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Event-based prospective memory cues are environmental stimuli that are associated with a previously established intention to perform an activity. Such cues traditionally have been placed in materials that receive focal attention during an ongoing activity. This article reports a direct comparison of event-based cues that occurred either within the focus of attention or at the periphery of such attention. When the cue occurred outside focal attention, manipulating that cue changed event-based prospective memory. The identical manipulation had no effect on event-based responding if the cue occurred within focal attention. These results suggest that cue characteristics can compensate for attention being directed away from an aspect of an ongoing task that contains event-based prospective memory cues.

Once a person decides to complete a task (e.g., wash a load of clothes) either that activity can be undertaken immediately or an intention must be committed to memory so that it can performed at some later time. If the activity is delayed, fulfilling the intention depends on successfully retrieving it during an appropriate window of opportunity. With event-based prospective memory tasks, the environment provides a cue that can stimulate retrieval of the intention (e.g., a hamper full of clothes). If the cue is detected and if the ongoing task demands are favorable, then the intention can be completed. If the cue occurs at an inopportune time, then presumably the intention remains in memory until it is retrieved again in the future. To date, research concerning event-based prospective memory has focused on the factors and the theoretical mechanisms that increase or decrease detecting the cue as a signal to recall the previously encoded intention. One factor that has been overlooked in this literature is whether the prospective memory cue occurs within the focus of cognitive attention or at the periphery of it, and this is the issue we address in this article.

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Almost all laboratory experiments on event-based prospective memory engage participants in some ongoing activity that is intended to approximate the demands of everyday life (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; McDaniel, Einstein, Graham, & Rall, 2004). For example, participants might rate the pleasantness of words, judge the sensibleness of sentences, or name famous faces in the ongoing task (Ellis, Kvavilashvili, & Milne, 1999; Maylor, 1996). When certain cues or a class of cue words appears (e.g., animal words or faces with beards), participants must make some overt response to indicate that they have remembered the intention. In all these studies, the prospective memory cue occurs in the focus of attention insofar as the stimulus being processed in the ongoing task is the cue itself or contains the features that should stimulate retrieval of the intention to respond differently to that cue. Clearly, when cues are salient (e.g., an uppercase word against a background of lowercase words) cue detection is better than when it is not distinct from its surrounding context (McDaniel & Einstein, 1993; Einstein et al., 2000). Moreover, when the demands of the ongoing task involve processing the relevant aspect of the cue, prospective memory is better. This benefit to cue detection has been called task-appropriate processing (Maylor, 1996, 1998) and occurs, say, when the cue is semantic (responding to animal words) and the ongoing task is semantically oriented (Marsh, Hicks, & Hancock, 2000). When the ongoing activity focuses attention on features of potential cues that are not associated with the intention, prospective memory is worse.

Extrapolating that result suggests that event-based cues that occur in the periphery of attention may be less effective in causing retrieval of the intention than cues that occur in the focus of attention. But to our knowledge, only one paradigm presented an event-based cue outside the focus of attention necessary to complete the ongoing activity (Kidder, Park, Hertzog, & Morrell, 1997; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). The event-based cue was a particular background pattern of the computer screen, whereas the ongoing activity was a verbal short-term memory test. In this case, the background pattern was irrelevant to processing the words for the memory test. Because the two studies using that paradigm had other theoretical aims, no variable was manipulated that contrasted changes in the characteristics of the cue. The goal in the present study was to manipulate a characteristic of a cue presented in focal attention and compare this with an identical manipulation of a cue presented outside focal attention. This manipulation was instantiated in these experiments by having participants form the intention to respond either to a red word in an ongoing lexical decision task or respond to a red border around the word. We manipulated the salience of the cue by changing the size of the border and the size of the word. For purposes of the present study, we are operationally defining *salience* as the amount of perceptual information located in the display that is related to the intention.

There are alternative predictions for such a manipulation. On one hand, cues that occur in the periphery may not be processed fully, so manipulating them may have no effect on event-based prospective memory. By this account, changing the size of the border around the word strings should not affect cue detection, but changes in cues that occur in the focus of attention may have a higher probability of being noticed and consequently influence detection (i.e., the size of the letter strings will alter cue detection). On the other hand, extrapolating the task-appropriate processing finding suggests that identical manipulations of cue salience might affect detection when the cue occurs outside focal attention but have no effect when the cue is processed focally. Under this scenario, increased salience of a cue in the periphery of attention increases cue detection because attention is drawn toward the periphery if intention-related information is contained in it. Because attention is already focused on the letter string being judged, border size will influence detection but stimulus size will not.

Regardless of which alternative comes to pass, the outcome of such a dissociation has important theoretical ramifications for theories of prospective memory. Currently, a debate exists as to what circumstances might cause cue detection to be a more effortful, resource-demanding task. Some theorists believe that cue detection requires resources (e.g., Smith, 2003; see also Marsh & Hicks, 1998), whereas others propose that cue detection can occur automatically or require a continuum of resources depending on the characteristics of the ongoing or prospective memory tasks (e.g., McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004). Although the present study was not intended to disambiguate these accounts, the outcome nevertheless speaks to the role of attention in prospective memory cue detection.

More specifically, cue salience should matter only when cue-focused processes (i.e., those that require attention) benefit cue detection and not when detection would be more automatic (McDaniel, Guynn, et al., 2004). Some attributes of potential cues may be routinely processed in the course of the ongoing task, and if such attributes are associated with the intention, then the probability of recollecting the intention will be stable regardless of how salient the relevant attribute is. By contrast, manipulations of attention toward attributes associated with the intention that are not routinely processed, perhaps because they are unnecessary for ongoing task performance, should increase the probability of cue detection. A variant of this logic has been applied to event-based prospective memory whenever a divided attention task has been used (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh & Hicks, 1998). In the current study, neither word color nor border color is relevant to determining a letter string's status as a word or a nonword. From this perspective, intention to respond to word color or border color would not be an automatic task as defined by the current specification of the multiprocess framework. However, word color most assuredly receives more processing because it is integrally bound to the stimulus being judged, whereas border color should receive more peripheral attention, and we chose these intentions by design to assess cue characteristics that occur either within or outside focal attention.

To these ends, we conducted two large-scale experiments that are presented together for brevity. Except for the intention to respond to the occurrence of a red border rather than a red word, the two experiments were identical. Each experiment orthogonally manipulated the size of the border (as large or small) and the size of the letter string in the ongoing lexical decision task (also large or small) as between-subject factors.

EXPERIMENT

METHOD

Participants

Undergraduate students from the University of Georgia volunteered in exchange for partial credit toward a course research requirement. Each participant was tested individually in sessions that lasted approximately 25 min. Two hundred eighty-four participants were pseudorandomly assigned to one of the four between-subject conditions in each experiment that result from crossing the two levels of border size with the two levels of stimulus size. The number of participants in each cell varied slightly.

Materials and procedure

The basic parameters of the ongoing lexical decision task were identical to those used by Marsh, Hicks, and Watson (2002) and Marsh, Hicks, Cook, Hansen, and Pallos (2003). The ongoing task consisted of 210 trials, with equal numbers of valid English words and pronounceable nonwords. The 105 valid words were chosen from the Kučera and Francis (1967) normative compendium. The nonwords were created by changing one or two letters in 105 different words chosen from the same source. Eight prospective cues occurred in the ongoing task, and they were positioned every 25th trial at trials numbered 25 through 200. In Experiment 1, the border around the letter string (always a valid word) was red on these eight trials, and in Experiment 2 a red word appeared. The same eight words appeared on the event-based cue trials in both experiments, but their order was randomized anew for each participant. Participants were not pre-exposed to these cue words or any other words that appeared in the ongoing task. Letter strings were presented in one of six different colors (other than red), as was the border around the letter string. Border and stimulus color were determined randomly online for each trial under the two constraints that the letter string and the border be different colors on any given trial and that all six noncue colors be used approximately as often. The color red never occurred in either the letter string or the border unless the trial was among the eight prospective memory cue trials, and only the feature relevant to responding (either border or letter string) was colored red.

Two different font sizes were chosen for presentation of the letter strings. The average number of pixels in the cue words was calculated for the two different font sizes to determine the size (width) of the border around the words. The large font was twice the size of the smaller font, and the latter was the standard graphic font for a screen resolution of 640 × 320 pixels. In the end, the border was rectangular and made of four connected lines that were either one or four pixels wide in the small and large conditions, respectively. Thus, the border was fixed in size around the location where the stimulus string would appear. This method roughly controls for the perceptual dimensions that may cause cue detection to be different when the cue size is manipulated. On average the border was approximately 0.5″ away from the letter string on all sides, but obviously this depended on the letter string length from trial to trial. To be clear, border color and font size were manipulated between participants, so any given participant saw the same font and border size on all 210 trials of the ongoing task.

All participants read the instructions for the experiment from the computer monitor. The instructions specified that participants should indicate whether letter strings were valid English words. Two labeled keys were provided for this purpose, and participants were asked to respond as quickly as they could without sacrificing substantial accuracy. The instructions indicated that we were also interested in participants' ability to carry out a task in the future. Depending on their assigned condition, they were asked to press the "/" key if the letter string or border surrounding it was red. After participants read these instructions, the experimenter cleared the screen and reiterated the instructions verbally. A distractor activity was administered for 5 min before the lexical decision ongoing task began in order to prevent the prospective memory task from becoming a vigilance task.

Each trial of the lexical decision ongoing activity began with a "waiting" message indicating that the participant should initiate the trial by pressing the spacebar with a thumb. A fixation point and warning tone occurred for 250 ms, followed by a blank screen of the same duration and then presentation of the border and letter string simultaneously. This display remained on the screen until a word or nonword response was made (the home keys "F" and "J" were used for this purpose). Consistent with our previous uses of this ongoing task, participants were asked to make their word response first and then press the "/" key during the waiting message that followed whenever the prospective memory cue was encountered.

RESULTS

Average cue detection is presented in Table 1 as a function of border and stimulus sizes. As summarized in the top half of Table 1, participants

Table 1. Average prospective memory performance (and cell sizes) in Experiments 1 and 2

	Small border	Large border
	Experiment 1: border intention	
Small font	.66 (.05)	.80 (.04)
	N = 37	*N* = 37
Large font	.68 (.05)	.85 (.02)
	N = 37	*N* = 34
	Experiment 2: word intention	
Small font	.73 (.05)	.70 (.05)
	N = 38	*N* = 36
Large font	.69 (.05)	.74 (.03)
	N = 31	*N* = 34

Note. Standard errors in parentheses.

who formed the intention to respond to the red border (Experiment 1) detected the cue more often when the border was large than when it was small, $F(1, 141) = 14.26$. The size of letter strings did not influence performance, and this factor did not interact with border size, both *F*s < 1.0. Because the ongoing task focused attention on the letter string and the border cue was outside the focus of that attention, prospective memory appears to benefit when a nonfocal cue is made more salient. The same was not true in Experiment 2 with a similar manipulation in the focus of attention, that is, the intention to respond to word color. An identical 2 × 2 analysis of variance with border and stimulus sizes resulted in no statistically significant effects, all $F(1, 135) < 1$. Therefore, manipulating a stimulus that is already receiving a good deal of focal processing appears to produce no further benefit to cue detection.

DISCUSSION

Before this study, prospective memory cues have not been manipulated to occur within versus at the periphery of the focus of the ongoing activity. That gap has now been filled, although clearly more work is needed. Nevertheless, the results suggest that if prospective memory cues occur in parts of the environment that are already receiving a good deal of focal processing, then the probability of detection may not be influenced greatly by changes in their characteristics. By contrast, cues that occur in the periphery of focal attention can be manipulated to attract attention toward a feature that will trigger recollection of the intention. Obviously, we have manipulated only one feature (size) in what justifiably can be classified as an intention about perceptual characteristics. Features other than color may not behave as peripheral cues in the same way as found here (an issue that we return to shortly). At this point we are less concerned with potential boundary conditions on such an effect and more concerned with the theoretical and practical ramifications of the outcome itself.

The role of attention in detecting event-based cues has begun to assume an important role in theories of prospective memory. Smith's (2003) preparatory attention and memory (PAM) model of cue detection argues that attention is a mandatory component of all event-based intentions, whereas the multiprocess theory argues for a continuum of the minimal attentional requirements supporting cue detection (McDaniel, Guynn, et al., 2004). In the latter theory, the amount of attention needed depends on the characteristics of the intention and the context in which a cue is encountered. Although the current results do not disambiguate these accounts, they clearly show that attention can be attracted toward a cue in the periphery, thereby increasing the probability of recollecting the intention. These same results also demonstrate that the kind of capacity or resources that Smith and McDaniel et al. debate are not the only kind of attentional limitation that is important to detecting an event-based cue.

The theoretical ramifications of the present study are best understood by appealing to Norman and Bobrow's (1975) resource allocation theory, on which Norman and Shallice's (1986) supervisory attentional system model was constructed. Performance on any set of tasks can be calculated as a function of both data and resource limitations. In the present case, resources are the amount of attention and effort that are devoted to a particular task (especially in dual-task situations). To a first approximation, if more effort is devoted to the ongoing task, fewer resources are available for cue detection and vice versa. Manipulations such as the relative importance of the ongoing task and the prospective memory task are examples of resource limitations that affect event-based cue detection (Kliegel, Martin, McDaniel, & Einstein, 2004; Smith & Bayen, 2004). Thus, current theories of prospective memory have considered the role of attention only in terms of resource allocation policies (Marsh et al., 2003) and have not considered data limitations to performance.

In the present case, more data are contained in a given display than can be processed efficiently. Given that focal attention is directed toward the letter string in this study, processing of information in the periphery is data limited (i.e., data exceed uptake). Carefully processing the information in the border would slow response time, so the data contained within it receive less analysis. If the data in the array were corrupt or had poor fidelity (e.g., blurring the letter strings), that would be another example of data limitations. Data-limited performance deficits can be modulated by a redistribution of resources (as is argued implicitly in current models of prospective memory such as PAM or the multiprocess view), but only to a point, and then any further modulations must be accommodated by altering the characteristics of the data themselves. We have demonstrated this fact by showing that increased data salience in the periphery of attention can modulate performance in the border intention condition. Thus, theories of event-based cue detection that have only begun to address resource limitations must also add data limitations to the list of factors that must be considered and eventually integrated into those theories.

This point is nontrivial because one important pillar of the multiprocess view of prospective memory (McDaniel & Einstein, 2000; McDaniel, Guynn, et al., 2004) is that automaticity of cue detection is driven in part by cue salience (which is a data-driven factor). Ironically, no other studies have systematically manipulated cue salience; rather, studies have defined it imprecisely as the distinctiveness or discrepancy of a cue's familiarity against a background. These definitions are not bad per se, but salience might be defined more usefully with reference to data limitations, and then only to resource allocations that participants make to overcome what they perceive to be a data limitation. Quite possibly, manipulations of salience may have nothing to do with resource allocations between the prospective and ongoing tasks, as defined in either PAM or the multiprocess view, but rather have more to do with overcoming data limitations to processing an array of information for any particular resource allocation policy (see Marsh, Hicks, & Cook, in press). Therefore, beyond resource allocation issues that make cue detection automatic, there is the orthogonal issue that the attention being allocated to a set of tasks can be made more efficient by overcoming data limitations. Although we are not prepared to incorporate this dimension into existing theories of event-based prospective memory, the present study clearly indicates that every researcher interested in how people fulfill their intentions will need to grapple with the implications of the present study.

One important direction for future work would be to equate the cue used in the focus of attention with that delivered at the periphery. In the present study, the focused attention condition delivered the cue (red) in a word stimulus, whereas the periphery condition delivered the cue (red) in a border stimulus. A better approach would have been to use, say, a flanker paradigm in which every trial contained three letter strings and participants made their lexical decision response to the center string only. To test whether changes to an event-based cue differ in the focus of attention, the red prospective cue could occur as either the center letter string or as one of the flanker letter strings. Presumably, flankers receive much less focal attention and are also data limited in their processing (Schmidt & Dark, 1998). However, this issue raises the more general question, What changes in the periphery of attention actually attract attention? For many years it was believed that perceptual singletons attract attention obligatorily and reflexively (e.g., Remington, Johnston, & Yantis, 1992). Singletons include abrupt onsets, the appearance of new objects in the display, abrupt changes in continuous motion, initiation of motion, and changes to an object that differentiate it from those in its immediate context. As it relates to prospective memory, cues that represent singletons could obligatorily attract attention and be immune from manipulations of salience, whereas static cues (such as the border used here) that do not cause a reflexive draw of attention may be more sensitive to manipulations of salience.

This point may be very important for studies that follow up on the work presented here. One way to test this idea using the current paradigm would be to have the border jiggle slightly after display onset. The motion should obligatorily draw attention to it and thereby mitigate any manipulation of perceived salience, operationally defined as size in the present study. Another strategy would be to manipulate whether the event-based cue was delivered in a stimulus that reflexively attracted attention. However, one issue that must be considered is that the latest theories of attention argue that no singleton ever obligatorily attracts attention (e.g., Pashler, Johnston, & Ruthruff, 2001). Rather, top-down processing from task instructions also determines what cues attract attention reflexively. For example, if the participant is expecting the border to jiggle on some trials, the motion that otherwise would have attracted attention obligatorily may not do so under those conditions. Therefore, depending on how the prospective memory instructions are delivered and what the task is, these instructions can modulate participants' expectations about cues in the periphery. Consequently, we believe that many interesting issues remain to be explored. As we have stated previously (Marsh & Hicks, 1998) and other have echoed, prospective memory lies squarely at the crossroads of attention and memory, and the former deserves a much larger role in theories of intention formation and completion than it has currently.

Notes

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