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Individual differences in event-based prospective memory: Evidence for multiple processes supporting cue detection

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The multiprocess view proposes that different processes can be used to detect event-based prospective memory cues, depending in part on the specificity of the cue. According to this theory, attentional processes are not necessary to detect focal cues, whereas detection of nonfocal cues requires some form of controlled attention. This notion was tested using a design in which we compared performance on a focal and on a nonfocal prospective memory task by participants with high or low working memory capacity. An interaction was found, such that participants with high and low working memory performed equally well on the focal task, whereas the participants with high working memory performed significantly better on the nonfocal task than did their counterparts with low working memory. Thus, controlled attention was only necessary for detecting event-based prospective memory cues in the nonfocal task. These results have implications for theories of prospective memory, the processes necessary for cue detection, and the successful fulfillment of intentions.

Many activities cannot be immediately performed because of various contextual, physical, or temporal constraints. In any of these situations, people can form an intention to fulfill the activity at a later point in time, when the opportunity affords itself. Event-based prospective memory is used when people rely on cues in the environment to elicit their intention from memory. Numerous researchers have attempted to account for how event-based cues, which occur in some ongoing-task context, engage prospective memory retrieval (Einstein & McDaniel, 1990; Marsh, Hicks, & Cook, 2005; Smith, Hunt, McVay, & McConnell, 2007). The multiprocess view suggests that people will engage a variety of cognitive processes to support event-based cue detection depending on both the nature of the ongoing task and the types of cues that will be encountered in the context of that task (McDaniel & Einstein, 2000). The present study was undertaken to provide empirical support for the notion that multiple processes are necessary for event-based cue detection. Specifically, an individual differences approach was used in order to examine the relationship between working memory capacity and event-based cue detection.

An event-based intention is typically composed of some action that needs to be carried out in the future which is associated with a set of potential cues that will serve to elicit the intention from memory. McDaniel and Einstein (2000) proposed the multiprocess view as a general theory for how event-based cues activate intentions at an appropriate time in the future. According to the multiprocess view, successful cue detection depends on several cognitive processes that people rely on. One important variable known to influence the recognition process necessary for event-based cue detection is the specificity or focality of the cues that are related to the previously formed intention (for more variables, see Einstein et al., 2005). Einstein and McDaniel (2005) operationally defined *focality* as the features of the event-based cue highlighted by ongoing-task processing, and they summarized the distinction between focal and nonfocal event-based cues by providing extensive examples of each. Specifically, high focal processing occurs when the ongoing task encourages processing features of the event-based cues similar to how they were processed at encoding (i.e., transfer-appropriate processing).

To empirically demonstrate this distinction, Einstein et al. (2005) asked college-aged participants to complete a category verification task and also to make a special response anytime they encountered a specific word during the task (e.g., *tortoise*). In another condition, participants formed the intention to make a special response anytime they encountered a word containing a specific syllable while completing a category verification task (e.g., TOR). Although the cues did not change between conditions, event-based cue detection was dramatically different (93% for the focal condition and 61% for the nonfocal condition). Even more telling, the category verification reaction times in the focal condition were systematically shorter than those in the nonfocal condition, thereby supporting the hypothesis that focused attention was not necessary for focal cue detection. Einstein et al. (2005) argued that the category verification task did not encourage conscious awareness of

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syllables, because the participants were engaging a greater degree of semantic processing, and this situation led to the participants in the nonfocal condition adopting more cue-focused processing at the expense of performance on the category verification task. These results are similar to previously established results arising from manipulations of cue specificity (e.g., respond to the word *cat* vs. respond any time you see an animal word; Marsh, Hicks, Cook, Hansen, & Pallos, 2003). Several researchers have investigated the focality of prospective memory cues by studying aging populations, manipulating divided attention, and measuring interference with ongoing activities.

Researchers investigating event-based prospective memory in older adults have demonstrated that nonfocal event-based cues are detected less frequently than focal event-based cues (Henry, MacLeod, Phillips, & Crawford, 2004; Kliegel, Jäger, & Phillips, 2008; Rendell, McDaniel, Forbes, & Einstein, 2007). Although prospective memory abilities are generally diminished in older adults, there have been several clear demonstrations of equivalent performance with that of younger adults in event-based prospective memory tasks (Einstein, Holland, McDaniel, & Guynn, 1992; Einstein & McDaniel, 1990; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). According to the multiprocess view, older adults do not have to engage attentionally demanding cue-focused processes to detect focal event-based cues, but they will rely on controlled-attention processes to bolster detecting nonfocal event-based cues. In many experimental cases, the degree of attentional control that will be necessary to perform a task seems to account for the diminished performance typically found in aging populations (e.g., West, 2004). Older adults simply cannot sustain their attention toward cue-focused processes that support accurate detection of nonfocal event-based cues.

On the basis of these results from aging populations, younger adults with their attention divided were hypothesized to detect fewer cues if they were not salient (Marsh & Hicks, 1998). When an attentionally demanding concurrent task is administered in addition to the ongoing task that event-based cues are embedded within, participants generally detect fewer cues, suggesting that event-based prospective memory relies on some optimal level of central-executive resources. Other researchers have followed up on this finding, and a general pattern of results has emerged. Divided attention hinders cue detection in cases in which participants have to detect nonfocal event-based cues (Marsh, Hancock, & Hicks, 2002; Marsh & Hicks, 1998; McNerney & West, 2007). In experiments in which participants could rely on spontaneous retrieval processes to detect focal event-based cues, there have been less pronounced effects of divided attention (Einstein, McDaniel, Smith, & Shaw, 1998; Guynn & McDaniel, 2007). Theoretically, spontaneous retrieval processes can be used to detect focal cues, even in attentionally demanding scenarios, because they may not require attention to be detected (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; but see Smith et al., 2007). In these circumstances, various event-based cues can still elicit the intention from memory, even when controlled attention is drawn away from active maintenance of the task set.

If there is some degree of controlled processing necessary for nonfocal event-based cue detection, there should be a commensurate increase in ongoing-task latencies when participants hold an intention related to these cues. Indeed, when participants perform a lexical decision task and possess an intention to respond to a nonfocal cue, they perform the task more slowly than a control group without an intention (Marsh et al., 2003). Evidence for such task interference from having an intention to respond to cues has also been found in a multitude of other experimental paradigms (Cook, Marsh, Clark-Foos, & Meeks, 2007; Einstein et al., 2005; Smith, 2003). Although costs to ongoing-task performance have been found in many studies, Einstein et al. (2005) convincingly demonstrated that under certain conditions, there are not always commensurate increases in ongoing-task latencies when participants hold focal event-based intentions. The aforementioned research dealing with attentionally demanding circumstances indicates that working memory may be an operative variable in successful cue detection.

Working memory capacity is broadly defined as the ability to keep task-relevant representations active in the face of distraction (Engle & Kane, 2004; Kane, Bleckley, Conway, & Engle, 2001). Maintenance of task-relevant representations depends critically on the ability to direct attention in a flexible manner (Norman & Shallice, 1986). Variation in working memory has been suggested to reflect the ability to flexibly control attentional resources, rather than the absolute amount of resources at a person's disposal (Conway & Kane, 2001). Recently, there have been several demonstrations of working memory differences underlying errors in goal maintenance in dichotic listening, Stroop, and antisaccade paradigms (Conway, Cowan, & Bunting, 2001; Kane & Engle, 2003; Unsworth, Schrock, & Engle, 2004). Unsworth et al. (2004) demonstrated that in prosaccade tasks, when prepotent behavioral tendencies corresponded with task goals (automatic; look *toward* the blinking cue), participants with high or low working memory capacity did not differ in their ability to perform this task, but when the task goal conflicted with prepotent tendencies (control; look *away* from the blinking cue), low working memory participants performed more poorly than high working memory participants.

More recent work has demonstrated that active maintenance is not the only contributor to working memory capacity's relation with other cognitive abilities (Unsworth & Engle, 2007). The dual-component model of working memory proposes that active maintenance in primary memory and controlled retrieval from secondary memory jointly contribute to individual differences in working memory performance. Thus, individuals with high working memory abilities are better able to keep representations active in the focus of attention and are also more efficient at retrieving representations that have momentarily been displaced by distraction (Unsworth, 2007). When control processes are necessary for successful cue detection and intention retrieval, individual differences in working memory capacity should be related to prospective memory. Therefore, we believe that individuals high in working memory ability should detect nonfocal event-based cues better than individuals low in working memory ability. Several investigators have explored the relation between event-based prospective memory and working memory, but hitherto, none have also examined the focal and nonfocal distinction (Brandimonte & Passolunghi, 1994; Cherry & LeCompte, 1999; Reynolds, West, & Braver, 2009; West & Bowry, 2005).

If prospective memory depends on some degree of attention control, strong correlations should be found between event-based cue detection and working memory span scores (Marsh, Hancock, & Hicks, 2002; Marsh & Hicks, 1998). Smith and Bayen (2005) employed a median split to create groups of high and low working memory participants on the basis of their performance on a counting-span task. They found that these participants differed in their overall prospective memory performance, such that high working memory participants' performance was significantly better than that of low working memory participants. Smith and Bayen (2005) concluded that preparatory processes that might be necessary for successful cue detection are not automatic but, rather, rely on some degree of working memory capacity. According to the multiprocess view, the prospective memory task used by Smith and Bayen (2005) could be considered a focal task (i.e., make a special response to any one of four specific words in the context of a sentence verification task). Alternatively, Breneiser and McDaniel (2006) found no significant correlation between performance on a working memory task and focal cue detection. Given these conflicting results, the relationship between working memory capacity and focal and nonfocal cue detection remains unresolved. Potentially, the participants in Smith and Bayen's (2005) experiments may have adopted a more stringent level of attention control because of the use of multiple focal cues, and thus, the correlation between working memory capacity and cue detection was found (Cohen, Jaudas, & Gollwitzer, 2008; Einstein & McDaniel, in press; Einstein et al., 2005). These inconsistent correlations between working memory and focal cue detection are an issue to which we will return in the Discussion section.

In the present experiment, we attempted to resolve the previously described inconsistent findings by employing an individual differences approach to investigate the effects of cue focality (i.e., specificity). A similar methodology to that found in Smith and Bayen (2005) was used, but the present experiment differs in a number of important ways. First, we defined our groups of high and low working memory capacity participants as being in the upper or lower quartile of a distribution of working memory span scores, rather than relying on a median split. Second, we used two complex-span tasks to create these groups. Using two complex-span tasks to create the groups of high and low working memory capacity participants reduces the likelihood that idiosyncratic complex-span and prospective-memory task relations will emerge. In addition, using multiple span measures increases the likelihood that the working memory construct is solely responsible for relations with other variables. Third, we manipulated the nature of the event-based prospective memory cues on the focality dimension. As was mentioned previously, this is the first individual differences analysis examining the relation between working memory capacity and cue focality in a young-adult population.

According to a multiprocess view, nonfocal cue detection depends on some degree of attentional control, whereas focal cue detection can occur via spontaneous retrieval processes. Therefore, we hypothesized that individuals who were high or low in working memory capacity would not differ in their detection of focal event-based cues. We further hypothesized that high working memory participants would detect more nonfocal cues than low working memory participants. In these nonfocal cases, detection of the cues should depend on some extra degree of preparatory processes and working memory (Smith & Bayen, 2005). Also, interference to ongoing-task performance should be apparent in the nonfocal condition but not in the focal condition (Einstein et al., 2005). According to the controlled-attention view of working memory capacity, high and low working memory capacity participants should not differ in their overall reaction times in the ongoing task (Conway & Kane, 2001). That is, high and low working memory participants will set similar attention allocation policies, leading to similar levels of interference to ongoing activities. In the absence of differences in ongoing-task costs, the differences in cue detection should reflect differences between high and low working memory participants' ability to maintain their attention allocation policies. In addition, interference when responding to the cue is another important variable for investigating the underlying cognitive processes that support cue detection and intention retrieval (Marsh, Hicks, & Watson, 2002). As was discussed previously, the dual-component model suggests that both attention and retrieval processes are important predictors of working memory. On the basis of the predictions from this model, we also explored whether individuals differed in interference to the focal and nonfocal cues. Fewer researchers have addressed individual differences in the component processes supporting either focal or nonfocal cue detection, so we will treat cue interference as an empirical issue.

METHOD

Participants and Working Memory Capacity Screening

The participants were recruited from the research participant pool at the University of Georgia. Individuals were selected on the basis of a *z* score composite of two complex-span tasks. Only participants falling in the upper (individuals with high working memory abilities) and lower (individuals with low working memory abilities) quartiles of the composite distribution were selected for inclusion.

Operation span. The participants solved a series of math operations while trying to remember a set of unrelated letters (F, H, J, K, L, N, P, Q, R, S, T, Y). The participants were required to solve a math operation and to judge whether their answer matched either a correct or an incorrect alternative [e.g., $(1 * 2) + 1 = 3$?]. After solving the operation and making their judgment, they were presented with a letter for 1 sec. The participants were given feedback about the accuracy of their math operations, and they had to maintain their performance level above 85%. Immediately after the letter was presented the next operation was presented. Three trials of each letter list length (3–7) were presented, with the order of list length varying randomly. At recall, the participants attempted to recall letters from the current set in the correct order, indicating their choice by clicking on the appropriate letters (see Unsworth, Heitz, Schrock, &

Engle, 2005). The participants received three sets (of list length 2) of practice. The score for all of the span measures was the proportion of correct items in the correct position.

Reading span. The participants were required to read sentences while trying to remember the same set of unrelated letters as in the operation span task. For this task, the participants read a sentence and determined whether the sentence made sense or not (e.g., "The prosecutor's dish was lost because it was not based on fact."). Half of the sentences made sense, whereas the other half did not. Nonsense sentences were made by simply changing one word (e.g., "dish" from "case") from an otherwise normal sentence. The participants were required to read the sentence and to indicate whether it made sense or not. After the participants gave their response, they were presented with a letter for 1 sec. At recall, the participants were asked to recall letters from the current set in the correct order, by indicating their choice by clicking on the appropriate letters. There were three trials of each list length, with list length ranging from 3 to 7. The participants received practice on all components of the reading-span task before beginning. The same scoring procedure as operation span was used.

Composite score. For the composite score, each of the complex-span tasks was z transformed for each participant. These z scores were then averaged together, and quartiles were computed from the averaged distribution. In the final analysis, there were 30 high working memory participants (z composite $= 1.26$, $SD = 0.30$) and 30 low working memory participants (z composite $= -1.32$, $SD = 0.42$).

Prospective Memory Materials and Procedure

The participants were instructed that they were going to be taking part in an experiment with multiple phases and that they would receive instructions for each phase before beginning that part of the experiment. In the first phase of the experiment, the participants decided whether strings of letters were valid English words or not (i.e., a lexical decision task). Following the lexical decision instructions, all of the participants were presented with 105 letter strings, of which 52 were valid English words and 53 were pronounceable nonwords. All words and nonwords were presented in uppercase. They were presented one at a time in the center of the screen (i.e., baseline lexical decision task). The participants were allowed to make their response by pressing one of two keys on the keyboard ("F" for *nonword* and "J" for *word*). After making each response, the participants were presented with a "waiting" message, at which point they pressed the space bar to initiate the next lexical decision trial.

After completing the baseline lexical decision task, the participants were told that we were interested in their ability to remember to perform an action in the future. Then, depending on a predetermined counterbalancing scheme, the participants were given either a focal or a nonfocal event-based intention. In the focal condition, the participants were instructed to make a special keypress ("/") during the "waiting" message after responding to the word PACKET. In the nonfocal condition, the participants were instructed to make a special keypress ("/") during the "waiting" message after responding to any word with the syllable TOR in it (Einstein et al., 2005). The syllable TOR only occurred on word trials in the lexical decision task (e.g., DOCTOR, FACTOR, PASTOR, and TRACTOR). The general parameters of the lexical decision task did not differ from those in the baseline condition, and the four focal and four nonfocal cues always occurred on the 25th, 50th, 75th, and 100th trial in each condition. Each participant completed the focal and nonfocal conditions, and these conditions were separated by a demographic questionnaire. For example, a participant would (1) complete the baseline condition, (2) form an intention to respond to the word PACKET in a future lexical decision task, (3) complete the focal condition, (4) answer some basic demographic questionnaires, (5) form an intention to respond to any word with the syllable TOR in it in a future lexical decision task, and finally, (6) complete the nonfocal condition. After the experimenter reiterated the instructions and was sure that the participant fully understood the requirements, a 2-min distractor task was administered after each intention was formed (i.e., embedded figures puzzle task). After these distractor tasks, the prospective memory tasks were not mentioned again. All analyses were first performed with a counterbalancing factor that controlled for whether the participants completed the focal or the nonfocal condition first.

RESULTS

There was no effect of counterbalancing on any of the dependent measures, and the subsequent results are from data pooled over the counterbalancing condition. Unless stated otherwise, all analyses reported had p values less than .05. All reaction times more than 2.5 *SD* from a participant's mean were excluded from the analyses. Table 1 displays the means for all analyses. The participants performed the lexical decision task accurately across all conditions ($M =$ .94). The proportion of event-based cues that were detected was submitted to a 2 (working memory capacity: high vs. low) $\times$ 2 (intention: focal vs. nonfocal) mixed factorial ANOVA (see Table 1 for cue detection). Replicating previous work (Einstein et al., 2005), more event-based cues were detected in the focal condition than in the nonfocal condition [$F(1,58) = 6.13$, $\eta_p^2 = .10$]. Also, high working memory participants detected more event-based cues than low working memory participants [$F(1,58) = 8.40$, $\eta_p^2 =$ .13]. Note that although cue detection was close to ceiling in the focal condition, there was variability in the overall amount of cues detected. Therefore, the 95% confidence interval around the high and low working memory participants' focal cue detection overlapped, but neither overlapped with 100% performance. Critically, there was an interaction between working memory capacity and intention type [$F(1,58) = 4.39$, $\eta_p^2 = .07$]. High and low working memory participants did not differ in their proportion of focal event-based cues that they detected, but they did differ in their detection of nonfocal event-based cues [$t(58) =$ 1.22, $p > .20$, and $t(58) = 2.80$, $d = 0.74$, respectively]. These results confirm our hypothesis that individuals would differ on event-based prospective memory tasks that require some degree of attentional control to be accomplished successfully (i.e., nonfocal cues). By contrast, there were no differences in cue detection between high and low working memory participants when they could primarily rely on spontaneous retrieval processes (i.e., focal cues).

Table 1
Mean Performance for High and Low Working Memory Capacity (WMC) Participants

	Cue Detection		Task Interference		Cue Interference	
	M	*SE*	*M*	*SE*	*M*	*SE*
High WMC						
Baseline			726.96	27.24		
Focal	.93	.03	708.43	22.97	821.99	124.61
Nonfocal	.92	.03	788.48	30.76	910.42	162.58
Low WMC						
Baseline			696.39	17.65		
Focal	.88	.03	698.47	16.31	780.81	159.71
Nonfocal	.68	.07	779.32	26.00	1,489.72	208.40

Note—*Cue interference* refers to only the first cue that the participants were presented with and successfully detected.

Mean latencies for the word trials of the lexical decision task were analyzed to further understand the role of attentional-control processes in event-based prospective memory (see Marsh et al., 2003). These reaction times were submitted to a 2 (working memory capacity: high vs. low) × 3 (condition: baseline vs. focal vs. nonfocal) mixed factorial ANOVA (see the Task Interference column in Table 1). There was a main effect of condition on mean latency to respond to words [$F(1,116) = 21.22$, $\eta_p^2 = .27$]. There were no latency differences between high and low working memory participants, and there was no interaction between condition and working memory capacity. In subsidiary analyses, two difference scores were calculated for each participant by subtracting their baseline reaction time from the mean reaction time when they had the focal or nonfocal intentions. These difference scores were submitted to a 2 (working memory capacity: high vs. low) × 2 (difference: focal vs. nonfocal) mixed ANOVA. There was no difference in mean reaction times between the baseline and focal conditions, but there was significant slowing in the nonfocal condition [$F(1,58) = 37.20$, $\eta_p^2 = .39$]. Again, there was no effect of working memory capacity and no interaction between working memory capacity and difference condition.

One potential criticism of the previous reaction time analysis is that the participants always completed the baseline lexical decision task before beginning the focal or nonfocal tasks (see Smith et al., 2007, for a detailed discussion of appropriate baseline measurement). In brief, a participant's performance on a lexical decision task can improve across conditions, and the allocation of preparatory attention to detecting focal cues could be masked by practice effects. To mitigate the concern that the effects of preparatory attention were masked because of the present experimental design, we divided the baseline lexical decision task into three equal blocks of trials, and mean word latencies between the second (M = 691 msec) and third (M = 683 msec) blocks of the task were compared. The first block of lexical decision trials in the baseline task was viewed as a practice phase in which the participants became familiar with the task parameters. There was no significant practice effect from the second block to the third block of the baseline lexical decision task, and there was no interaction with working memory capacity (all ps > .4). Reanalyzing the reaction time data from all conditions, using only the third block of latencies in the baseline condition to compute difference scores rather than overall baseline latencies, gave an identical pattern of results. Therefore, there was no effect of working memory and no interaction between working memory and the difference scores. The only significant finding was that the participants performed the lexical decision task slower in the nonfocal condition than in the focal condition [$F(1,58) = 37.20$, $\eta_p^2 = .39$]. This result provides additional support for the assumptions that both high and low working memory participants predominately relied on spontaneous retrieval in the focal condition and that reaction time differences between the focal condition and the baseline condition were not obscured by practice effects.

Next, we examined the latency to respond successfully on cue trials only (i.e., see the Cue Interference column in Table 1). There were no overall differences in interference to the event-based cues between the high and low working memory participants and no interaction with cue type, but a closer inspection of the cue interference measure yielded an interesting pattern of results. When the analysis was restricted to only the interference on the first cue that the participants received and subsequently detected in the lexical decision task, there was a 2 (working memory capacity: high vs. low) × 2 (cue interference: focal vs. nonfocal) interaction [$F(1,35) = 4.65$, $\eta_p^2 = .12$]. Ongoing-task latencies were controlled in this analysis. This interaction occurred because low working memory participants were much slower to respond to the first nonfocal cue than high working memory participants [$t(35) = 2.19$, $d = 0.74$]. There was no overall difference between cue interference in the focal condition for high and low working memory participants. Perhaps when they were presented with the first nonfocal cue, low working memory participants had a much more difficult time retrieving the target action than did high working memory participants. Although this is an interesting finding, the result should be interpreted with caution because of the restricted sample (i.e., not all participants detected the first cue) and the failure to find an overall difference in cue interference.

DISCUSSION

In the present work, we sought to test one of the primary assumptions of the multiprocess view. The multiprocess view assumes that people will rely on different processes based on several important contextual variables. Such variables influence individuals' metacognitive judgments about the ease with which cues can be detected (e.g., focality in the present study). On the basis of the results from this study, the distinction between focal and nonfocal event-based cues was replicated (Einstein & McDaniel, 2005; Einstein et al., 2005; Rendell et al., 2007). Given that there was an interaction between working memory and event-based cue type, there were clearly multiple factors at play, depending on the type of intention that the participants were trying to fulfill. Also, there was more slowing to the ongoing lexical decision task when the participants held a nonfocal event-based intention. However, extending previous findings, we found that high working memory participants detected nonfocal cues more often than low working memory participants; this outcome was not the case for focal cues. These effects reflect differences in attentional control as opposed to overall amounts of attention (Conway & Kane, 2001). Thus, high and low working memory participants' ongoing-task latencies did not differ among the baseline, focal, and nonfocal conditions. This pattern of data was predicted from the multiprocess view of event-based prospective memory and could contravene the preparatory attention and memory model.

According to the multiprocess view, spontaneous retrieval processes can be used to remember intentions in many circumstances. Specifically, when attention is oriented toward processing features of the event-based cue in a manner similar to that at encoding, spontaneous retrieval of the intention may occur (Einstein et al., 2005). These retrieval processes are not necessarily automatic in the sense of being decoupled from attentional processes. Rather, different amounts of attention are going to be useful to varying degrees, depending on a host of factors (Einstein & McDaniel, 2008). Clearly, after the cue has been noticed as being relevant, more controlled retrieval processes will have to be initiated to search for the relative meaning (e.g., discrepancy plus search; McDaniel, Guynn, Einstein, & Breneiser, 2004). In the present experiment, when low working memory participants could rely on spontaneous retrieval processes to support cue detection, their impoverished ability to control their attention did not hinder cue detection. Thus, their overall levels of focal event-based cues that were detected resembled that of the high working memory participants. But, when the same participants were given a nonfocal event-based intention, they had to rely on some increased level of attentional control to detect the nonfocal cues, which resulted in the low working memory participants' detecting fewer nonfocal cues than did the high working memory participants (Einstein et al., 2005; Marsh et al., 2003; Smith & Bayen, 2005).

The preparatory attention and memory model is an alternative conceptualization of event-based prospective memory. This view suggests that preparatory attention is always allocated in service of detecting cues once an intention has been established (e.g., Smith, 2003; Smith & Bayen, 2004; Smith et al., 2007). On the basis of the differences in reaction times between the focal and nonfocal lexical decision task that were found here, the participants did not engage preparatory attention in a manner entirely consistent with the preparatory attention and memory model. If preparatory attention solely determined event-based cue detection, the high and low working memory participants should have differed in their overall levels of cue detection in the focal condition in a manner similar to that in the nonfocal condition, but this was not the pattern of results that we observed. These results are at odds with the preparatory attention and memory model of event-based prospective memory, which assumes that working memory will always be an important predictor of cue detection.

In the present study, low working memory participants presumably suffered from degraded attentional processes, which were insufficient for allocating attention across both prospective memory tasks (Smith & Bayen, 2005; West, Bowry, & Krompinger, 2006). In situations in which people need to maintain goals that are inconsistent with prepotent tendencies, working memory capacity becomes an important variable (Conway et al., 2001; Kane & Engle, 2003; Unsworth et al., 2004). In these studies, high working memory participants were less susceptible to both internal and external distraction, which led to better performance on tasks such as dichotic listening, Stroop, and antisaccade. Kane and colleagues have demonstrated that low working memory participants are more susceptible to mind wandering and task-unrelated thoughts (Kane et al., 2007; McVay & Kane, 2009). For example, in the present experiment, low working memory participants could have lost their overall task set because of unrelated thoughts in the nonfocal condition. This loss of task set would cause the low working memory participants to detect fewer nonfocal event-based cues (see also West, Krompinger, & Bowry, 2005). The present results suggest that even if low working memory participants were not actively maintaining their task set in the focal condition, spontaneous retrieval processes were still sufficient to support detection of focal event-based cues.

Theoretically, the expected match between cue-focused processing at encoding and retrieval will influence a participant's degree of attentional allocation during the ongoing task. By *attention allocation*, we are referring to the relative amounts of attention that participants decide to pay to each component of their ongoing behaviors (i.e., their entire task set). The degree to which people will rely on various processes to set an attentional allocation policy is presumably based on their metacognitive beliefs about their own prospective memory abilities, how difficult they feel the cues will be to detect, and expectations about the context in which cues will occur later (Einstein & McDaniel, 2008; Meeks, Hicks, & Marsh, 2007). The perceived difficulty of detecting cues is one critical variable that will determine metacognitive judgments about how much attention will be necessary for successful remembering of an intention.

The results from the present study suggest that both high and low working memory participants allocated attention equally across both the focal and nonfocal conditions. In the nonfocal condition, low working memory participants allocated the same amount of attentional resources to support cue detection, but they failed to detect the nonfocal cues at the same level as high working memory participants. The participants' metacognitive judgments about the difficulty of detecting nonfocal event-based cues are typically well calibrated, and their attentional allocation policies are generally efficient (Marsh et al., 2005; Meeks et al., 2007). Therefore, low working memory participants may have set their attentional allocation policy at the outset of the nonfocal task, and then task-unrelated thoughts may have interfered with their ability to maintain the attentional set, which subsequently caused them to miss nonfocal cues (West et al., 2005). Under this theory, high working memory participants were less susceptible to task-unrelated thoughts and thus maintained their attentional allocation policy.

We would be remiss not to point out one apparent inconsistency with our findings and those previously reported. Specifically, Marsh et al. (2005) demonstrated that high effort toward an ongoing task hurts event-based cue detection under transfer-appropriate processing conditions (i.e., high effort toward a semantic task diminished detection of semantic cues but left the detection of orthographic cues unaffected). Thus, high working memory participants may outperform low working memory participants, even in focal conditions because of a high degree of processing overlap. The participants in Marsh et al. (2005) were asked to allocate a high level of attention to the ongoing task in order for cue detection to be diminished. In the present study, allocation of attention to the various components of the participant's task set was not manipulated. Furthermore, the lexical decision task may not have been demanding enough to relate meaningfully to working memory capacity and to create a difference in focal cue detection (i.e., high and low working memory participants had equivalent reaction times in the lexical decision task). Nevertheless, in transfer-appropriate processing situations, high working memory capacity participants may be less affected by manipulations of effort toward ongoing tasks than low working memory capacity participants. At best, the relation between working memory capacity and transfer-appropriate processing conditions in event-based prospective memory requires further investigation.

A potential shortcoming of the present study is that focal cue detection was at high levels, which may have obscured an effect of working memory capacity. Furthermore, ceiling effects should reduce the variability in responding, thereby biasing our analyses toward finding a difference between groups of participants. However, high and low working memory participants did not differ in their focal cue detection even though there was variance in responding. An additional limitation of the present design is that cues were not counterbalanced across conditions (e.g., PACKET and TOR as compared with TORTOISE and TOR). In future work in this area, effort toward various components of the task set for both high and low working memory capacity participants should be manipulated, cues should be counterbalanced across focal and nonfocal conditions, and an effort should be made to achieve cue detection in a lower range of the response scale to avoid ceiling effects.

Another future direction would be to investigate the retrieval component of prospective memory as it relates to individual differences. On the basis of the differences in the cue interference measure, a future endeavor will be to delineate individual differences in the retrieval processes that occur when participants notice an event-based cue. Studies in which output monitoring has been capitalized on would be a good starting point, because there difficulty of the retrieval component of prospective memory has been manipulated (e.g., Marsh, Hicks, Hancock, & Munsayac, 2002). In these studies, participants typically have to give a new response each time they detect a different event-based cue. Thus, to be successful in output-monitoring paradigms, participants have to maintain an attentional allocation policy consistent with the allocation policy that participants may have employed in the present study, and they must also engage in controlled retrieval whenever a new cue is encountered. According to the dual-component model of working memory capacity described earlier (Unsworth & Engle, 2007), low working memory participants should make more errors in output-monitoring paradigms because of both failures in active maintenance of task goals and failures of controlled retrieval. In these situations, low working memory participants' deficits would be especially pronounced (Marsh, Hicks, Cook, & Mayhorn, 2007).

The individual differences approach taken in the present study has proven useful in distinguishing among various theories of prospective memory, and it has the potential to further elucidate the aspects of attention control and controlled retrieval that underlie event-based prospective memory. The extreme-groups design used in the present study has a tendency to inflate effect sizes (Conway et al., 2005). Nevertheless, this approach is useful for demonstrating that there are important relations between variables, but future researchers should investigate the entire distribution of participants and also examine multiple cognitive constructs. Of course, these results demand further scrutiny and more ecologically valid paradigms. For example, in a highly demanding scenario, individuals with high working memory capacity could be so focused on a current task goal that they would fail to detect cues related to their intention that occurred in the context of that task. Nonetheless, this work provides additional support for the multiprocess view of prospective memory but also suggests important future directions. By this theory, an individual's ability to detect cues and to retrieve intentions seems to multiply, depending on a combination of processes that can be configured in various ways to optimize their likelihood of remembering. Individuals will certainly differ in their ability to capitalize on the underlying attention and retrieval processes necessary for fulfilling intentions, and they will also differ in their ability to regulate these processes.

AUTHOR NOTE

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REFERENCES

BRANDIMONTE, M. A., & PASSOLUNGHI, M. C. (1994). The effect of cue-familiarity, cue-distinctiveness, and retention interval on prospective remembering. *Quarterly Journal of Experimental Psychology*, **47A**, 565-587.

BRENEISER, J. E., & MCDANIEL, M. A. (2006). Discrepancy processes in prospective memory retrieval. *Psychonomic Bulletin & Review*, **13**, 837-841.

CHERRY, K. E., & LECOMPTE, D. C. (1999). Age and individual differences influence prospective memory. *Psychology & Aging*, **14**, 60-76.

COHEN, A.-L., JAUDAS, A., & GOLLWITZER, P. M. (2008). Number of cues influence the cost of remembering to remember. *Memory & Cognition*, **36**, 149-156.

CONWAY, A. R. A., COWAN, N., & BUNTING, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review*, **8**, 331-335.

CONWAY, A. R. A., & KANE, M. J. (2001). Capacity, control and conflict: An individual differences perspective on attentional capture. In C. L. Folk & B. S. Gibson (Eds.), *Attraction, distraction and action: Multiple perspectives on attention capture* (pp. 349-372). Amsterdam: Elsevier.

CONWAY, A. R. A., KANE, M. J., BUNTING, M. F., HAMBRICK, D. Z., WILHELM, O., & ENGLE, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, **12**, 769-786.

COOK, G. I., MARSH, R. L., CLARK-FOOS, A., & MEEKS, J. T. (2007). Learning is impaired by activated intentions. *Psychonomic Bulletin & Review*, **14**, 101-106.

EINSTEIN, G. O., HOLLAND, L. J., MCDANIEL, M. A., & GUYNN, M. J. (1992). Age-related deficits in prospective memory: The influence of task complexity. *Psychology & Aging*, **7**, 471-478.

EINSTEIN, G. O., & MCDANIEL, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **16**, 717-726.

EINSTEIN, G. O., & MCDANIEL, M. A. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science*, **14**, 286-290.

Einstein, G. O., & McDaniel, M. A. (2008). Prospective memory and metamemory: The skilled use of basic attentional and memory processes. In A. S. Benjamin & B. H. Ross (Eds.), *The psychology of learning and motivation* (Vol. 48, pp. 145-173). San Diego: Elsevier.

Einstein, G. O., & McDaniel, M. A. (in press). Prospective memory and what costs do not reveal about retrieval processes: A commentary on Smith, Hunt, McVay, and McConnell (2007). *Journal of Experimental Psychology: Learning, Memory, & Cognition*.

Einstein, G. O., McDaniel, M. A., Manzi, M., Cochran, B., & Baker, M. (2000). Prospective memory and aging: Forgetting over short delays. *Psychology & Aging*, **15**, 671-683.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influence of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **21**, 996-1007.

Einstein, G. O., McDaniel, M. A., Smith, R. E., & Shaw, P. (1998). Habitual prospective memory and aging: Remembering intentions and forgetting actions. *Psychological Science*, **9**, 284-288.

Einstein, G. O., McDaniel, M. A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N., & Breneiser, J. (2005). Multiple processes in prospective memory retrieval: Factors determining monitoring versus spontaneous retrieval. *Journal of Experimental Psychology: General*, **134**, 327-342.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 44, pp. 145-199). San Diego: Academic Press.

Guynn, M. J., & McDaniel, M. A. (2007). Target pre-exposure eliminates the effect of distraction on event-based prospective memory. *Psychonomic Bulletin & Review*, **14**, 484-488.

Henry, J. D., MacLeod, M. S., Phillips, L. H., & Crawford, J. R. (2004). A meta-analytic review of prospective memory and aging. *Psychology & Aging*, **19**, 27-39.

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working memory capacity. *Journal of Experimental Psychology: General*, **130**, 169-183.

Kane, M. J., Brown, L. E., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science*, **18**, 614-621.

Kane, M. J., & Engle, R. W. (2003). Working memory capacity and the control of attention: The contributions of goal maintenance, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General*, **132**, 47-70.

Kliegel, M., Jäger, T., & Phillips, L. H. (2008). Adult age differences in event-based prospective memory: A metaanalysis on the role of focal versus nonfocal cues. *Psychology & Aging*, **23**, 203-208.

Marsh, R. L., Hancock, T. W., & Hicks, J. L. (2002). The demands of an ongoing activity influence the success of event-based prospective memory. *Psychonomic Bulletin & Review*, **9**, 604-610.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **24**, 336-349.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2005). On the relationship between effort toward an ongoing task and cue detection in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **31**, 68-75.

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **29**, 861-870.

Marsh, R. L., Hicks, J. L., Cook, G. I., & Mayhorn, C. B. (2007). Comparing older and younger adults in an event-based prospective memory paradigm containing an output monitoring component. *Aging, Neuropsychology, & Cognition*, **14**, 168-188.

Marsh, R. L., Hicks, J. L., Hancock, T. W., & Munsayac, K. (2002). Investigating the output monitoring component of event-based prospective memory performance. *Memory & Cognition*, **30**, 302-311.

Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **28**, 652-659.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval. *Applied Cognitive Psychology*, **14**, S127-S144.

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **30**, 605-614.

McNerney, M. W., & West, R. (2007). An imperfect relationship between prospective memory and the prospective interference effect. *Memory & Cognition*, **35**, 275-282.

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **35**, 196-204.

Meeks, J. T., Hicks, J. L., & Marsh, R. L. (2007). Metacognitive awareness of event-based prospective memory. *Consciousness & Cognition*, **16**, 997-1004.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. E. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (pp. 1-18). New York: Plenum.

Rendell, P., McDaniel, M. A., Forbes, R. D., & Einstein, G. O. (2007). Age-related effects in prospective memory are modulated by ongoing task complexity and relation to target cue. *Aging, Neuropsychology, & Cognition*, **14**, 236-256.

Reynolds, J. R., West, R., & Braver, T. (2009). Distinct neural circuits support transient and sustained processes in prospective memory and working memory. *Cerebral Cortex*, **19**, 1208-1221.

Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **29**, 347-361.

Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **30**, 756-777.

Smith, R. E., & Bayen, U. J. (2005). The effects of working memory resource availability on prospective memory: A formal modeling approach. *Experimental Psychology*, **52**, 243-256.

Smith, R. E., Hunt, R. R., McVay, J. C., & McConnell, M. D. (2007). The cost of event-based prospective memory: Salient target events. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **33**, 734-746.

Unsworth, N. (2007). Individual differences in working memory capacity and episodic retrieval: Examining the dynamics of delayed and continuous distractor free recall. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **33**, 1020-1034.

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, **114**, 104-132.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods*, **37**, 498-505.

Unsworth, N., Schrock, J. C., & Engle, R. W. (2004). Working memory capacity and the antisaccade task: Individual differences in voluntary saccade control. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **30**, 1302-1321.

West, R. (2004). The effects of aging on controlled attention and conflict processing in the Stroop task. *Journal of Cognitive Neuroscience*, **16**, 103-113.

West, R., & Bowry, R. (2005). Effects of aging and working memory demands on prospective memory. *Psychophysiology*, **42**, 698-712.

West, R., Bowry, R., & Krompinger, J. (2006). The effects of working memory demands on the neural correlates of prospective memory. *Neuropsychologia*, **44**, 197-207.

West, R., Krompinger, J., & Bowry, R. (2005). Disruptions of preparatory attention contribute to failures of prospective memory. *Psychonomic Bulletin & Review*, **12**, 502-507.

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