Remembering to Remember: An Examination of the Cognitive Processes Underlying Prospective Memory☆

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Successfully fulfilling intentions is a problem central to goal-directed behavior, and although there are many reasons why individuals succeed or fail in attaining their goals (e.g., motivation, practicality, or opportunity), even the best intentions are likely to fail if we forget to perform intended actions at appropriate times. This highlights the need for good prospective memory, or remembering to perform a delayed intention at the appropriate time, in accomplishing our goals. Whether our goals are as simple as remembering to get groceries after work, or as important as adhering to a new medication routine, successful prospective memory is critical for efficient functioning and independent living.

Given the importance of prospective memory in everyday life, it is probable that we spend a large amount of time and effort planning courses of action and making sure to remember when these actions need to be performed. Gardner and Ascoli (2015) recently provided support for this idea. The researchers probed young and older adult participants through their mobile phones to determine if they were currently experiencing an autobiographical memory, a prospective memory, or neither. Specifically, participants were asked to categorize their thoughts by whether they were recalling a specific event from their past (e.g., thinking about last year's vacation), envisioning future-related actions or events (e.g., imagining what will need to be done at work today), or neither of these things (e.g., focusing on the task at hand). Young adults had approximately 13 autobiographical memory and 17 prospective memory thoughts per hour. For older adults, the estimated rate of prospective memory, but not autobiographical memory, thoughts increased dramatically to 31 per hour. Further evidence for the ubiquity of prospective memory comes from Crovitz and Daniel's (1984) use of a forgetting diary, in which they showed that as much as 50% of reported memory failures were prospective in nature.

This highlights another distinctive feature of prospective memory: the ease with which we can fail to remember to execute intended actions. Most people regularly experience forgetting to upload an attachment to an email, walking out the door without their lunch, missing a dose of medication, or failing to wish a friend happy birthday. This is largely due to the fact that for most prospective memory intentions, no one is there to prompt you to recall your intention. For example, in contrast to many retrospective memory tasks, in which there is an explicit request from the experimenter to recall (i.e., the experimenter puts you in a retrieval mode; Tulving, 1983), prospective memory tasks require a large degree of self-initiated retrieval (Craik, 1986). In the absence of a prompt to recall, people must "remember to remember" by their own volition.

A central focus of prospective memory research has been to understand how people self-generate the retrieval of intentions and how they remember to execute these intentions at appropriate times. In this chapter we review two theories that have stimulated much research toward explaining the cognitive underpinnings of prospective remembering, and then we consider a recently proposed theory that challenges these predominant theoretical approaches. As well, we review the empirical support for each of these three theories: the preparatory attentional and memory (PAM) processes theory (Smith, 2003), the multiprocess theory (McDaniel and Einstein, 2000, 2007), and the recently advanced delay theory (Heathcote et al., 2015).

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This is an update of G.O. Einstein, M.A. McDaniel, R.L. Marsh and R. West, 2.45 – Prospective Memory: Processes, Lifespan Changes, and Neuroscience, In Learning and Memory: A Comprehensive Reference, edited by John H. Byrne, Academic Press, Oxford, 2008, Pages 867–892.

Preparatory Attentional and Memory Processes

The PAM theory posits that both preparatory attentional processes and memory processes are involved in the successful retrieval (and execution) of intentions (Smith, 2003). Specifically, PAM theory states that people engage attentional processes to scan the environment for cues that signal the appropriateness of performing the intended action. Upon encountering cues, the person initiates a retrospective recognition check to determine if any of the specific cues are associated with the opportunity to execute the intended action (we will label such a cue as the "target event"). For example, given the intention to give a friend a message, one would engage attentional processes toward evaluating the environment for pertinent events (e.g., people). Upon encountering these events, each event would be subjected to a recognition check to determine if that event was recognized as the target event (e.g., your friend). If so, then you would retrospectively recall what message you needed to give the friend. Critically, under this theory some degree of cognitive resources must be devoted either with explicit monitoring or maintenance of preparatory processes toward initiating a recognition check.

The PAM theory assumes that successful prospective memory requires the use of limited-capacity attentional resources, thereby stating that failures in prospective memory occur when preparatory processes are not engaged. Put another way, if one encounters the correct target event but is not in a preparatory state (e.g., attention is instead focused solely on the task at hand), then successfully remembering to perform the intention is impossible (Smith et al., 2007). Because intentions are typically executed within the context of an ongoing task, such as remembering to take your medication *with breakfast* or remembering to pick up groceries *on the way home from work*, PAM theory has been supported by research showing costs to the ongoing task from having a concurrent prospective memory task. Specifically, maintaining the preparatory processes necessary for successful prospective remembering should draw on the attentional resources normally devoted toward, for example, driving home from work.

To test this hypothesis, participants in a typical laboratory paradigm are required to engage in an ongoing task and are additionally asked to perform a prospective memory task in the presence of a particular event. For example, as an ongoing task, participants might be asked to determine if a string of letters forms a word (a lexical decision task), and then are additionally asked to press the *F1* key when particular target words appear. Results frequently show that participants are significantly slower making lexical decisions with an embedded prospective memory task than when performing the ongoing task alone. Further, participants who exhibit more slowing, or costs, to the ongoing task often have higher prospective memory performance (Smith, 2003). Therefore, it appears that people allocate mental resources to scan their environment for cues to perform prospective memory tasks (e.g., looking for their friend to wish them happy birthday), and this reduces their efficiency in performing ongoing tasks. Additional support for PAM theory comes from studies showing that variables that are associated with the availability of working memory resources, which are thought to be critical for monitoring or maintaining a preparatory attentional state, affect prospective memory performance. Specifically, studies have shown that dividing attention or increasing the attentional demands of the ongoing task impairs prospective memory performance (Einstein et al., 1997), that prospective memory declines with age (Kliegel et al., 2008; Uttl, 2011), and that working memory capacity predicts prospective memory performance (Brewer et al., 2010).

Multiprocess Theory

Although there is ample evidence for the existence of monitoring or maintenance processes in prospective memory, the PAM theory's assumption that prospective memory always comes at a cost appears counterintuitive to everyday experience (e.g., catching sight of your medicine bottle seems to trigger retrieval of the intention to take it) and maladaptive (i.e., engaging preparatory processes often over long delays would be heavily taxing; West and Craik, 1999). Therefore, it makes sense that an adaptive memory system would contain processes that support retrieval even after an intention has been "set aside for later." In line with this view, the multiprocess theory (McDaniel and Einstein, 2000, 2007) proposes that bottom-up spontaneous retrieval processes, in addition to top-down monitoring processes (i.e., preparatory attentional processes), can support prospective remembering. Spontaneous retrieval, which is often experienced as an intention "popping into mind," occurs when the processing of a relevant cue leads to retrieval in the absence of monitoring; for example, after forming the intention to wish a friend happy birthday, simply catching sight of your friend at work could remind you that today is her/his birthday. This is counter to the assumption of PAM theory, in which some degree of capacity must be engaged in remembering to wish your friend happy birthday or you will fail to do so.

Most laboratory research investigating the existence of spontaneous retrieval faces the difficult challenge of eliminating demand characteristics that encourage the use of monitoring strategies. As can be seen in **Table 1**, many features of laboratory paradigms encourage monitoring in a variety of ways; for example, the use of relatively simple ongoing tasks makes it easier to monitor, more difficult prospective memory tasks (e.g., those that present participants with several different prospective memory target events) likely bias participants toward allocating attentional resources to the PM task, or task instructions can influence participants to prioritize the prospective memory task (McDaniel et al., 2015). Because the presence of monitoring makes isolating spontaneous retrieval processes difficult, research testing for the existence of spontaneous retrieval requires carefully designed experiments to discourage participants from engaging preparatory processes.

A commonly examined variable affecting the likelihood of participants adopting a monitoring approach, for example, is the manipulation of focal and nonfocal cue processing. Cue focality is determined by the degree of overlap between the processing required by the ongoing task (e.g., "Is this string of letters a word?") and the processing required by a prospective memory cue

Table 1 Suggestions for creating experimental paradigms that minimize monitoring and isolate spontaneous retrieval

1. Use an event-based prospective memory task with as many of the following characteristics as possible.
   a. Use a single focal target cue.
   b. Minimize cues or demand characteristics (such as the title of the experiment) that suggest to participants that you are interested in their prospective memory.
   c. Emphasize the importance of the ongoing task, minimize the importance of the prospective memory task, and remind participants of the importance of the ongoing task from time to time.
   d. Use many trials on the ongoing task and delay the onset of the first target. Also, limit the number of occurrences of the target event.
   e. Do not specify the order of performing the prospective memory and ongoing task responses. That is, make it clear to participants that they can perform the prospective memory response at any point after seeing the target (including several trials later).
2. Use a suspended (or completed) intention paradigm.

Adapted from McDaniel, M.A., Umanath, S., Einstein, G.O., Waldum, E.R., 2015. Dual pathways to prospective remembering. Front. Hum. Neurosci. 9, 392. http://dx.doi.org/10.3389/fnhum.2015.00392. Copyright 2015 by McDaniel, Umanath, Einstein and Waldum. Reprinted with permission.

(e.g., "Is this a target word?"). Determining whether or not a string of letters forms a word and determining if a specific word is being presented both require you to access the semantic content of the item, this would be considered a focal prospective memory task. A nonfocal prospective memory task, by contrast, would have little overlap between the processing required by the ongoing task and prospective memory cue. For instance, a nonfocal task might be determining whether or not a word contains a particular syllable (e.g., *tor*, as in the word *tortoise*) during an ongoing lexical decision task, because performing the ongoing lexical decision task does not encourage or require syllabic processing. Having a nonfocal task increases the likelihood that participants will use a monitoring strategy, presumably because obtaining high prospective memory requires them to engage in both semantic and syllabic processing for each item in a serial fashion (and thus they show increased costs to the ongoing task). As an example that occurs outside the laboratory, given the intention to drop off your dry cleaning, a focal cue would be seeing the dry cleaner on the side of the road as you drive home from work. In this case, remembering that you have dry cleaning to drop off is likely to pop into mind upon seeing the store. A nonfocal cue, by contrast, would occur if the dry cleaner was not directly on your drive home from work, but located a few streets off of the main road (and out of your line of sight). In this case, monitoring would be required to remember to take the appropriate turn, or you could easily drive past and forget to drop off your dry cleaning.

Although cue focality has a major impact on whether or not people adopt a monitoring approach, in laboratory experiments participants often monitor even with focal cues (Smith et al., 2007). Accordingly, additional steps must be taken in laboratory paradigms to encourage the disengagement of preparatory processes (see **Table 1**). Scullin et al. (2010), for example, discouraged monitoring by waiting to present the one focal target item, *crossbar*, until the 501st trial (after approximately 12 min of lexical decisions without encountering target items). By the 500th trial there was no slowing in the prospective memory condition relative to the control condition, and thus according to PAM theory, prospective memory accuracy should be low. Participants remembered to perform the prospective memory task 73% of the time, however, demonstrating that successful retrieval of an intention can occur without devoting additional resources toward monitoring. By contrast, when a nonfocal cue (a word beginning with the letter *c*) occurred on the 501st trial, participants remembered to perform the prospective memory task only 18% of the time.

Furthermore, one may examine individual differences to address the question of whether or not spontaneous retrieval exists in the absence of monitoring. Einstein et al. (2005; Experiment 4) showed that participants with no costs to the ongoing task (participants with confidence intervals below zero; i.e., individuals who performed the ongoing task significantly faster *with* a prospective memory task relative to without) still obtained near-ceiling prospective memory performance (.91) that was not significantly different from participants showing high costs (.96).

Another method for eliminating monitoring has been to use an intention-interference, or suspended intention, paradigm (see **Fig. 1**), in which participants are given a focal prospective memory intention (e.g., press the *Q* key if the word *corn* appears) in the context of an ongoing task, subsequently perform these tasks, and are then asked to suspend the intention until later (e.g., "We'll get back to those tasks later, but for now we would like you to perform a different task"). Critically, in the following "suspended phase," participants do not believe the prospective memory task to be active and thus have no reason to monitor (and research shows that they do not; Knight et al., 2011; Marsh et al., 2006). The question of interest is how participants react when previously relevant target words are re-presented during this suspended phase. According to PAM theory, participants will not retrieve information related to the prospective memory task and should treat target items (e.g., *corn*) identically to matched-control items (e.g., *fish*). The research shows, however, that participants are significantly slower to respond to target items, which has been taken as evidence for spontaneous retrieval (Cohen et al., 2005, 2011; Einstein et al., 2005; Mullet et al., 2013).

From the slowing alone, it is not clear how much of the intention is retrieved in a suspended intention paradigm. The slowing could reflect a discrepancy or noticing response to target items (Breneiser and McDaniel, 2006), but there is some evidence that this slowing reflects full conscious recollection of the prospective memory intention (Anderson and Einstein, 2016). Specifically, Anderson and Einstein had participants perform a modified version of a suspended intention paradigm (**Fig. 1**) in which the intention

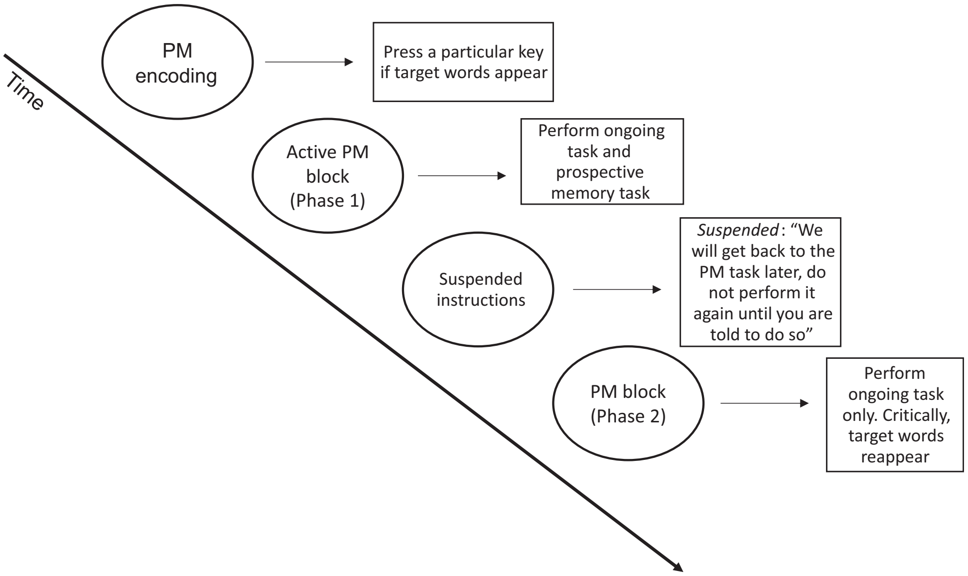

Figure 1 Example of a suspended intention paradigm. Slowing to target words in Phase 2 suggests spontaneous retrieval of the intention in Phase 1.

was completed, rather than suspended until later, and probed participants for their thoughts throughout the completed phase. After performing the intention in the first phase, participants were told they would move on to a new task and that the prospective memory task should not be performed again. Shortly after encountering previous target and control words, they were asked to report any thoughts they were having at the time they were stopped. Participants reported thinking about the prospective memory task approximately 20% of the time shortly after encountering previous target words, but only 2% of the time following control words. Thus, it appears that the slowing seen in a suspended or completed intention paradigm is often due to the actual recollection of the previous prospective memory intention.

It has been hypothesized that the disassociation between resource-demanding monitoring processes and relatively automatic spontaneous retrieval processes should be reflected in studies of aging, such that older adults should perform equally well as young adults on tasks that encourage spontaneous retrieval. Metaanalytic reviews generally show age-related decrements in prospective memory (see Kliegel et al., 2008; Uttl, 2011), but, importantly, there is an interesting mix of findings with a number of studies showing no age differences (Cherry and LeCompte, 1999; Einstein and McDaniel, 1990; Einstein et al., 1992, 1997). One interpretation of this pattern is that age differences may be less prominent (and perhaps nonexistent) with prospective memory paradigms that encourage reliance on spontaneous retrieval processes. The critical prediction here is that spontaneous retrieval can be triggered by the processing of a strong focal cue, lessening the self-initiated retrieval requirements offered by many prospective memory tasks. In a series of experiments conducted by Mullet et al. (2013), young, young-old, and old-old participants showed no age differences when spontaneous retrieval was encouraged. Specifically, in Experiment 1 (as shown in **Fig. 2**), they found age differences when nonfocal, but not focal, cues were used (see Rendell et al., 2007 for similar findings), and in Experiment 2 they found that older adults slowed significantly more than young adults to target words when using a suspended intention paradigm. These results support the exciting possibility that spontaneous retrieval is preserved in older adulthood and that this preservation can attenuate age differences in prospective memory under certain conditions.

Neuroscientific Evidence for Multiple Retrieval Processes

As mentioned previously, the multiprocess theory proposes that monitoring relies on attentionally demanding processes associated with maintaining an intention in working memory or scanning the environment for target events, whereas spontaneous retrieval is a more reflexive process that can occur involuntarily in the processing of a relevant focal cue. Developments in the field of neuroscience provide other methods for testing the multiprocess theory by attempting to find neural dissociations reflecting these qualitative differences. Specifically, under conditions in which participants are engaged in monitoring processes (e.g., with nonfocal cues), one would expect to see involvement in brain regions associated with attentional engagement, such as the prefrontal cortex and other frontal regions, and that the activation in these areas is generally sustained throughout the ongoing task. When participants are not monitoring (e.g., with focal cues), however, one would expect to see an absence of sustained frontal activation but a presence of transient activation (potentially hippocampal regions) during trials on which prospective memory is successful.

Although most neuroimaging studies in prospective memory have not focused on isolating spontaneous retrieval processes (see Cona et al., 2015; McDaniel et al., 2015 for reviews), and thus there are few studies in which monitoring processes are likely to be disengaged, there is some evidence to support the claim that different neural routes support monitoring and spontaneous retrieval.

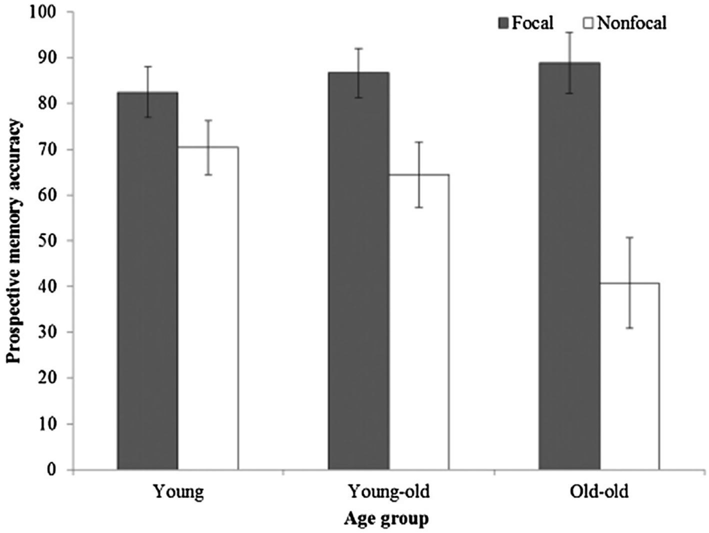

Figure 2 Prospective memory performance as a function of age (young, young-old, old-old) and cue focality (focal, nonfocal). Older adults showed impairment on nonfocal but not focal tasks. Reprinted with permission from Mullet, H.G., Scullin, M.K., Hess, T.J., Scullin, R.B., Arnold, K.M., Einstein, G.O., 2013. Prospective memory and aging: evidence for preserved spontaneous retrieval with exact but not related cues. Psychol. Aging 28, 405–416. Copyright 2013 by the American Psychological Association.

For example, McDaniel et al. (2013) found sustained activation during ongoing task processing in prefrontal areas associated with attentional control during a nonfocal prospective memory task but not during a focal prospective memory task (see also Reynolds et al., 2009). Further, using a completed intention paradigm, Beck et al. (2014) found no sustained activation in the rostrolateral prefrontal cortex during the following block (in which no prospective memory task was required, but previous targets reappeared). Although they found no evidence for sustained activation, or monitoring, Beck et al. did observe transient activity in the ventral parietal cortex, the precuneus, and the posterior cingulate cortex when previous prospective memory targets reoccurred. Because there was no behavioral indication of monitoring during this completed phase, it is likely that the transient activation in these areas reflected spontaneous retrieval processes triggered upon encountering previous target words.

There is also converging evidence with structural neuroimaging for a functional distinction between monitoring and spontaneous retrieval. Scullin et al. (2013a) showed that participants with a history of hypertension had reduced white matter in the anterior prefrontal cortex (aPFC), but no reduction in white or gray matter in any other brain regions, relative to a control group of participants with no history of hypertension. When asked to perform both focal and nonfocal prospective memory tasks, the hypertension group showed decrements in nonfocal, but not focal prospective memory, and this was accompanied by an absence of costs to the ongoing task, suggesting they were unable to maintain the attentional control necessary for detecting a nonfocal cue. Additional research has shown that hippocampal volume was significantly correlated with focal prospective memory performance, but had no correlation with nonfocal task performance (Gordon et al., 2011). Taken together, these studies support the view that different prospective memory processes rely on different brain structures; namely, it appears the frontal regions such as the aPFC are involved in attentionally demanding monitoring processes, but that hippocampal regions can support spontaneous retrieval.

Further, research has shown support for a dissociation in the neural routes of prospective memory by examining special populations where different brain regions are selectively affected. For example, nondemented individuals with Parkinson's disease, which disrupts many executive control processes assumed to be involved in monitoring, exhibit impairment for nonfocal, but not focal, tasks (Foster et al., 2009). Critically, there is also evidence to suggest that cognitive impairment or decline does not uniformly affect nonfocal tasks and frontal processes, but that the type of prospective memory impairment depends on which brain regions are affected. Patients with amnestic mild cognitive impairment (MCI; clinical dementia rating = .5), which is often accompanied by damage to hippocampal regions, show significantly greater decline on focal tasks than on nonfocal tasks, relative to cognitively normal individuals (clinical dementia rating = 0; McDaniel et al., 2011). Although this dissociation is not always found (Lee et al., 2015), it provides support for the distinction between spontaneous retrieval and monitoring processes, as well as their reliance on different brain regions. Niedźwieńska and Kvavilashvili (2016b) provided further support for this hypothesis by also showing that individuals with amnestic MCI displayed more impairment on focal than nonfocal tasks (see **Fig. 3**). Related work from the same researchers (Niedźwieńska and Kvavilashvili, 2016a) additionally found that amnestic MCI patients experienced fewer involuntary autobiographical memories, supporting the distinction that spontaneous retrieval of prospective and retrospective memories is largely dependent on the hippocampus and surrounding regions, rather than attentional processes dependent on frontal regions.

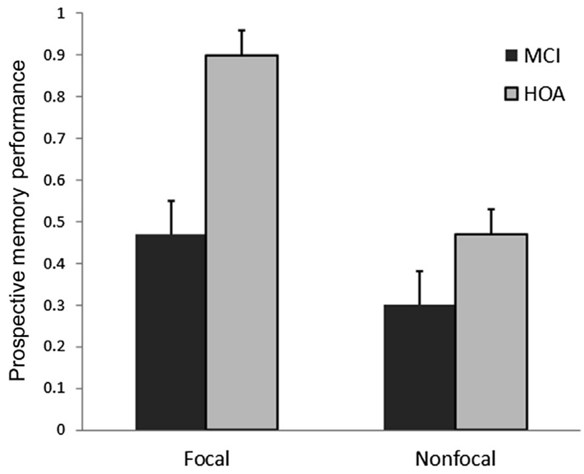

Figure 3 Focal and nonfocal prospective memory performance in patients with amnestic mild cognitive impairment (MCI) and healthy older adults (HOA). Results indicated a greater decline in focal prospective memory performance than nonfocal performance for MCI patients when compared to HOA. *Error bars* represent standard error of the mean. Reprinted with permission from Niedźwieńska, A., Kvavilashvili, L., April 2016. Prospective memory in older adults with mild cognitive impairment: is automatic retrieval more disproportionately impaired? In: Poster Presented at the Annual Cognitive Aging Conference, Atlanta, GA.

Mechanisms Supporting Spontaneous Retrieval

Given (1) the behavioral evidence that relatively high levels of prospective remembering can be observed even when there are no costs to the ongoing task and (2) the converging neuroscientific evidence for multiple processes in prospective memory, it appears that spontaneous retrieval is a relatively automatic process that does not require the engagement of many cognitive resources. Two mechanisms have been proposed as possible explanations for how spontaneous retrieval occurs: reflexive associative retrieval and discrepancy plus search.

Reflexive Associative Retrieval

According to the reflexive associative retrieval hypothesis, a strong associative link between the target and the intended action is formed during encoding or planning, and the processing of one component of the association leads to the rapid retrieval of the other. This is based largely on Moscovitch's (1994) view of the hippocampus and other medial temporal structures (see also, Cohen et al., 1999; Eichenbaum, 2004), in which associative units are formed at encoding between the stimulus and preexisting memory representations (to the degree with which attentional resources are devoted toward encoding). Subsequent processing of the stimulus can then lead to rapid and obligatory retrieval of its counterpart. In the context of a typical prospective memory task, for example, participants might encode the intention to press the *Q* key if the word *corn* appears, thereby forming a strong association between the target stimulus (*corn*) and the intended action (press the *Q* key). Then, full processing of the cue *corn* will lead to a spontaneous retrieval of the associated intention to press the *Q* key. Critically, under this view, full processing of the cue is required for spontaneous retrieval, which helps explain why certain conditions influence the likelihood of these reflexive, relatively automatic processes, such as cue focality and salience, dividing attention, and emphasis of task instructions (Einstein et al., 1997, 2000; Harrison et al., 2014; Kliegel et al., 2001).

Evidence in support of this hypothesis comes from studies in which the preexperimental associative strength between the target and intended action varies across conditions (McDaniel et al., 2004). Specifically, participants were asked to rate words on a variety of characteristics (e.g., pleasantness), but if a particular target word appeared, such as *spaghetti*, they were to write down the associated action word *sauce* (as another example, *needle–thread*). The high associative strength condition received semantically related target and action words such as those in the previous example, whereas the low associative strength condition received unrelated pairs such as *spaghetti–needle* or *sauce–thread*. Analogously, in everyday life a highly associated target–intention pair might be to remember to get eggs when you go to the grocery store, as opposed to a poorly associated pair such as remembering to go get eggs when you take a shower. As predicted from the reflexive associative retrieval framework, high-association target–intention pairs were more likely to be executed than low-association pairs, presumably because the high semantic association bolstered the target–action link.

There is also evidence that strong associations, and thereby improved prospective memory, can be experimentally manipulated. Implementation intentions, for example, are thought to create high associative links between the intention and previously unrelated contextual cues (Gollwitzer, 1999). Taking the form "When *x* occurs, I must remember to perform *y*," implementation intentions can take a general intention (e.g., I need to remember to take my medication) and provide strong contextual associations (e.g., *When I have breakfast, I will take my medication*) that increase the likelihood of reflexive retrieval upon encountering the contextual cues (i.e., those associated with breakfast). More specifically, tying the intention to environmental stimuli increases the likelihood of spontaneous retrieval, because eating breakfast can now serve as a strong cue for the intention to take medication (see Gollwitzer and Sheeran, 2006; McDaniel et al., 2008; McFarland and Glisky, 2012; Rummel et al., 2012, for evidence showing that implementation intentions increase prospective memory performance).

Discrepancy Plus Search

Another proposed mechanism of spontaneous retrieval that has received experimental support is the discrepancy-plus-search hypothesis (McDaniel et al., 2004). This is based on Whittlesea and Williams' (2001a,b) theory that people go through their day with certain expectations about the quality or fluency of their processing. Such evaluations can lead to experiences of discrepancy, in which one's expectations about how fluent processing should be do not coincide with the actual processing fluency that is experienced. Upon experiencing discrepancy, the cognitive system tries to identify a cause. In a prospective memory experiment, for example, within the routine of performing an ongoing task, the processing of a prospective memory target (presented in the context of new items) may elicit a feeling of discrepancy (i.e., because of prior encoding, prospective memory targets are discrepant from the current context). The unexpected fluency of the prospective memory target interrupts ongoing task processing, and the person then searches for the attribution of such discrepancy, retrospectively recalls the prospective memory task, and performs the intention.

Support for this hypothesis was reported in an experiment that manipulated the preexposure of *nontarget items* (McDaniel et al., 2004). Specifically, for half of the participants, the nontarget items on the ongoing task had been previously seen on a recognition memory test. For the other half of the participants, the nontarget items on the ongoing task were completely novel. Prospective memory performance was impaired when the nontarget items were preexposed, relative to when they were novel. Interpreted within the discrepancy-plus-search framework, when the expectation is that all items are going to be novel, a previously encoded prospective memory target is more likely to elicit feelings of discrepancy (i.e., the processing of the target item is experienced as more fluent than expected in the context of novel items) than when there is the expectation that all items will be familiar (see also, Breneiser and McDaniel, 2006; Lee and McDaniel, 2013).

A recent experiment conducted by Rummel and Meiser (2016) also provides strong support for the discrepancy-plus-search hypothesis by showing that discrepancy can induce prospective memory responding even for nontarget items. Their critical prediction was that if people spontaneously retrieve prospective memory intentions based on how discrepant the target items are from the ongoing task, then nontarget items that elicit similar feelings of discrepancy could produce false responses or commission errors. In the experiment, Rummel and Meiser introduced primes for 54 ms prior to each lexical decision trial and manipulated the number of target items participants needed to remember. Specifically, they primed lure words with the exact same word to elicit feelings of fluency (which would be discrepant from nonprimed control words), and participants were told to press a certain key when any of either 6 or 12 target words appeared. Manipulating prospective memory list length in this way would presumably affect search processes, such that having 12 target words should increase the retrospective memory demands and thereby might increase participants' indecisiveness about whether a discrepant item is in fact a prospective memory target. Although there were no significant differences based on list length, they found that primed nontarget words produced significantly more false responses than neutral words. Consequently, it appears that feelings of discrepancy alone can lead to consideration of the prospective memory task and in some cases inappropriate execution of intentions.

The Dynamic Interplay Between Monitoring and Spontaneous Retrieval

A hallmark feature of the multiprocess theory is its flexible allowance for different strategies and processes to interact when producing successful prospective memory. Whereas most of the research described thus far has focused on isolating monitoring and spontaneous retrieval as a way to inform their existence and their underlying mechanisms, it is likely the case that the two operate in concert in everyday situations, supporting each other for appropriate execution. For example, it is highly unlikely that people monitor continuously in all situations, but might flexibly adjust their monitoring strategies in response to differing task demands. Further, spontaneous retrieval when the target event is not present (see Kvavilashvili and Fisher, 2007) could trigger monitoring processes until the correct target event is reached.

Take as an example the potential complexity arising from a simple delayed intention: remembering to go get groceries on the drive home from work. You might encode the intention in the morning after looking at a miserably empty refrigerator, but the present concern of work comes first, and you must delay the intention until later that day. When you get to work, given that it will be 8 h or so before you will be driving home, it would be cognitively demanding and inefficient to monitor. Still, spontaneous retrieval to get groceries might occur throughout the day, such as when you see your sparse lunch. At that point, monitoring would again be inappropriate, but upon leaving work and getting in your car, you might again spontaneously retrieve the intention. At this point, monitoring is a fruitful strategy, and perhaps you engage maintenance or rehearsal processes to help guide you to the grocery store rather than home as usual. Further, it is not a necessary prerequisite that monitoring be engaged continuously for the entire drive home, but could be triggered transiently throughout the drive, such that you think about the task before appropriate turns, but let the intention lapse from working memory when you are clearly not driving home anymore, but to the grocery store.

A similar position was first proposed by Marsh et al. (2006b), when they observed that ongoing task response times were only slowed in a condition that was not informed of the context at which the prospective memory task must be performed. Specifically, when the intention was linked to a specific context (e.g., targets will only appear in the third phase of the experiment), they found no evidence of monitoring until the specific context was encountered (e.g., the third phase of the experiment). By contrast, for participants who were not informed when the prospective memory targets would occur, there was evidence of monitoring (all three

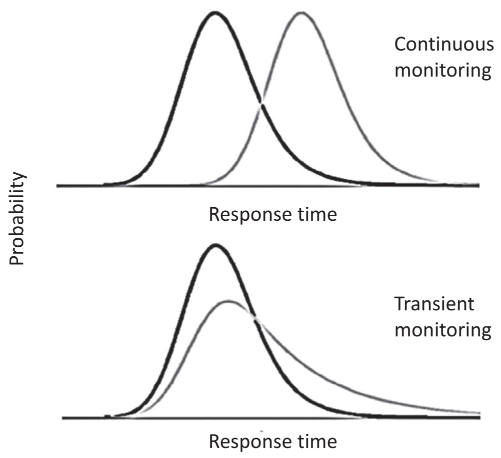

Figure 4 Depiction of continuous and transient monitoring using an ex-Gaussian modeling technique. Both result in mean differences reflecting costs to the ongoing task, but continuous monitoring shifts the whole distribution, whereas transient monitoring skews the distribution.

phases). Therefore, it appears that people can strategically deploy monitoring processes in response to task demands (see also Kuhlmann and Rummel, 2014). Further, Smith et al. (2016) varied whether participants performed an ongoing task with pictures that were presented in a meaningful order (where the sequence of pictures represented a meaningful walk on campus) or in a random order. Relative to the random order condition, participants in the ordered pictures condition strategically increased their monitoring as the relevant context approached and decreased monitoring in nonrelevant contexts.

There is also evidence to suggest that people can engage in monitoring either transiently or continuously and that transient monitoring profiles are more likely to result in prospective memory failures—presumably because the targets appeared during a lull in monitoring behavior. Ball et al. (2015) demonstrated this by having participants engage in an experiment similar to Marsh et al. (2006a), in which some participants were informed when prospective memory targets would occur. Ex-Gaussian modeling of these data allowed the researchers to examine the shape of response time distributions when they had a nonfocal prospective memory task relative to when they did not. The analyses revealed that those participants who were not told when to expect prospective memory targets had skewed distributions, suggesting that they intermittently monitored in the preceding phases (see **Fig. 4**, lower panel). This skew produced a mean slowing in response times, or costs; note that if participants had been monitoring continuously, then the entire distribution would have shifted (**Fig. 4**, upper panel). Further, because the task was nonfocal, participants who engaged in continuous monitoring had higher prospective memory performance than those who only monitored transiently (e.g., they let their attention lapse and missed the nonfocal targets). When this modeling technique is applied to focal tasks as well (Loft et al., 2014), however, the distinction between transient and continuous monitoring had no functional influence on prospective memory performance. Thus, it appears that when participants engage in intermittent monitoring with a nonfocal cue, they are more likely to show impaired prospective memory, but spontaneous retrieval may offset this impairment when focal cues are used.

Scullin et al. (2013b) more explicitly examined this interplay between monitoring and spontaneous retrieval. They found no evidence for monitoring preceding the presentation of target items (under conditions that discourage a monitoring strategy). But, for participants who spontaneously retrieved the intention upon encountering target items, increased costs (monitoring) followed successful execution of the task. This is presumably because noticing a prospective memory cue alerted participants that other cues were likely to occur in that context. Participants who missed the prospective memory target, however, showed no costs to the ongoing task in the following trials. This led Scullin et al. to propose the dynamic multiprocess framework, suggesting a relationship similar to that described above, in which monitoring processes are difficult to maintain for extended periods of time but can be flexibly engaged following spontaneous retrieval (e.g., retrieving the intention to go to the grocery store upon getting into your car after work, and monitoring until execution).

Delay Theory

Although much research has been devoted toward understanding the nature of spontaneous retrieval, or successful prospective memory in the absence of costs, less research has attempted to understand the underlying processes involved in prospective memory when costs are present. As described in the preceding sections of this chapter, the predominant interpretation of costs is that they reflect internal preparatory processes, or monitoring, that involve scanning the environment for target events or rehearsing the prospective memory task. Central to this theory is the assumption that monitoring is a cognitively taxing process in which the prospective memory task competes for resources with the ongoing task. The more resources devoted toward the prospective memory task, the fewer resources remaining for performing the ongoing task, thus slowing response times on the ongoing task. There is converging evidence for this conceptualization in studies of aging (e.g., older adults are worse on nonfocal tasks; Kliegel et al., 2008), working memory (e.g., working memory capacity predicts performance under conditions in which participants monitor; Smith, 2003), and neuroimaging (e.g., nonfocal but not focal PM is associated with sustained aPFC processes; McDaniel et al., 2013).

Recently, Heathcote et al. (2015; see also, Loft and Remington, 2013) proposed a provocative "delay theory" of prospective memory costs. To provide support for the theory, they applied an evidence accumulation model (the linear ballistic accumulator) that characterizes a fast, two-option decision (such as a lexical decision) as reflecting the rate at which information for the decision accumulates and the boundary settings that determine when the accumulated information is sufficient for a decision. The delay theory assumes that prospective memory costs reflect a more conservative boundary setting for the ongoing-task decision (to allow time for information relevant for the prospective memory task to become available). Thus, the change in ongoing task performance when a prospective memory task is present relative to when it is not should be captured solely by the parameter estimates (obtained from the evidence accumulation model) for the decision boundary; the theory predicts no change in the rate of information accumulation parameter.

Using parameter estimates derived from the evidence accumulation model, Heathcote et al. (2015) observed changes primarily in the decision boundary parameter, suggesting that the costs associated with having a nonfocal prospective memory task were due to participants "relaxing" their decision boundaries. Specifically, Heathcote and colleagues proposed that participants were raising their word/nonword decision threshold on the lexical decision task to allow more time for prospective memory information to be accumulated. Under this theory, information relevant to the ongoing task and the prospective memory task are accumulated in parallel (but at different rates), and both types of information compete in a horse-race fashion to determine the response selection. In their experiment, for example, participants were asked to perform a lexical decision task, but were additionally told to press the *F1* key if they saw a word or a nonword containing the syllable *tor* (a nonfocal task). Within the delay theory framework, semantic information (e.g., "Is this item a word?") and syllabic information (e.g., "Does this item contain *tor*?") accumulate simultaneously, and successful prospective memory will occur only if syllabic information has accumulated sufficiently before the accumulated semantic information exceeds the decision boundary (for the lexical decision task). Therefore, the observed change in the decision boundary parameter suggests that participants strategically raised their threshold for responding, allowing time for both types of information to accrue, thereby supporting successful retrieval in the nonfocal prospective memory task.

This theoretical framework is supported by behavioral evidence from Loft and Remington (2013) showing that forcing participants to withhold responding over certain delays (600–1600 ms) raises nonfocal prospective memory accuracy to levels comparable with focal prospective memory. As seen in **Fig. 5**, work from Lourenço et al. (2013) additionally showed that when participants are told that nonfocal prospective memory targets will only occur on word trials in a lexical decision task, there was less slowing on nonword trials, implying that participants were successfully able to adjust their decision threshold based on the task demands (and the formal modeling of these data supports this account; Heathcote et al., 2015). More specifically, on nonword trials, once lexical information had accrued (e.g., this is not a word), participants immediately executed their decision, but on word trials they delayed their responding presumably to allow prospective memory information (e.g., "Is this a target word?") to reach threshold.

Challenges for Delay Theory

Delay theory has difficulty accounting for other behavioral evidence, however, and it is not apparent that a complete reformulation of the interpretation of costs is required as of yet. For example, because delay theory is presented as an overarching theory of

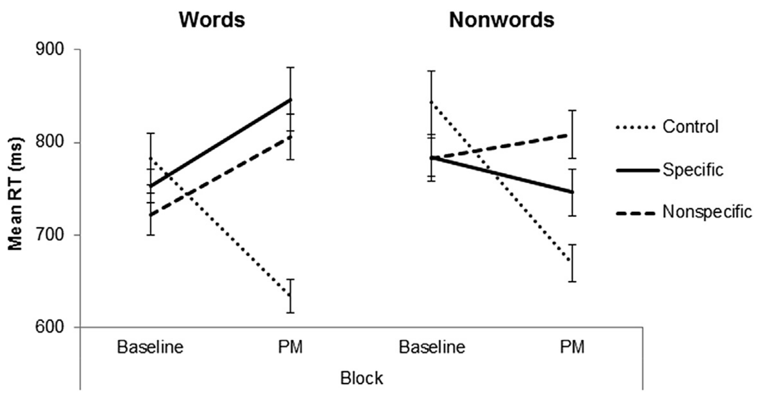

Figure 5 Mean correct response time (RT) in milliseconds (ms) in the lexical decision task as a function of block and condition for words (left) and nonwords (right). The control condition received no prospective memory task, the specific condition was told the targets would only occur on word trials, and the nonspecific condition was not informed about what trials would contain targets. *Error bars* represent ±1 *SE*. Reprinted with permission from Lourenço, J.S., White, K., Maylor, E.A., 2013. Target context specification can reduce costs in nonfocal prospective memory. J. Exp. Psychol. Learn. Mem. Cogn. 39, 405–416. Copyright 2013 by the American Psychological Association.

prospective memory, rather than a theory of nonfocal prospective memory, it should be able to explain the patterns obtained when focal cues are present. Yet, it is unclear how delay theory would account for the increased costs found when more than two focal targets are encoded in the prospective memory task (Gollwitzer and Cohen, 2008; Cohen et al., 2008; Smith, 2003). With one focal target, delay theory would account for the absence of cost by assuming that information for the prospective memory target cue accrues at a rate that is no slower than that required for the ongoing task; accordingly, participants do not adjust their decision threshold when the prospective memory task is present. With more than two focal targets, on the delay theory model (as currently constructed; Heathcote et al., 2015) the decision threshold should still not require adjustment. This is because the information accrual dynamics are presumed to operate in a parallel processing horse-race fashion, and thus the number of focal targets should not influence the information accumulation rate (an alternative prediction might be made if there are limited capacity constants, however, e.g., Townsend, 1990).

More generally, to accommodate the corpus of findings (showing either the presence or absence of costs) with delay theory, one must assume that participants somehow adjust their decision threshold as a function of a complex array of task characteristics with a high degree of sensitivity. Namely, it would have to be assumed that participants strategically adjust their decision criteria in response to not only the focality of the prospective memory target, but also the number of targets, the salience of targets, the length of trial sequences for which a target is not encountered, and the difficulty of the ongoing task to name a few (Cohen et al., 2008; Einstein et al., 1997, 2000; Kliegel et al., 2001; Scullin et al., 2010; see **Table 1**).

Neuroimaging results provide further complications for delay theory: participants engaging in nonfocal tasks show sustained aPFC activation—an area strongly associated with attentional control—whereas for focal prospective memory tasks this sustained activation was absent (McDaniel et al., 2013). Therefore, the question is why a single underlying process (information accumulating in parallel and the accompanying threshold changes) would leave different neural footprints depending on the type of cue given. More specifically, why does a change in decision threshold for the ongoing task when a nonfocal cue is present require sustained aPFC activation but these same mechanisms do not require sustained aPFC with a focal cue?

A Test of Delay Theory

Thus far, no experimental evidence has been reported to directly contrast delay theory with the widely accepted monitoring view (for nonfocal prospective memory targets). Accordingly, in this section we report a just-completed experiment conducted in our lab (Anderson, Rummel, and McDaniel) that attempted to illuminate differences in the behavioral footprints produced by conditions in which participants were instructed to either monitor (*monitoring* condition) or increase their decision threshold during a nonfocal prospective memory task (*boundary* condition). These footprints and the associated diffusion model parameters were then compared to a standard prospective memory condition. Critically, this experiment maintained the exact methodology of the Heathcote et al. (2015) study, comparing a control block lexical decision task to a prospective memory block containing the additional intention to press the *Q* key to items containing the syllable *tor*.

The results revealed that the monitoring and boundary conditions did in fact show diverging patterns. Prospective memory accuracy was significantly higher when participants were encouraged to monitor ($M = .73$) relative to when they were encouraged to slow down in responding to the ongoing task ($M = .55$) (i.e., employ a more conservative decision threshold). By contrast, cost was higher for the boundary condition than for the monitoring condition, as was the increase in ongoing task accuracy. These dissociative patterns across the monitoring and boundary conditions (in terms of prospective memory performance and ongoing-task cost/accuracy) provide initial support for the assumption that the instructional conditions produced different approaches to the prospective memory task. To gain further support for this assumption, we used Ratcliff diffusion modeling to index the underlying dynamics of the cost. We expected that participants in the boundary condition should display a higher value for decision threshold (between the control block and the prospective memory block) than participants in the monitoring condition. This is exactly what occurred. The decision boundary became significantly more conservative for the boundary condition than for the monitoring condition. Together, these findings suggest that the conditions produced somewhat different processes during the prospective task: monitoring instructions were associated with much smaller changes in decision boundary than was boundary adjustment instructions (more conservative), but significantly higher prospective memory.

Critically, this experiment also included a condition with standard prospective memory instructions. This standard condition displayed prospective memory accuracy (.60) that was intermediate between the boundary and the monitoring conditions. Importantly, the standard condition showed significantly less slowing and significantly poorer ongoing task accuracy than the boundary condition. Thus, prospective memory accuracy did not significantly differ between the standard and boundary conditions, but the differences in ongoing task performance suggest that there were distinct behavioral differences between the standard condition and a condition that appeared to capture a delayed responding process (akin to that proposed by delay theory). The parameter estimates derived from the diffusion modeling further support this conclusion. The boundary condition demonstrated significantly greater decision threshold change from control block to active block than the standard condition, but this was not accompanied by a corresponding increase in prospective memory accuracy. Finally, regression analyses (collapsed across all three conditions) predicting prospective memory accuracy indicated that both the change—from control to prospective memory blocks—in drift rate (which can be interpreted as reflecting a capacity demanding monitoring process; Heathcote et al., 2015) and the participant's working memory capacity were related to prospective memory performance. By contrast, the change in decision thresholds was not. These patterns align with a monitoring view of costs (and of an underlying prospective memory process) more so than the delay theory of costs.

The above patterns notwithstanding, it may be worth noting that prospective memory responding was not at floor when participants were encouraged to raise their decision threshold. In fact, they remembered to perform the task over 50% of the time, suggesting that delayed responding may be a fruitful strategy for prospective remembering. It is possible, therefore, that monitoring and delayed responding are two alternative strategies for remembering to execute intentions, which participants may engage depending on the task demands. For example, the efficacy of monitoring has been shown in numerous situations, and the evidence suggests that continuous maintenance of an intention with few attentional lapses greatly increases the likelihood of appropriately performing the action. Delaying ones responding, however, could serve as a process that mitigates the damage of attentional lapses. For example, if you are not monitoring and in a hurry to leave to work, you may forget your keys on the kitchen table as you race out the door. If you are not in a hurry, however, the accumulation of relevant prospective memory information (e.g., those are *my* keys on the table, and I might need them to get to work) may reach threshold before you leisurely leave for work.

Summary

We have examined three theories of prospective memory—the preparatory attentional and memory theory, the multiprocess theory, and delay theory—and the related empirical evidence for each. Although each theory has merit, research in prospective memory provides clear evidence for the importance of both monitoring (or perhaps delayed responding) and spontaneous retrieval processes, creating a framework in which multiple processes (perhaps often in dynamic interplay) can help us remember to execute delayed intentions. As mentioned at the beginning of the chapter, of critical importance is the ease with which people can forget to execute intentions if they are not maintained in working memory, and the speed at which our thoughts can exit consciousness. For example, requiring participants to delay their execution of an already retrieved intention (as might be the case if you retrieve the intention to take your medication when you are in your bedroom, but then must keep the intention activated until you reach your medication in the kitchen) by just 5 s under extremely demanding divided attention conditions can cause forgetting of 25% in young adults (Einstein et al., 2003) and 50% in older adults (McDaniel et al., 2003). When the fact that delayed intentions are easily lost is coupled with evidence suggesting that people have poor metacognitive awareness of this fallibility (Einstein et al., 2000), it is probable that many naturalistic prospective memory failures are due to a reliance on monitoring processes. Offloading our demands on the environment, for example, by providing oneself strong focal cues, offers the potential to prevent many of these failures and to avoid many of the costs associated with relying on monitoring.

As stated at the beginning of this chapter, the central problem concerning prospective memory is how people self-initiate the retrieval of intentions when there is no external agent to prompt a search. Monitoring processes are difficult to maintain, and attentional lapses greatly increase the likelihood of observing prospective memory failures. Therefore, people who exhibit successful prospective memory are those who appropriately engage in a variety of strategies depending on the task demands, creating strong external cues to encourage spontaneous retrieval, and monitoring continuously when target events approach. With the ubiquity of smartphones and other related technologies, our ability to offload intentions is now easier than ever, but the metacognitive awareness to do so at opportune moments may make these behaviors less common than would be expected. Although there appears to be a general bias toward relying on spontaneous retrieval processes (Kvavilashvili and Fisher, 2007), efficient prospective remembering requires one to know when spontaneous retrieval is likely, when monitoring processes are necessary, and how to use both external reminders and internal strategies such as implementation intentions to support prospective memory.

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