 was necessary for observing the effects of performing a PM task on persisting activation (i.e., performed vs. non-performed target words in Phase 2). To match the number of presentations of target and control items, the two matched control items were each presented once during the practice trials. After receiving the PM instructions, participants filled out a demographics questionnaire and then completed the 80 LDT trials in Phase 1, which included two presentations of one of the PM targets and its corresponding control (at trials 36 and 40, and 72 and 76), while the other PM target and its corresponding control were not presented.

Phase 2

Next, participants received suspended or completed instructions that were adapted from Bugg and Scullin (2013). Specifically, participants in the suspended instructions condition were told “YOU WILL COME BACK TO THE LEXICAL DECISION TASK AND THE PRESSING THE Q KEY TASK LATER, PLEASE DO NOT PERFORM THESE TASKS AGAIN UNTIL YOU ARE TOLD TO DO SO.” Participants in the completed instructions condition were told “YOU HAVE NOW COMPLETED THE LEXICAL DECISION TASK AND THE PRESSING THE Q KEY TASK. THOSE TASKS SHOULD NOT BE PERFORMED AGAIN.” Directly following these instructions, participants completed the Mill Hill vocabulary test (Raven, Raven, & Court, 1998) on the computer, which took approximately 10 min.

Phase 2 was introduced as the “speed task”, and was described as similar to the lexical decision task in Phase 1 (in that they had to press Yes for words and No for non-words), but different in that their sole aim was to respond as quickly as possible without sacrificing accuracy. After participants wrote down and told the experimenter the instructions, they were informed that in the context of the speed task they would receive thought probes (a procedure adapted from Plimpton et al., 2015 and Reese & Cherry, 2002), inquiring what was on their mind at the time, as well as anything that triggered those thoughts. Participants were instructed that all thoughts were of interest, ranging from what they would have for dinner to specific thoughts about the experiment.
participants were told that they could repeat thoughts if they were recurring and that it was okay to not report a thought if they happened not to be thinking about anything in particular at the moment. Participants recorded their thoughts by typing directly on the computer and then pressed the Enter key to submit them. After doing so, a new window prompted participants to indicate whether or not the thoughts were triggered by something specific, and if so, what they believed the trigger to be. Participants again pressed the Enter key to submit their response, after which they resumed the speed task. The speed task contained 324 trials, with six presentations of each target and control item (all other words and non-words were also presented six times). Because one target and one control were not seen in Phase 1, half of the words and non-words were new, and the other half were repeated from Phase 1. Following Scullin et al. (2012), there were at least 11 trials separating PM targets, and there were at least 11 trials separating control words (though not necessarily 11 trials separating targets and controls). Target and control items were grouped, such that all four words were seen before any was repeated.

An initial thought probe occurred on the 10th trial, which was designed to assess thoughts prior to the presentation of any target or control items. A thought probe occurred after the first, third, and sixth presentation of each target and control. In order to make the thought probe procedure appear more continuous, we included an additional thought probe between the first and third sets of target and control presentations (trial 89) and another probe was introduced between the third and sixth sets of target and control presentations (trial 192). Therefore, there were a total of 15 thought probes; one following the first, third, and sixth presentation of each target and control item (12), one on trial 10, and two inserted to improve continuity. Importantly, so that participants would not associate thought probes with target or control words, the thought probes occurred after the item following the target or control word (this item was determined randomly for each participant). The entire experiment lasted approximately 45 min.

**Materials**

This experiment was programmed using E-Prime 2.0. Using the Balota et al. (2007) norms, words and non-words were between 5–8 characters in length, had a Log_Freq_HAL of 10–13, and had mean response times of 640–750 ms. The precise words and non-words from this list were selected using random.org after removing any proper nouns or contractions. Thirty-eight words and non-words (19 each) were selected for Phase 1, and every item was presented twice. Fifty words and non-words were selected for Phase 2 (25 each) and every item was presented six times. However, half of the words in Phase 2 were repeated from Phase 1 and half were new. The PM target/control pairs corn and fish, and dancer and writer were borrowed from Bugg and Scullin’s (2013) study and were matched on number of letters and syllables, Log_Freq_HAL, mean response times, and mean accuracy (using the Balota et al., 2007 norms).

We counterbalanced which items served as the PM target and control words. Thus, half of the participants received corn and dancer as their PM targets, and the other half received fish and writer as targets. The other two words served as matched controls in each condition. We also counterbalanced which target item was presented (and had the potential to be performed) in Phase 1. Thus, half of the participants were presented with corn and fish (one target and one control) in Phase 1 (but not dancer
and writer), whereas the other half were presented with dancer and writer in Phase 1 (but not corn and fish). We also counterbalanced the order of target and control words in Phase 2 by creating four word order conditions. The first condition was randomly determined (constraints on randomization mentioned previously) and the other three conditions systematically manipulated the order of the target and control items such that across the four counterbalancing orders, each item occurred equally often in each position.

Results

For all analyses, the alpha level was set at .05. Unless otherwise noted, the standard analysis conducted for each dependent variable was a 2 × 2 × 2 mixed analysis of variance (ANOVA) that included the within-subjects variables of word type (target, control) and prior performance in Phase 1 (performed, non-performed), and the between-subjects variable of instructional condition (suspended, completed). Previous studies examining response times for completed intentions report medium effects (Scullin et al., 2009, 2011) to large effects (Walser et al., 2012, Walser, Goschke, et al., 2014; Walser, Plessow, et al., 2014). Studies examining commission errors typically observed medium-sized effects (Bugg et al., 2013; Bugg & Scullin, 2013; Scullin et al., 2012). For our ANOVA analyses, we had excellent power (.98) to detect a medium-sized effect of the critical interactions between instruction condition (suspended, completed) and word type (target, control) or performance (performed, non-performed). For the additional chi-square analyses, on the other hand, we had less than optimal power (.67) to detect medium-sized effects of instruction condition or performance. We report effect sizes for all significant effects.

Although our major aim was to examine whether the PM intention was deactivated in Phase 2, we first tabulated the proportion of correct PM responses in Phase 1. A PM response was considered correct if participants pressed the Q key to the target or within three items of the target. PM performance was nearly perfect and did not differ between the suspended (M = .94, SE = .04) and completed (M = .97, SE = .03) conditions, t (62) = .58, p > .05.

Phase 2 lexical decision task

Accuracy on the lexical decision task in Phase 2 was high and did not differ between the suspended (M = .91, SE = .01) and completed (M = .92, SE = .01) conditions, t (62) = .51, p > .05. Next, we tabulated the mean untrimmed response time (Mullet et al., 2013) for accurate responses to the performed and non-performed target items (and corresponding control items) in Phase 2 and conducted the 2 × 2 × 2 mixed ANOVA described above. Four participants (two from each condition) were excluded from this analysis for failing to have any accurate responses to either performed or non-performed target words. There was a main effect of word type, F (1, 58) = 7.06, MSE = 18318.27, η² = .06, indicating that participants were significantly slower to respond to target words (M = 560 ms, SE = 20) than control words (M = 514 ms, SE = 12). In addition, there was no evidence that completed instructions (relative to suspended instructions) reduced slowing to target items, nor that performing the intention reduced slowing (both F’s < 1) (see Table 1 for a summary of the means in Experiment 1).

There was a significant interaction between performance and instruction conditions, F (1, 58) = 4.40, MSE = 7742.88, η² = .01, such that participants in the suspended instruction condition were faster responding to performed target and control items (M = 499 ms, SE = 20) than non-performed target and control items (M = 524 ms, SE = 22) whereas participants in the completed instruction condition showed the reverse pattern (performed, M = 573 ms, SE = 20; non-performed, M = 551 ms, SE = 22). It is unclear why this pattern emerged, but the important results are that participants exhibited slowing to target items relative to controls, and that this was not affected by instruction condition or performance. No other main effects or interactions were significant (Fs < 3.06, ps > .09).

One possible explanation for why we failed to find an effect of performance on slowing to target items is that...
not all participants performed the PM task in Phase 1. To examine this possibility, we excluded the three participants who failed to have any correct PM responses in Phase 1 for the above analysis and found no changes in the statistical conclusions (this was the case for every analysis, and thus we report the results throughout with all participants).

**Post-target response times**

Because persisting activation might interfere with lexical decisions even after the immediate trial on which a target or control word appears (Rummel et al., 2012), we examined response times to the item immediately following target or control words. As can be seen in Table 1, participants were slower to respond on trials following target words ($M = 609$ ms, $SE = 17$) than those following control words ($M = 566$ ms, $SE = 15$), $F(1, 62) = 10.72$, MSE $= 10985.88$, $\eta^2 = .07$. In addition, there was no evidence that completed instructions (relative to suspended instructions) reduced slowing to target items, nor that performing the intention reduced slowing (both $F$s $< 1$). No other main effects or interactions were significant (all $F$s $< 2.87$, $p$’s $> .10$).

**Commission errors**

A commission error was counted if a participant pressed the Q key on trials containing a target word (each target occurred six times, so there were a total of 12 opportunities) as well as up to 3 trials following the target word. Zero participants made a commission error to a control word, so we eliminated the variable word type (target, control). On average, there were 18% commission errors. Therefore, one experimenter subsequently coded the remaining thought probe responses. Importantly, the results indicated that participants were not thinking about the PM task at the start of Phase 2. Only two participants indicated thinking about the PM task on trial 10 and both were in the suspended condition.

First, we performed a mixed ANOVA to determine if the proportion of thoughts about the PM task following target and control trials differed as a function of the other two independent variables. There was a main effect of word type, $F(1, 62) = 55.24$, MSE $= .04$, $\eta^2 = .30$, indicating a greater proportion of thoughts about the PM task following target words ($M = .20$, $SE = .02$) than control words ($M = .02$, $SE = .01$). Importantly, there was no evidence that completed instructions or performance led to fewer thoughts about the PM task (both $F$s $< 1$). Additionally, it is of interest that across both instruction conditions 66% of the participants reported thinking about the PM task at least once.

Our clear impression is that participants understood our suspended and completed instructions at the end of Phase 1. Some of their responses to the thought probe procedure, however, indicated confusion about the task after seeing several target words. Therefore, we examined thoughts following the very first occurrence of a target word – that is, when participants were least likely to be thinking about the PM task. Because of our counterbalancing, 32 participants saw a performed target word first, and 32 participants saw a non-performed target word first. On average, 39% of the participants reported thinking about the PM task to the first target. We conducted a series of chi-square goodness of fit analyses to determine whether thoughts about the PM task after the first presentation of a target word varied as a function of prior performance in Phase 1 (performed, non-performed) or instruction condition (suspended, completed). There were no significant differences based on performance, $\chi^2(1, N = 64) = .07$, $p > .05$, or instruction condition, $\chi^2(1, N = 64) = .59$, $p > .05$.

**Discussion**

All four of our dependent measures (slowing to target words, post-target response times, commission errors, and thoughts about the PM task) revealed no significant differences between participants in the completed instruction condition relative to those in the suspended condition, and thus support the view that intentions persist and are not fully deactivated after completion. Further, there was no evidence that performing the intention aided the deactivation of the PM task. It should be noted that we had excellent power to detect effects of completion instructions (and effects of performance) on slowing to target items, slowing to post-target items, and on the proportion of thoughts about the PM task. We had less than optimal power, however, to examine how these variables influenced commission errors.
Initial responses to the thought probe procedure provide support for the idea that participants were clear at the start of Phase 2 that the PM task was suspended or completed. Their responses to the first thought probe on trial 10 (prior to the occurrence of the first target) ranged from “I do not have any thoughts”, to “I’m thinking about sustainability”, to “I was thinking about the paper that I have due on Friday.” After seeing the first target item, however, participants often reported thinking about the PM task (e.g., “The previous exercise when I hit Q for corn made me think about that word”) and sometimes their responses indicated confusion (e.g., “I hope we were still supposed to press Q when we saw corn”). In general then, it appears that encountering a focal PM target after an intention has been suspended or completed often leads to conscious retrieval of the intention.

**Experiment 2**

The purpose of the second experiment was to explore what conditions, if any, serve to deactivate completed PM intentions. In addition to testing participants in a condition nearly identical to the completed condition in the first experiment (hereafter referred to as the control condition), we tested for persisting activation in three additional groups: clarity, one-off, and new PM task. In the clarity condition, we strengthened the completion instructions (after Phase 1) by having participants repeat out-loud and write down the instructions and by proceeding directly to Phase 2 (without an intervening vocabulary test). These changes should make it clear that the PM task had been completed and reduce or eliminate confusion.

Participants in the one-off condition received instructions preceding Phase 1 explicitly specifying that only one target word would appear, and that after performing the PM task to that single target, the PM task was completed. This manipulation should not only make completion of the PM task more salient, but also eliminate the indeterminate nature of the task in Phase 1, such that participants have a concrete understanding of when the task will be complete before performing the task, rather than after the fact, as in the other three conditions. Moreover, this condition more closely approximates many PM demands outside the laboratory where we intend to perform an action only once (e.g., give a friend a message), and it may be that knowing that you have completed the intention at the time of performance facilitates deactivation.

The new PM task condition was given a different PM task to perform during Phase 2, to clarify to participants that the previous PM task had been completed and was now irrelevant. Further, it is possible that this may be the mechanism underlying how we update our PM demands, such that moving forward to address a new PM task deactivates the old task and effectively takes its place. This might be expected on the basis of the theory of retrieval-induced forgetting (Anderson, Bjork, & Bjork, 1994), in which the processing and retrieval of current information serves to inhibit related information.

Contrary to this prediction, however, Walser et al. (2012) found persisting activation when using a repeated PM paradigm. Participants engaged in eight phases of a number categorization task (determine whether a number is even or odd) but during each phase they were given a new PM task in which they were to press the spacebar if the presented numbers had certain features, such as a particular border or bolded font. In addition to presenting current PM targets in each successive phase, old PM targets were also presented, and slowing to these targets indicated persisting activation. Across four experiments they found slowing to previous targets, which they interpreted as evidence for persisting activation. Moreover, they proposed that current PM demands activate previously completed and related PM tasks. Another possible explanation, however, is that having eight separate PM tasks created confusion about which PM target was current. Therefore, inclusion of the new PM task condition in the current study served as a stronger test of whether new PM demands help to deactivate or to reactivate previously completed PM intentions.

**Method**

**Participants and design**

Young adult participants (N = 86) were Furman University undergraduates (M age = 19.65, SD = 1.26) who either received $8.00 compensation or course credit. This experiment was a 2 x 2 x 4 mixed factorial that included the between-subjects variable condition (control, N = 21; clarity, N = 22; one-off, N = 22; new PM task, N = 21), and the within-subjects variables word type (target, control) and prior PM performance during Phase 1 (performed, non-performed).

**Procedure**

The procedure in the control condition in Experiment 2 was identical to that of the completed instruction condition in Experiment 1, except that we included only one presentation of one target word (and its corresponding control word) in Phase 1. This was done in order to satisfy the requirements of the one-off condition and to keep the conditions consistent across groups.

The procedure in the other three groups was identical to that of the control group except for the changes listed below. In the clarity condition, participants were asked to write down and repeat out-loud the instructions following Phase 1 that indicated that the PM task was complete. Also, the Mill Hill vocabulary test was eliminated, and participants proceeded directly to Phase 2 following the instructions that the PM task was complete. In the one-
off condition, participants were told that the PM task was to press the Q key if they saw either the word corn or dancer (fish and writer in the counterbalanced condition), but that only one of the two words would be presented, and that after the presentation of one of the target words the PM task would be complete. In the new PM task condition, participants were told, as part of the instructions for the speed task (at the start of Phase 2), that they were to perform a new PM task, in which they were to press the P key if they saw the word leaf. However, the actual speed task was identical to all other conditions, and the PM target never appeared. In an attempt to minimize monitoring, participants were additionally told that the speed task was their primary goal and that they did not need to look for the target because it would “pop out” (Harrison, Mullet, Whiffen, Ousterhout, & Einstein, 2014).

Results

As in Experiment 1, the alpha level was set at .05 for all analyses. Unless otherwise noted, the standard analysis conducted for each dependent variable was a 2 × 2 × 4 mixed ANOVA that included the within-subjects variables of word type (target, control) and prior performance in Phase 1 (performed, non-performed), and the between-subjects variable of condition (control, clarity, one-off, new PM task). For ANOVA analyses, we had excellent power (.98) to detect a medium-sized effect of the critical interactions among condition (control, clarity, one-off, new PM task) and word type (target, control) or performance (performed, non-performed). The chi-square analyses, however, again showed only modest power to detect significant effects of condition (.63) or performance (.79). We report effect sizes for all significant effects.

As in Experiment 1, we first tabulated the proportion of correct PM responses in Phase 1. PM performance did not differ between among conditions (control, M = .81; clarity, M = .86; one-off, M = .68; new PM task, M = .86), χ²(3, N = 86) = 2.94, p > .05.

Phase 2 lexical decision task

Accuracy on the lexical decision task was high (M = .92) and did not differ among conditions (F = 1.21, p = .31). Next, we tabulated the untrimmed mean response time for accurate responses to the performed and not performed target items (and corresponding control items) in Phase 2 and performed the 2 × 2 × 4 mixed ANOVA described above. One participant (clarity condition) was excluded from this analysis for failing to have any accurate responses to target word trials. There was a main effect of word type, F(1, 81) = 14.95, MSE = 6403.00, η² = .05, indicating that participants were significantly slower to respond to target words (M = 552 ms, SE = 13) than control words (M = 518 ms, SE = 9). Importantly, there was no evidence that any of the three experimental conditions showed reduced slowing to target items relative to the control condition (F = 1.07, p = .37), nor that performing the intention reduced slowing (F < 1). No other main effects and interactions were significant (all F’s < 1) (see Table 2 for a summary of the means in Experiment 2).

Because we were interested in whether PM performance facilitated deactivation, we conducted the above analysis excluding participants who failed to have any correct PM responses in Phase 1. For this analysis (and for all others) there were no changes in the statistical conclusions regarding performance, and we report the results with all participants throughout.

Post-target response times

As in Experiment 1, we also examined response times to the item immediately following target or control words. The results revealed a main effect of word type, F(1, 82) = 27.66, MSE = 11660.25, η² = .09, indicating that participants were significantly slower to respond on trials following target words (M = 622 ms, SE = 15) than those following control words (M = 561 ms, SE = 10).

In addition, there was a significant interaction between word type and condition, F(3, 82) = 3.18, MSE = 11660.25, η² = .03. A post-hoc test of this effect (Tukey’s Honestly

Table 2. Summary of means and standard error of the means for each of the four conditions in Experiment 2.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Clarity</th>
<th>One-off</th>
<th>New PM task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SE</td>
<td>M</td>
<td>SE</td>
</tr>
<tr>
<td>Accurate response times</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Target</td>
<td>572</td>
<td>31</td>
<td>536</td>
<td>20</td>
</tr>
<tr>
<td>Performed</td>
<td>587</td>
<td>51</td>
<td>521</td>
<td>16</td>
</tr>
<tr>
<td>Non-performed</td>
<td>526</td>
<td>28</td>
<td>507</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>542</td>
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<td>505</td>
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<tr>
<td>Target</td>
<td>624</td>
<td>36</td>
<td>639</td>
<td>28</td>
</tr>
<tr>
<td>Performed</td>
<td>631</td>
<td>43</td>
<td>564</td>
<td>17</td>
</tr>
<tr>
<td>Non-performed</td>
<td>587</td>
<td>28</td>
<td>555</td>
<td>16</td>
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<tr>
<td></td>
<td>613</td>
<td>37</td>
<td>541</td>
<td>11</td>
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<tr>
<td>Post-target response</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>(ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td>.25</td>
<td>.08</td>
<td>.08</td>
<td>.04</td>
</tr>
<tr>
<td>Performed</td>
<td>.21</td>
<td>.07</td>
<td>.08</td>
<td>.05</td>
</tr>
<tr>
<td>Non-performed</td>
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<td>.05</td>
<td>.14</td>
<td>.05</td>
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<tr>
<td></td>
<td>.03</td>
<td>.02</td>
<td>0</td>
<td>.02</td>
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<tr>
<td>Proportion of thoughts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
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<tr>
<td>Performed</td>
<td>.22</td>
<td>.06</td>
<td>.18</td>
<td>.06</td>
</tr>
<tr>
<td>Non-performed</td>
<td>.15</td>
<td>.05</td>
<td>.14</td>
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<tr>
<td></td>
<td>.03</td>
<td>.02</td>
<td>0</td>
<td>.02</td>
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<tr>
<td>Proportion of commission</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Target</td>
<td></td>
<td></td>
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<tr>
<td>Performed</td>
<td>.06</td>
<td>.04</td>
<td>.06</td>
<td>.04</td>
</tr>
<tr>
<td>Non-performed</td>
<td>.02</td>
<td>.02</td>
<td>0</td>
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</tr>
</tbody>
</table>
Significant Difference Test) indicated significantly more slowing on trials following target words than those following control words in the new PM task condition (M slowing = 122 ms) relative to the control group (M slowing = 28 ms). Simple effects were also examined within each of the four conditions to determine if this interaction was due to successful deactivation in one of the groups. Post-target slowing was significant in all conditions except the control group, F (1, 20) = 1.48, MSE = 10756.64.

There was no evidence that performance influenced post-target response times (F < 1). All other main effects and interactions were not significant (all F's < 2.36, p's > .08).

**Commission errors**

As in Experiment 1, we tabulated the proportion of commission errors made out of the number of opportunities (12) to make a commission error. Zero participants made a commission error to a control word so we did not include the variable word type (target, control). We conducted a 2 x 4 mixed ANOVA to determine if there were differences based on prior performance in Phase 1 (performed, non-performed) and condition (control, clarity, one-off, new PM task). Although the mean proportion of commission errors was numerically higher in the control group (M = .23, SE = .05) than in the other groups (clarity, M = .08, SE = .05; one-off, M = .05, SE = .05; new PM task, M = .07, SE = .05) the effect of condition was only marginally significant, F (3, 82) = 2.34, MSE = .12, p = .08, and a post-hoc test of this effect (Tukey's) indicated no significant differences among groups (see Table 2). Additionally, there was no significant effect of performance (F = 1.93, p = .17) or of an interaction between performance and condition (F < 1). Thirty-three percent of participants made at least one commission error in the control condition, as compared to 14% in the clarity and one-off conditions, and 10% in the new PM task condition. These differences were not significantly different, χ²(3, N = 86) = 5.04, p > .05.

**Thought probes**

We used the same criteria that we used in Experiment 1 to tabulate thoughts about the PM task. Because of the high inter-rater reliability in Experiment 1 (.99), the experimenter alone coded all thought probe responses. Zero participants reported thinking about the PM task on trial 10 (prior to the occurrence of the first target), indicating that they were not thinking of the PM task at the start of the Phase 2 in any of the conditions.

First, we performed a mixed ANOVA to determine if the proportion of thoughts about the PM task following target and control trials differed as a function of the other two independent variables. As can be seen in Table 2, there was a main effect of word type, F (1, 82) = 38.01, MSE = .04, η² = .22, indicating a greater proportion of thoughts about the PM task following target words (M = .15, SE = .02) than control words (M = .01, SE = .01). There was no effect of condition or performance, and there was no significant interaction (all F's < 1.07, p's > .35). Additionally, it is of interest that 50% or more of the participants in all groups reported thinking about the PM task at least once (control, 52%; clarity, 50%; one-off, 50%; new PM task, 52%) and that this did not differ based on condition, χ²(3, N = 86) = .05, p > .05.

As in Experiment 1, we examined thoughts following the very first occurrence of a target in order to determine whether the occurrence of a target led to retrieval of the PM intention when they were least likely to be thinking about the PM task. Because of our counterbalancing, 46 participants saw a performed target word first, and 40 participants saw a non-performed target word first. On average, 27% of the participants reported thinking about the PM task to the first target. We conducted a series of chi-square goodness of fit analyses to determine whether thoughts about the PM task after the first presentation of a target word varied as a function of prior performance in Phase 1 (performed, non-performed) or condition (control, clarity, one-off, new PM task). There were no significant differences based on performance, χ²(1, N = 86) = 1.27, p > .05, or condition, χ²(3, N = 86) = .60, p > .05.

**Discussion**

The goal of Experiment 2 was to examine whether there are conditions that facilitate the deactivation of intentions and disengage spontaneous retrieval processes. To determine this, we created three experimental conditions designed to make deactivation more likely and compared them to a control group that exhibited high activation in Experiment 1. We found strong evidence for persisting activation in every condition and especially on the measures of PM target response times, post-target response times, and reported thoughts about the PM task. Therefore, our results suggest that PM intentions remain active even when participants are clear that the PM task has been completed, when a more externally valid one-off PM task is used, and when participants are given a new PM task. We again obtained numerous null findings, and therefore wish to highlight that we had excellent power to detect an effect of condition (or performance) on slowing to target items, slowing to post-target items, and on the proportion of thoughts about the PM task, but that we had less than optimal power for the chi-square analyses.

**General discussion**

**The persistence of spontaneous retrieval**

In line with previous research (e.g., Scullin et al., 2009, 2010), our results provide strong evidence that PM target cues spontaneously trigger retrieval of intentions in the absence of monitoring. It is unlikely that participants were monitoring for PM cues during the suspended and
completed phases (indeed only two participants across all of our conditions – both in the suspended phase – indicated thinking about the PM task on trial 10) and yet all of our dependent measures showed clear evidence of spontaneous retrieval.

Moreover, it seems that this spontaneous retrieval process is not neatly deactivated once it has been completed. Counter to the deactivation view (Marsh et al., 1998; Scullin et al., 2009, 2011) but consistent with the persisting activation view (Scullin & Bugg, 2013; Scullin et al., 2012; Walser et al., 2012), we found evidence for the persistence of spontaneous retrieval after the intention had been completed. Our use of multiple measures and especially the thought probe procedure helps clarify the nature of persisting activation. Without the benefit of the thought probe data, it could be that the slowing to target items that is typically observed during a suspended phase reflects qualitatively different retrieval processes relative to the slowing observed during a completed phase. More specifically, slowing during the suspended phase could reflect conscious retrieval of the intention, whereas slowing after the intention has been completed could simply reflect a discrepancy or noticing response (McDaniel et al., 2004). Also, using commission errors alone to estimate persisting activation or deactivation may be limiting in the sense that a lack of commission errors does not necessarily indicate deactivation. Rather, it could reflect persisting activation accompanied by good understanding of the task demands and good cognitive control, as appeared to be the case in the three novel conditions in Experiment 2. These problems highlight the usefulness of the thought probe procedure for illuminating the retrieval experiences of participants. The results of this research suggest that encountering PM cues after the intention is no longer relevant often leads to conscious retrieval of thoughts related to the PM task, and there was no lessening of this experience after the intention was completed (relative to when it was suspended).

Additionally, the thought probe procedure helps us evaluate whether or not participants were confused about the PM task being completed. The lack of thoughts about the PM task before encountering target words in our completed conditions suggests that participants were not confused at the beginning of Phase 2. Instead, it is likely that upon seeing target words they reflexively retrieved the completed PM intention and some then questioned whether the task was still in effect. This, combined with the more qualitative analysis of participants’ full responses (some participants actually reported their confusion explicitly), suggests that confusion is difficult to eliminate in this paradigm. The thought probe responses, combined with the evidence for persisting activation in the clarity condition, imply that confusion arises as a result of persisting activation, rather than persisting activation arising as a result of confusion.

It could be argued that the results obtained from Experiment 1 were simply the product of an artificial laboratory setting, and that persisting activation is less common in the real world. The indeterminate nature of the PM task in Experiment 1 might not have approximated the finality found in most daily PM tasks. It could also be that deactivation is more likely when one understands at the time of performance that the task has been completed (e.g., when you give a message to your friend there is no doubt as to whether or not the task is finished). The one-off condition in Experiment 2 was an attempt to address these problems, and the results suggest that persisting activation is likely to be found under conditions more representative of the real world (see also Penningroth, 2011 for evidence of persisting activation in more complex, naturalistic PM tasks).

The new PM task condition was created to determine whether moving forward to address new PM demands would help to deactivate completed intentions. Our new PM task during Phase 2 contained a new target and response (press the P key if you see the word leaf), whereas Walser et al.’s (2012) task successively manipulated targets but maintained the response (press the spacebar) across 8 PM phases. Nonetheless, our results support their conclusion that moving on to address new PM demands does not deactivate and possibly reactivates completed intentions. For example, our finding of significantly greater persisting activation in the post-target response-times measure for this group could indicate that addressing new PM tasks serves to enhance persisting activation. A possible explanation for this finding is that participants were monitoring for the new target word, and that maintaining this active retrieval mode resulted in heightened residual activation.

**Conditions that produce commission errors**

Bugg and Scullin’s (2013) stop-tag theory proposes that we associate a stop-tag to the PM intention, such that upon retrieving the intention we also retrieve the tag that it is no longer in effect. Their deactivation theory, on the other hand, suggests that after the completion of an intention it becomes disassociated, potentially through a consolidation mechanism. They further proposed that performing a PM response facilitates one or both of these processes. Although we did not find an effect of performance in Experiment 2, we did find that all three experimental conditions had nominally reduced commission errors relative to the control group. Coupling the evidence for reduced commission errors and no reduction in reported thoughts with our observation of slowed response times provides better support for stop-tag theory. Specifically, this combination of results implies that our manipulations helped participants better associate a stop-tag with both the performed and non-performed target words (i.e., both corn and dancer) such that the intention was retrieved, but with it came a tag notifying that it was no longer in effect.
An important remaining issue is why performing a PM response lowered commission errors in Bugg and Scullin (2013) but had no effect in our experiments. Our results showing slowing as well as conscious thoughts to target events after the intention has been completed suggests that failure to produce commission errors is not the result of deactivation of the target-action association (Bugg & Scullin, 2013). Instead, our results indicate that participants retrieve the PM intention when they process a non-salient target event after they have been told that the PM task has been finished. Based on Bugg and Scullin’s finding of generally larger effects with between-subjects manipulations of performance relative to within-subjects manipulations (as was the case in our research), it may be that performance helps signal completion (and reduced commission errors) when all tasks have been performed. It is also possible that the effects of performance observed by Bugg and Scullin in reducing commission errors could be limited to salient target events and to failures of executive control. Perhaps salient target items lead to rapid retrieval of the associated PM action and this action is difficult to stop or inhibit unless it has been previously performed.

**Theoretical and practical considerations**

An important question concerns what is meant by persisting activation. Our preferred interpretation is based on the reflexive associative retrieval process proposed by McDaniel and Einstein (2007). In this context, the idea is that the associative link between the target event (e.g., corn) and the action (press the Q key) remains sufficiently intact after the intention has been completed such that later processing of the target event continues to produce spontaneous retrieval of the intention. Our results suggest there is little weakening of this association following completion instructions (relative to suspended instructions), and that instructions that help clarify that the PM task has been completed do little to attenuate the strength of the cue-action link (clarity condition). Further, the strength of the link was not reduced when participants knew at the time of performance that the task was completed (one-off condition) or when they were given a new PM task. Another reasonable interpretation is that the persisting after-effects were due to residual heightened activation of the intention (Walser et al., 2012). Within this view, the activation level for the intention remains in a heightened state for a while after it has been completed, and this leads to enhanced sensitivity to PM-related cues. At this point, our data do not allow us to distinguish between these theoretical explanations.

Additionally, it may be that there are individual differences in the ability to weaken or disassemble the association (e.g., Scullin et al., 2011) or in the ability to inhibit the activation of the intention after completion. For example, Goschke and Kuhl (1993) distinguish between individuals who have a state- or action-orientation towards PM tasks. Those with a state-orientation are characterized by their greater likelihood to ruminate on incomplete tasks and their inability to inhibit irrelevant PM information. Accordingly, they show greater intention superiority effects, and might be expected to show greater persisting activation in the present paradigm. Some participants in our studies (approximately 44% in Experiment 1 and 49% in Experiment 2) never mentioned thinking about the PM task when probed. It could be that these participants were successful in their deactivation of the intention. Additional analyses, however, indicated that none of the dependent measures was influenced by whether or not participants reported thinking about the PM task. Further research is needed to determine whether there are individual differences in this ability as well as the variables that are related to this ability.

Similarly, it could be the case that a relatively small proportion of participants (i.e., those unable to deactivate the intention) drove our observation of persisting activation. For example, only about 27% of participants reported thinking about the PM task to the first target event, yet in situations where the PM task is still active approximately 83% of young adults successfully respond to a focal target (Uttl, 2011). For several reasons, however, we believe the thought probe procedure is a conservative estimate of PM retrieval. First, thought probes occurred after the trial following a target or control item, rather than directly following target and control words, and participants may have moved on to new thoughts at that point. Second, participants were told to report only what they were thinking at the time, and that if they had no thoughts to say nothing (which many did). Finally, our coding procedure did not include cases where participants simply mentioned the target words (e.g., “There was corn again”), as they could be thinking about the target words in relation to something other than the task (e.g., what they had for lunch).

One possible limitation of our research is that the thought probe procedure itself could have led participants to think about the no longer relevant PM task. That is, perhaps the thought probe procedure induced participants to generate thoughts about the PM task that would not have been present in the absence of the prompt to report their thoughts. We believe this is unlikely for several reasons. One is that participants were simply asked to report what was on their minds and were not encouraged to produce thoughts for every prompt. We told participants in the second phase (in the context of the speed task) that we were interested in their stream of consciousness and to simply report what they were thinking – and that it was okay to report no thoughts. Second, the thought probe procedure was not closely tied to the PM task. The prompt to report a thought always occurred in conjunction with a novel non-target item and only 6 of the 15 probes occurred proximal (within one item) of a target item. Consistent with our attempt to prevent connections being made between the thought probe procedure and the PM task, there was no indication in the
thought probe responses or post-experimental questions that such an association had been formed.

In light of the strong support for persisting activation, there is still an open question about what is necessary to successfully deactivate intentions (Hicks, Marsh, & Russell, 2000). It might be that increasing the delay between completing the PM task and encountering associated cues (Walser, Plessow, et al., 2014), or that diverting attention away from these associated cues (e.g., by occupying working memory; Walser, Goschke, et al., 2014), is necessary for deactivation. Additionally, it might be necessary to more dramatically vary the retrieval context between Phase 1 and Phase 2. In our experiments, participants engaged in a lexical decision task for both the performance and completion phases, and this task matching could help maintain persisting activation (Scullin et al., 2012). Further, Scullin et al. (2009, 2011) found evidence for the deactivation of completed intentions in young adults, and a key feature of these two studies may be the change in the ongoing task between the performance phase (image rating task) and the completion phase (lexical decision task). Notably, this feature was absent in most studies showing evidence for persisting activation (Bugg et al., 2013; Scullin & Bugg, 2013; Scullin et al., 2012; Walser et al., 2012; cf. Penningroth, 2011).

Our results suggest that PM intentions will often continue to be spontaneously retrieved after they have been completed – at least when PM cues occur in similar contexts. Given that spontaneous retrieval appears to be preserved with normal aging (Mullet et al., 2013), older adults may retrieve the intention to take their medication with relative ease; however, remembering whether or not they have already taken their medication requires a controlled memory search that older adults should find more difficult (Jennings & Jacoby, 1993). This dark side to spontaneous retrieval could lead to considerable problems with commission errors, in which catching sight of the medicine bottle is likely to trigger retrieval of the intention and, uncertain as to whether or not the medicine has already been taken, it could be mistakenly taken again. Therefore, this study suggests that completed PM intentions are likely to remain active, and that measures taken in light of this may be helpful in preventing commission errors and reducing task interference. For example, removing or altering cues to signal completion could help prevent these problems, such as throwing away finished to-do lists or using a daily pill planner for one’s medication.

Note
1. Following Scullin et al. (2009) and Bugg and Scullin (2013), a possible dissociation of the cue-action link formed at PM encoding is based on the multiprocess theory’s view of the hippocampal system as an associative memory mechanism. Theorists such as Moscovitch (1994) suggest that the hippocampus serves to bind relational information together, such that processing part of the resulting unit can lead to rapid retrieval of its counterpart (as when processing a focal cue can lead to spontaneous retrieval). By this view, it is also possible that the hippocampus can function to disassemble these associations when no longer relevant.

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