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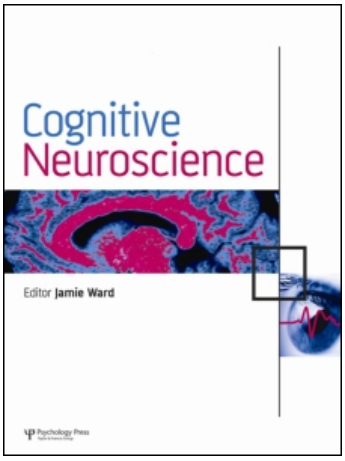

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On the role of episodic future simulation in encoding of prospective memories

Gene A. Brewer [a]; Richard L. Marsh [a]
[a] University of Georgia, Athens, GA, USA

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On the role of episodic future simulation in encoding of prospective memories

Gene A. Brewer and Richard L. Marsh
University of Georgia, Athens, GA, USA

Simulating future events is dependent on a similar neural circuitry to that which supports retrieving contextual information about past events. The current study examined two novel predictions from recently reported episodic future simulation studies. Prospective memory is broadly defined as the usage of episodic memory processes to encode and retrieve intentions at some appropriate moment in the future. The results from two experiments are consistent with the idea that episodic future simulation is an important component of encoding prospective memories (i.e., forming intentions for the future). Furthermore, the results necessitate further neuroscientific investigations of encoding prospective memories and additionally suggest that current theories of prospective memory need to be updated to fully account for our ability to encode, retrieve, and fulfill intentions for the future.

Keywords: Prospective memory; Episodic memory; Future simulation.

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INTRODUCTION

Memory is essential for planning and coordinating activities that will need to be carried out in the future. Only recently have researchers begun to appreciate the critical role that retrospective memory processes play in fulfilling such intentions (Marsh, Cook, & Hicks, 2006). By this account, the realization of delayed intentions relies on episodic memory, and recent theorizing has attempted to elucidate the conditions under which attentional processes are necessary for the retrieval of these declarative memories (Einstein et al., 2005; Marsh & Hicks, 1998; Smith, 2003). These declarative representations have been labeled event-based prospective memories to reflect a person's reliance on processing some constellation of perceptual cues to elicit an appropriate action in the future. Most research dealing with event-based prospective memory has investigated how cues are detected in the environment and how appropriate actions that are associated with these cues are retrieved from memory. The present study capitalized on recent neuroimaging research dealing with episodic future simulation in order to test two novel predictions about how people use episodic memory to *encode* event-based prospective memories. More specifically, we believe that such memories consist of a simulated future context, perceptual cues that may occur in that context, and a target action to carry out at the moment in the future in which the cue is encountered.

To study event-based prospective memory, researchers have developed a paradigm that resembles real-world scenarios in which people must remember to perform a specific action at an appropriate moment in the future. Imagine forming the intention to give a colleague a message when you see them at work. When you encounter your colleague later that day, you may or may not remember to give them the message. To simulate this scenario in the laboratory, participants are typically engaged in an ongoing task (e.g., lexical decision task) in which event-based prospective memory cues infrequently occur (e.g., animals; Marsh, Hicks, & Watson, 2002). When

Correspondence should be addressed to: Gene A. Brewer, Department of Psychology, University of Georgia, Athens, GA 30602-3013, USA. E-mail: gabrewer@uga.edu

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participants detect a cue in the ongoing task they must retrieve their intention and make a target response (e.g., press the slash key). This basic paradigm has been instrumental in clarifying the attention and retrospective memory processes that are necessary for successful event-based prospective memory (for a review see McDaniel & Einstein, 2007). Moreover, this basic paradigm has been useful for distinguishing prospective memory from retrospective memory.

Prospective memories differ from retrospective memories in several important ways (Marsh et al., 2006). First, prospective memories have a dual nature in which intentions consist of not only a retrospective component, but also a prospective component (Einstein & McDaniel, 1990). In many respects the prospective component of an intention is what separates it from other retrospective memories. To wit, the association of a target action to some type of cue is what distinguishes a standard retrospective memory from an event-based prospective memory. Second, intentions about future activities reside in memory at an above baseline level of activation (i.e., the intention superiority effect). This superiority effect is typically demonstrated when intention-related information is processed differentially when it is encountered in the context of some ostensibly unrelated ongoing task (Goschke & Kuhl, 1996; Marsh, Cook, Meeks, Clark-Foos, & Hicks, 2007). Third, prospective memories require some level of self-initiated processing to be retrieved whereas retrospective memories sometimes do not (Craik, 1986). In cases where ongoing task processing draws attention away from relevant features of the event-based cues, people may need to allocate preparatory-attentional resources for monitoring for those features in order to successfully fulfill delayed intentions (Einstein & McDaniel, 2005; Marsh & Hicks, 1998; Smith, 2003). Fourth and finally, prospective memories consist of two contextual representations whereas retrospective memories typically consist of only one. That is, when people encode a prospective memory they not only have a mnemonic representation of that original encoding episode, but they also simulate a representation of the future in which event-based cues might be noticed and the target action might ultimately be carried out. This *future-simulation* ability is related to the constructive nature of episodic memory and is quite important for the realization of delayed intentions (Atance & O'Neill, 2001).

A unique feature of the human memory system is its ability to reconstruct and re-experience past events (Johnson, 2006; Tulving, 1983). Our declarative memory system is flexible, and as a result we are also able to construct and experience future events before they occur (Atance & O'Neill, 2001). Recently, research has examined the neural network responsible for mental time travel (Addis, Wong, & Schacter, 2007; Buckner & Carroll, 2007; Schacter & Addis, 2008; Szpunar, Watson, & McDermott, 2007). The findings from these studies indicate that people recruit similar neural structures when they remember the past as when they envision the future. Theoretically, this episodic-memory network plays a role in recapitulating perceptual context and these cortical–subcortical structures are critical for both remembering the past and envisioning the future (Okuda et al., 2003). Thus, episodic information is useful for creating representations of event-based prospective memories which are to be carried out in the future.

THE CURRENT STUDY

The current study tested two novel predictions, using standard event-based prospective memory paradigms, which were derived from neuroimaging evidence from episodic future simulation studies. The first prediction was that the strength of the association between the event-based cues and the ongoing task context in which they will occur influences their likelihood of detection. Szpunar and McDermott (2008) demonstrated that participants report stronger subjective experiences of the quality of their representations of the future when they are imagined in a familiar context (e.g., their home vs. a jungle). Thus, when people encode an event-based prospective memory they presumably associate potential cues to some expected context. As such, when the cue-to-context association is weak, people should have a lower likelihood of detecting event-based cues.

The second prediction from future-simulation studies was that episodic memory could be used to create more elaborate representations of a future context in which an intention would be fulfilled. D'Argembeau and Van der Linden (2004, 2006) found that people report envisioning future events in similar contexts as they have experienced past events. They have also found that individuals who have higher visual imagery capabilities report stronger phenomenological experiences while future-looking. Based on these findings, more elaborate event-based prospective memories should have higher likelihoods of being fulfilled. The following experiments tested these two predictions using a standard event-based prospective memory paradigm in which participants completed a lexical decision task after forming the intention to make a special response whenever they detected a rarely occurring event-based cue (e.g., any animal word).

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EXPERIMENT 1

Participants

Undergraduate students from the University of Georgia volunteered in exchange for partial credit toward a research appreciation requirement. Each participant was tested individually in sessions that lasted approximately 25 min. A total of 90 participants were randomly assigned to one of three between-subjects conditions. Each group differed in the level of encoded association between the prospective memory intention and the ongoing task.

Materials and procedure

The parameters of the ongoing lexical decision task were nearly identical to those used by Marsh et al. (2002). There were 210 lexical decision trials, with equal numbers of valid English words and pronounceable nonwords. The 105 valid words were chosen from the Kučera and Francis (1967) norms. The nonwords were made in house by changing one or two letters of 105 different, valid English words to make them pronounceable nonwords. Word and nonword responses were made by pressing either the F or J (home) key on the keyboard. The ongoing task was self-paced and each trial began with a "waiting" message. Participants were instructed to press the *space bar* with their thumb to initiate the following letter string presentation. After pressing the *space bar* a fixation point appeared onscreen for 250 ms, and then the letter string appeared in the center of the monitor at the same place the fixation point had occupied. Eight event-based prospective memory cues occurred every 25 trials. The event-based cues were randomly assigned to each of these eight positions anew for each participant. In addition to completing the lexical decision task, participants were also instructed to respond to animals in all three conditions, with the only difference between groups being the encoding conditions of the intention to make a special response to animals.

In the no-association condition, participants were instructed to press the slash key anytime that an animal occurred during the experiment immediately after they signed informed consent. Importantly, at this point in the experiment the participants in the no-association condition were not aware that the event-based cues (i.e., animal words) would occur in a lexical decision task. Therefore, the participants were not even aware that they would complete a lexical decision task in the experiment or that the animal cues would be presented as words. Thus, participants in this condition could not create an association between their intention to respond to animals and the ongoing task in which these event-based cues would eventually occur. In the regular-association condition, participants were given the ongoing task instructions with the prospective memory instructions following directly afterwards. This condition resembles previous paradigms typically utilized in the prospective memory literature (e.g., Marsh et al., 2002). In the strong-association condition participants were given the ongoing task instructions with the prospective memory instructions following afterwards as well. Additionally, participants in the strong-association condition were asked to form an implementation intention using visual imagery to imagine themselves responding to animals in the context of making the word–nonword judgments in the ongoing task (Gollwitzer, 1999; McDaniel, Howard, & Butler, 2008). More specifically, for 30 s participants closed their eyes and imagined completing the lexical decision task while repeating the statement "If I see an animal then I will press the slash key after making a word response" (Meeks & Marsh, in press). In all conditions the experimenter reiterated the instructions to the participants and started the next phase after the participants acknowledged that they understood the instructions.

Results and discussion

As can be seen in Figure 1, the stronger the association between the event-based prospective memory cues and the lexical decision task, the greater the number of event-based cues that were detected in that ongoing task. The difference between cue detection in the three conditions was significant, $F(2, 87) = 17.20$,

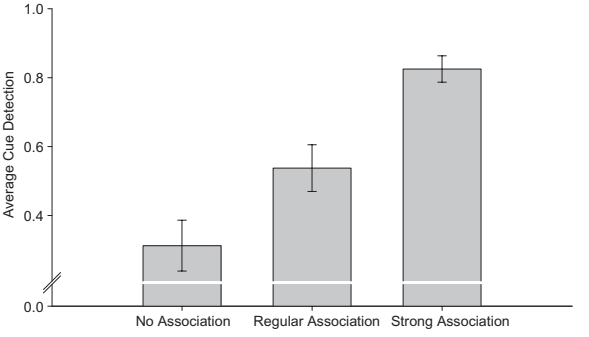

Figure 1. Means and standard error bars representing the proportion of event-based cues detected in three conditions, reflecting the encoded strength of the association between the cues and context in which they were to occur.

$p < .001$, $\eta^2 = .28$. Post-hoc tests indicated that each condition significantly differed from the other conditions, smallest difference $t(58) = 2.24$, $p < .05$. One potential interpretation of this result is that participants in the no-association condition may not have understood the instructions. Nevertheless, at least half of the participants in the no-association condition detected cues indicating that weakened encoding led to their detection failures rather than misunderstanding the instructions. Also, as mentioned previously, all participants indicated to the experimenter that they understood the instructions after reading and having them explained. Therefore, the results from Experiment 1 clearly demonstrate that the association formed at encoding between event-based prospective memory cues and the context in which they will ultimately occur is of great importance for successful cue detection (Marsh, Hicks, & Cook, 2008). Given that the associations formed between the cues and the future context in which they were to occur mattered, we reasoned that people with episodic information about a future context in which an intention could be fulfilled would encode their intention more elaborately (i.e., more cohesive future simulation). The quality of a mnemonic representation directly influences its likelihood of being retrieved (Tulving, 1983). Consequently, in Experiment 2 we provided participants with episodic information about their future context by manipulating the amount of practice that they had with the lexical decision task before they encoded their event-based intention. If participants with practice have more relevant contextual elements available when they encode an intention for the future, then they should successfully complete that intention more often. This prediction was tested in Experiment 2.

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EXPERIMENT 2

Method

Participants

Undergraduate students from the University of Georgia volunteered in exchange for partial credit toward a research appreciation requirement. Each participant was tested individually in sessions that lasted approximately 25 min. A total of 70 participants were randomly assigned to one of two between-subjects conditions. The primary between-subjects variable was whether or not participants received practice with the ongoing lexical decision task before forming the intention to respond to words denoting animals.

Materials and procedure

The ongoing task characteristics were similar to Experiment 1 except in the following regards. Participants in the no-practice condition received the intention to respond to animals after being instructed about the lexical decision task whereas the participants in the practice condition completed an initial 40 trials of practice with the lexical decision task before encoding the intention to respond to animals. To equate performance in all regards except intention formation, both groups of participants performed the lexical decision task for 40 trials. At this juncture, the computer paused and a message informed the participants that they were to receive additional instructions from the experimenter. In the no-practice condition, the experimenter merely reminded the participants of their event-based intention and asked them to complete a math task (i.e., multiplying two three-digit numbers) before continuing with a longer sequence of the same judgments. In the practice condition, participants were instructed that we were also interested in whether they could detect animal words during the lexical decision task. After acknowledging that they understood the instructions, the participants in the practice group completed the same math task before continuing the lexical decision task. The time to deliver the no-practice versus event-based instructions in the two different conditions was equated by the experimenter with a handheld stop watch. Participants in both conditions encountered animal words six times over the succeeding 170 lexical decision trials. In all other respects the two conditions were treated identically.

Results and discussion

As can be seen in Figure 2, participants in the practice condition detected more cues than participants in the no-practice condition, $t(68) = 2.72$, $p < .01$, $d = 0.66$. Therefore, having more episodic information about the lexical decision task at the time of encoding allowed participants in the practice condition to form a more elaborate intention. Participants in the no-practice condition were simply reminded about their intention, but this reminding did not result in the same benefit of having experience with the lexical decision task.

GENERAL DISCUSSION

Consistent with research on episodic future simulation, the results from the two experiments presented here provide original evidence that aspects of encoding are

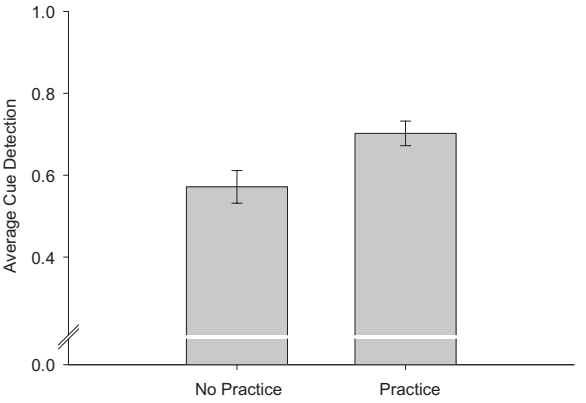

Figure 2. Means and standard error bars representing the proportion of event-based cues detected as a function of the degree of experience participants had with the lexical decision task before forming their intention.

an important factor in event-based prospective memory. In Experiment 1, the strength of the cue-to-context association formed at encoding determined the likelihood that an event-based prospective memory was fulfilled. This result clearly demonstrates that the strength of the cue-to-context association is an important variable in determining event-based cue detection (Atance & O'Neill, 2001). In Experiment 2, participants in the practice condition encoded more information about the future context in which event-based cues were to occur when they formed the intention to make a special response to animal words. *Ceteris paribus*, this episodic information allowed the participants in the practice condition to simulate a more detailed representation of the future and ultimately had the effect of improving cue detection (Okuda et al., 2003; Szpunar & McDermott, 2008). These results speak directly to theories of prospective memory and they are also important for guiding future neuroimaging studies of episodic future simulation as it relates to prospective memory. A primary goal for prospective memory researchers has been to delineate how event-based cues are detected, and further, how behavioral plans that are associated with these cues are retrieved from long-term memory. Several theories have been proposed that address these detection and retrieval processes supporting event-based prospective memory (McDaniel & Einstein, 2000; Smith, 2003). These approaches are informative in describing detection and retrieval processes that operate in prospective memory, but do not explicitly address encoding processes in any specific detail. For example, in the multiprocess theory of event-based prospective memory it is proposed that people rely on multiple cognitive processes to support cue detection and target retrieval (Einstein et al., 2005). One important variable that influences the types of cognitive processes that people rely on is the degree to which ongoing task processing focuses them on the relevant features of event-based cues (Einstein & McDaniel, 2005). More specifically, when processing in the ongoing task highlights features of the cue in a similar manner to when they were processed at encoding, the likelihood that the intention will be fulfilled increases dramatically. Einstein and McDaniel (2005) related this finding to the transfer-appropriate processing literature (Morris, Bransford, & Franks, 1977; Roediger, Gallo, & Geraci, 2002).

The current results extend the notion of transfer-appropriate processing by demonstrating the importance of considering future contexts when encoding event-based prospective memories. That is, when a future context can be simulated at encoding, intentions are more likely to be fulfilled. Theoretically, when there is high degree of overlap between the simulated context at encoding and the retrieval context in which event-based cues are encountered, the intention will be fulfilled more often. This effect is presumably driven by the encoding-specificity principle (Tulving & Thomson, 1973). Thus, both the focus encouraged by ongoing cognitive processing *and* the degree of contextual overlap between the simulated and the actual retrieval contexts will influence event-based prospective memory. Both of these variables underscore the importance of investigating a variety of encoding processes that are used to create prospective memories. Clearly, these results suggest that neuroimaging techniques will be a valuable tool for studying the encoding processes that support forming intentions for the future. Noninvasive neuroimaging techniques have been used, with much success, to investigate the encoding process during *retrospective* memory formation (Wagner et al., 1998). We are arguing here that these subsequent memory designs can further clarify the relation between retrospective and prospective memory as well as helping to specify the encoding conditions that will lead to more efficient intention retrieval.

Building on this idea, we know that episodic memory is a flexible system that allows people to remember past events and simulate future events (Atance & O'Neill, 2001; Buckner & Carroll, 2007; Schacter & Addis, 2007; Tulving, 1983). As such, the reliance on declarative representations for guiding future behavior is an important function of episodic memory (Dudai & Carruthers, 2005; Suddendorf & Corballis, 1997). Previous neuroimaging research has pointed to similar neural regions that support episodic

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memory, future simulation, and encoding intentions for future behavior (Schacter & Addis, 2007; Simons, 2009, Szpunar et al., 2007). Based on the results from the current study, and preliminary neuroimaging data, a critical nexus exists between episodic future simulation and encoding prospective memories. This hypothesis is supported by the present behavioral results but remains to be tested with functional neuroimaging techniques. Functional imaging researchers can capitalize on the current findings by having participants complete multiple encoding–retrieval runs in an fMRI environment. For example, participants could encode faces (e.g., event-based cues) and plan to make special (e.g., target) responses to those faces later in the context of an unrelated ongoing task. In the ongoing task participants would encounter the faces and make their special responses before moving on to the next encoding phase. Furthermore, the degree of association between the faces and the ongoing task could be manipulated to assess the neural underpinnings of association in prospective memory. Analogous to the subsequent memory designs described earlier, this approach would elucidate the encoding and retrieval conditions that engender successful fulfillment of intentions as well as identifying the neural regions that support encoding of prospective memories. A similar approach has been successfully applied in the fMRI environment and it has been suggested that patterns of activation in the medial prefrontal cortex can be decoded to determine which of two intentions participants were currently maintaining (Haynes et al., 2007). As discussed previously, similar brain regions have also been implicated in memory for contextual information as prospective memory (i.e., source memory; Johnson, Hashtroudi, & Lindsay, 1993; Mitchell & Johnson, 2009; Simons, 2009).

According to the source monitoring literature, people monitor the source of their memories by capitalizing on average differences in episodic features that are associated with different types of experience (Lindsay, 2008). This approach to remembering is both constructive and feature-based, which is in line with the episodic simulation research described previously (Mitchell & Johnson, 2000). According to our view, prospective memories consist of varying levels of different episodic features including the encoding context, the prospective retrieval context, the potential event-based cues, and the behavioral plan that needs to be fulfilled. The results from the current study indicate that manipulation of the episodic features available at encoding has direct consequences on the fulfillment of event-based prospective memory. Recent evidence for a neuropsychological nexus between source memory and prospective memory has come from Burgess, Shallice, Gilbert, Simons, and colleagues (e.g., Simons, Schölvinck, Gilbert, Frith, & Burgess, 2006). For example, when participants link their event-based intention to a specific future context, their likelihood of fulfilling that intention increases dramatically (Marsh et al., 2008). Thus, contextual information and association are important determinants of successfully fulfilling intentions.

Together, these research traditions have made substantial progress on explaining and predicting the detection of event-based prospective memory cues. However, a more general theory of intention retrieval from long-term memory will become necessary to account for encoding and retrieval interactions, attentional shifts over time, metacognitive strategies, and the successful use of context as a marker for engagement of cue-focused processes (Einstein & McDaniel, 2008). Also, given that different types of intentions (e.g., event-, time-, and activity-based prospective memories) will have considerable overlap in terms of their retrospective components and general mnemonic features, a more general theory of prospective memory could be developed to account for encoding and retrieval of these ostensibly disparate types of intentions. One route toward theorizing on this topic would be to appeal to Johnson et al.'s (1993) source monitoring framework (Marsh et al., 2006). When encoding different types of intentions, people may use different memorial attributes, or qualitative characteristics, depending on the nature of that intention (Bower, 1967; Underwood, 1969). In more ecological settings people probably encode intentions consisting of multiple characteristics rather than relying on only perceptual, conceptual, or temporal cues like those intentions formed in most laboratory investigations.

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