Event-Based Prospective Memory for Poorly Attended Events

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Abstract. In the most frequently used paradigm for studying event-based prospective memory (PM, Einstein & McDaniel, 1990), participants perform an ongoing task and are asked to perform an additional task when a particular stimulus (the PM cue) is presented. In this study three experiments examined how PM performance depends on stimulus selection, which is a major process involved in executive task control according to current theorizing. Participants made semantic judgments about a target word accompanied by two nontargets (distracters). The target was indicated by its spatial position (Experiment 1) or color (Experiment 2). The findings indicated that PM performance was much poorer when the PM cue was irrelevant to the ongoing task, in spite of the fact that nontargets were processed semantically as shown in Experiment 3.

Keywords: event-based prospective memory, selective attention, executive control

In their review, McDaniel and Einstein (2000) described the following story, which provides a classical example of an everyday event-based prospective memory (EBPM): "I intended to bring home several floppy disks from my office for my daughter. Though the intention had been formed the previous week and I was hopeful I could strategically prompt myself to retrieve the intention once at the office, I had not remembered the task on any day of that week. . . .Monday of the following week, I was carefully reviewing my floppy disks for a particular file and in so doing became aware that I needed to take some blank disks home. The idea illustrated here is that when the disks became a *focus of attention of an ongoing task*, those cues (the disks) seemed to automatically stimulate retrieval that I had also to complete the task of returning home with several blank disks" (p. S136, italics added). In this example, the sight of the disks served as the PM cue, and reviewing the disks was the ongoing task. Einstein and McDaniel (1990) developed a popular tool for investigating EBPM. In their paradigm, the PM event is embedded in this ongoing task—for example, requiring participants to execute a special response when a critical word is presented.

Some theories suggest that executive control processes operate in EBPM when, for example, searching memory for the required intention (e.g., McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004) or monitoring the environment for the presentation of the PM cue (e.g., Smith, 2003; Smith & Bayen, 2004). The relevant studies typically manipulate the difficulty of the ongoing task (e.g., Einstein & McDaniel, 1996; Marsh, Hancock & Hicks, 2002; Marsh & Hicks, 1998), introduce an additional task in an attempt to tax the limited resources (Einstein, McDaniel, Smith & Shaw, 1998; Einstein, Smith, McDaniel & Shaw, 1997; McDaniel, Robinson-Riegler & Einstein, 1998) or observe decrements in performance in the ongoing task (e.g., Marsh, Hicks, & Watson, 2002; Smith, 2003). All of these studies can be broadly related to dual-task coordination or "divided attention." The aforementioned theories emphasizing active monitoring are usually contrasted with theories suggesting that PM performance relies on spontaneous recollection of the intended action (e.g., Einstein & McDaniel, 1996; see Einstein, McDaniel, Thomas, Mayfield, Shank, et al., 2005), which presumably does not require executive processing. A third class of theories suggests that executive monitoring and spontaneous recollection are two optional strategies, whose employment depends on factors such as task constraints and individual differences (Einstein et al., in press; McDaniel & Einstein, 2000). We argue that this classification of the strategies may be inaccurate because even when participants perform the ongoing task, they nevertheless need to maintain a balance between the need to focus selective attention and the need to detect the PM cues. Furthermore, maintaining such a balance is among the most critical components of executive functioning according to some theorists (e.g., Goschke, 2000).

Studying the role of selective attention in PM success is important for two major reasons. First, there is abundant evidence for the distinctiveness of selective attention abilities and dual-task coordination abilities of the type employed in many studies on PM (e.g., Lansman, Poltrock, & Hunt, 1983; Pashler, 1991) as well as growing evidence for the multifactorial nature of executive skills in general (e.g., Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). In that respect, Miyake et al. have shown that individual differences in dual-task performance are poorly explained by three other executive abilities—shifting, inhibition, and working-memory updating—suggesting that dual-task coordination constitutes a separate skill. Second, elaborate theories of executive control, such as Logan and Gordon's (2001) ECTVA, place heavy emphasis on selective attention as a primary means for task control. Specifically, the role of selective attention is to ensure that response selection is mostly affected by task relevant information. If the PM cue is categorized as being irrelevant to the ongoing task, its information is prevented from

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affecting behavior, and as such, it is also less likely to invoke the required PM response. Given these considerations, a more comprehensive picture of the role of executive processes in EBPM must take into account selective attention. In the present work, we therefore concentrated on PM performance when the PM cues were relevant to the ongoing task (targets) and when PM cues were irrelevant for the ongoing task (nontargets).

What would one predict for nontargets? Assume, for example, that participants adopt a spontaneous recollection strategy, by which they focus on the ongoing task and rely on the fact that PM cues would lead to an effortless, spontaneous retrieval of the intended action. On the one hand, one may argue that such a strategy is inefficient for nontargets serving as PM cues because these stimuli would not be processed deeply enough to allow for spontaneous retrieval of intentions. However, Henik, Ro, Merrill, Rafal, and Safadi (1999) showed that nontarget stimuli that flanked the target stimuli were processed to the level of their meaning. Even more relevant is a study by Ste-Marie and Jacoby (1993), who showed that under dual-task conditions, such as those involved in the PM paradigm, words that flank the target word elicit automatic recognition responses. These considerations suggest that nontargets serving as PM cues can elicit spontaneous PM responses.

Three studies by Maylor (1993, 1996, 1998) examined EBPM where the PM cues were unattended. Specifically, she asked participants to name pictures of famous people as the ongoing task and mark the trial number if the person was wearing glasses or had a beard. The PM cues, beard or glasses, were presumably not in the focus of participants' attention, and the results indicated age-related deficits in PM performance. Similarly, Park, Hertzog, Kidder, Morrell, and Mayhorn (1997) used a working-memory task as the ongoing task. The PM cue was the background on which the word was presented. When a given background appeared, they had to press a special key. However, because the theoretical focus was different than that of the present study, none of these studies compared attended to unattended conditions.

More recently, Einstein, et al. (in press) compared an attended and an unattended condition within an experiment but between groups. For example, in some experiments the ongoing task required deciding if a target word matches a category name. In the focal group, the PM cue was a word. In the nonfocal group, the PM cue was a syllable. The rationale was that the category-verification task required attending to whole word meanings and not to individual syllables, and therefore a PM cue that is a word is in the focus of attention whereas a syllable is less so. These researchers found that PM success was considerably lower when the PM cue was a syllable than when it was a word. However, because the comparison was conducted across groups, participants adopted different processing strategies (which is, in fact, what these authors tried to demonstrate). Specifically, participants in the focal group, with a moderate emphasis on the PM task, tended to rely on spontaneous PM-cue detection. Those in the nonfocal group relied on strategic monitoring, searching for the PM cue. This strategic difference was seen in the fact that there were no costs in ongoing task performance when a spontaneous retrieval strategy was adopted, whereas such costs were observed when a monitoring strategy was adopted. Another potential limitation of Einstein et al.'s study for the present focus is the fact that selective attention applied to levels of processing and not to stimulus selection. This feature may be critical given that everyday situations often involve selecting stimuli. For example, when driving, events taking place on the road are relevant for the ongoing task, but the sight of a post office box, in which one needs to place a letter, is irrelevant for the ongoing task. Moreover, attending to stimulus dimensions (as in manipulations related to levels of processing) has been shown to be functionally dissociable from stimulus selection (e.g., Shalev & Algom, 2000).

Until this article was accepted for publication, we were unaware of any study that examined the role of stimulus selection in PM, and we planned the present study to fill this gap in the literature. After the paper was accepted, a new publication was brought to our attention (Hicks, Cook, & Marsh, 2005). These researchers required participants to form the intention to either respond to a red word in an ongoing lexical decision task or respond to a red border around the word. The study also manipulated the salience of the cue by changing the size of the border and changing the size of the word. The results showed that PM performance improved if the PM cue was more salient, but this was only true for PM cues not receiving attention (it was the border surrounding the word) and not when the PM cue received attention (it was the color of the word). The influence of attention on PM performance was not evaluated because the two critical conditions (attended vs. poorly attended PM cue) appeared in separate experiments, and also, the PM cue differed. Nonetheless, the raw trend shows that the PM performance was slightly *poorer* for the attended condition in comparable conditions. It was .66 and .80 for a small and a large border, respectively, when the border was the PM cue and .73 and .69 for a small and a large font size, respectively, when the word was the PM cue.

In the present experiments, we compared a condition with focal PM-cue processing to a non-focal condition, both taking place within the same blocks of trials, thus preventing, as much as possible, strategic differences between these two conditions. Moreover, we focused on the role of stimulus selection rather than focusing on levels of processing. Specifically, we presented participants with word triplets and asked them to classify one of the words, the target, as concrete or abstract while ignoring nontargets (distracters). The target word was marked by its central position (e.g. "cat—book—love" with "book" being the target) in Experiment 1, whereas in Experiment 2, the words were presented serially and centrally, and the target was marked by its red color. The PM cue was the word "cup," (SEFEL) and it could appear either as a target word or as a nontarget. In Experiment 3, we provide evidence that in spite of not being selected for action, nontargets were still processed semantically, as seen in a semantic priming effect.

Experiment 1

Although in this experiment, the ongoing task was performed only on the middle word, we took the following additional measures to ensure that participants would focus on it exclusively or nearly exclusively. First, the word triplet was presented for a limited duration, so that failing to focus in the middle was likely to result in missing the central word. Second, we told the participants that their memory for the middle words would be tested afterward, and we did perform such a test at the end of each block. Third, the PM events were presented almost always in the middle and only rarely as flanker words. Finally, as a manipulation check, we also compared recognition memory for the flanker and the middle words. However, recognition of the flanker words was tested only in the end of the last block.

Method

Participants

Thirty-one Achva College undergraduates volunteered to participate in the experiment in exchange for an extra introductory course credit. All the participants reported normal or corrected-to-normal vision and were native Hebrew speakers (Hebrew was the language of the experiment). At the end of the experiment, we requested each participant to explain the task. Four participants did not understand the task, and their results were therefore excluded from all the analyses. An additional participant was excluded because he failed in all the PM tasks. Consequently, we are reporting the results of only 26 participants.

Stimuli

A computer program written in MEL 2.0 software was used. The program was operated using a PC with a 14″ screen. The stimuli were 2,131 concrete and abstract Hebrew nouns. These nouns were selected from three dictionaries, Barkali (1970), Even-Shoshan (1995), and Choueka (1997) according to the following guidelines: we did not use words that appeared to be very rare (we relied on subjective estimates because there are no up-to-date Hebrew frequency counts); we used only words that are clearly concrete or clearly abstract words (again, based on our judgment); and we did not include synonyms for words already included. The decision of what words to include (based on these criteria) was made by a psychology graduate student and a professional language editor. The words were presented on the screen using a font with letter height of 5 mm (∼.5 degree). The target word was presented in the middle of the screen and was flanked by two different distracter words, each placed 5 mm from the target word. The words were all presented in white on black background.

Procedure

Half of the targets were concrete, and half were abstract. Because we, in fact, nearly exhausted the useable words, we could not maintain this proportion for nontargets, and for these words the proportion was roughly .4 abstract and .6 concrete. Also, words were assigned to triplets so as to form different combinations of concrete and abstract words. The triplets in an experimental block were randomly ordered, and so were the words in the recognition memory test. Also, there were two sets of stimuli, so that half of the participants performed Set 1 in Session 1 and Set 2 in Session 2, and the other half received the reverse assignment. Although the triplet lists were fixed for a given block of trials, the order of blocks was randomized, except for one block that was always given at the end of Session 2 and was used to test recognition of flanker words.

The experiment consisted of two identically structured sessions of 45 min each and separated by 2–4 days. Participants were first instructed about the concreteness judgment task (concrete vs. abstract). They used their right hand to respond to the task, pressing the “4” key of the number pad with their index fingers to respond to a concrete word and the “6” key of the number pad with their middle fingers to respond to an abstract word. They were then asked to also press the yellow key (the “1” key on the upper left corner of the keyboard), using the index finger of their left hand, whenever the PM cue word, the Hebrew word SEFEL (cup) was presented, regardless of whether it was in the middle of the triplet. The instructions emphasized that the execution of the PM task should always follow the concreteness judgment and that both tasks should be performed accurately and quickly. Also, participants were informed that at the end of each experimental block, they would be given a recognition test of their memory of the central target words (the ones about which the judgments of concreteness were made).

The first block was a warm-up block that included 9 trials, none of which involved the PM cue word. There were 15 experimental blocks in a session. Each consisted of 18 trials. The PM cue word was presented once in each block, 12 times in the center and 3 times as a flanker word. Each trial consisted of the presentation of a word triplet for 400 ms, followed by a mask (a line of asterisks) for 1,500 ms. Incorrect concreteness judgments were followed immediately by an error message. A reminder of the PM task was given to a participant once, at the end of the first experimental block, if he or she failed to respond to the PM cue.

A recognition memory test followed the last concreteness judgment of a block. It included centrally presented words, the 18 words presented earlier in the middle of the triplet, and 36 lures. The lures included 18 words that served as flankers and 18 new words. The cue word did not appear in the recognition memory test, so that if this word appeared in the middle of the triplet in the block preceding the recognition memory test, only the other 17 words appearing in the middle of a triplet were presented in the recognition memory test, and if this word appeared as flanker in the block preceding the recognition memory test, only 17 of the flanker words were presented. Thus, only 53 words were presented in the recognition memory test.

During the recognition test, the participants indicated whether the word presented to them appeared as a target word beforehand by pressing the number pad keys, “2” (yes) and “8” (no). In the last block of Session 2, the recognition test was changed without warning, and the participants were required to judge for each word if it was presented as a distracter word.

Results

Alpha level was .05 in all the analyses.

The major finding is that EBPM performance was very low when the PM cue was irrelevant to the ongoing task.

PM Performance

Because the instructions were to respond first to the ongoing task, PM-RT may not be very informative. It is sufficient to mention that the trends were in the same direction as those seen in PM success (i.e., probability correct). PM success was four times higher when the PM cue was presented in the center (.90) as compared with when it served as a flanker word (.21 and .26 for left and right flankers, respectively). A planned comparison revealed that performance was better when the PM cue word appeared as a target than when it appeared as a nontarget, $F(1, 25) = 177.36$.

Recognition Memory

The *P*(HIT)-*P*(FA) rates for the centrally presented words (all but one of the recognition tests) and for the flanker words (the very last recognition memory test) were .57 (*P*(HIT) = .66, *P*(FA) = .09) and .04 (*P*(HIT) = .26, P(FA) = .22), respectively, $t(25) = 15.54$. Our procedure confounds time-on-task with target position. However, *P*(HIT) was .69 and 64, and *P*(FA) was .10 and .08 in Sessions 1 and 2, respectively, which suggests that time-on-task did not affect performance considerably.

Ongoing Task Performance

Mean concreteness judgment reaction time (RT, measured from triplet presentation) was 851 ms for concrete words and 875 ms for abstract words, a significant difference, $F(1, 25) = 13.19$. The mean proportion of errors (PE) was .24 for both word types.

Experiment 2

Because one could argue that the participant did not process the nontargets at all, we ran a second experiment in which triplets of words were presented serially at fixation, for 250 ms each, with the nontargets presented in white and the targets presented in red, thereby giving nontargets a perceptual advantage that would make it even more unlikely that PM failures resulted from failure to perceive the PM cue.

Method

Participants

Thirty-five of the 41 participants were included in the analysis. We excluded six participants as follows: two participants because they made too many errors (PE $>$ 2 *SD*s above the mean) in the concreteness judgment task; one because he did not understand the instructions; and three because they failed to show up for Session 2.

Stimuli and Procedure

The words were presented serially at fixation, for 250 ms each. The target words for the concreteness judgment task were colored in red, and the distracter words were colored in white, both on black background. All the other aspects were the same as in Experiment 1. The order of words within the triplets was counterbalanced between participants to prevent item-specific artifacts.

Results

The results of Experiment 2 indicate a much poorer PM performance for stimuli that were not relevant to the ongoing task, in spite of the fact that they appeared in the visual focus.

PM Performance

PM success for targets was almost identical to that seen in Experiment 1. However, PM success for PM words presented as distracters was much higher than in Experiment 1, confirming our suspicion that visual focusing helped in filtering out distracter information in that experiment. Still, PM success was about 1.5 times larger for PM cues presented as targets (.92) as compared with PM cues presented as distracters (.60), $t(34) = 9.25$. The serial order (first, second, third) of the PM cue neither had a significant effect nor interacted with attention.

Recognition Memory

P(HIT)-*P*(FA) values were .48 (*P*(HIT) = .60, *P*(FA) = .12) and .00 (*P*(HIT) and *P*(FA) = .29) in the fully attended and the poorly attended conditions, respectively, $t(34) = 14.74$. The values did not differ significantly between Session 1 (.61 and .13) and Session 2 (.60 and .10).

Ongoing Task Performance

Mean concreteness judgment RT (measured from the onset of the red words) was 863 ms for concrete words and 878 ms for abstract words, a difference that approached significance, $F(1, 34) = 3.64$, $p = .06$. The mean PE was .24 for concrete words and .23 for abstract words, $F(1, 34) = 22.21$.

Experiment 3

One could still argue that the participants in Experiment 2 processed only the color of the word and did not reach a level of processing (lexical or semantic) required to identify the PM cue. One reason for this suspicion is that Henik, Friederich, and Kellogg (1983) and Smith (1979), as well as many others since then, have shown in a semantic priming task that directing attention to superficial levels of the prime stimulus eliminated the semantic priming effect.

The suggestion in the previous paragraph seems unlikely given that Henik et al. (1999), who used a variant of the Stroop color-naming paradigm, showed that words that flanked the target stimulus (as in Experiment 1, where nontargets were probably less deeply processed than in Experiment 2) were processed according to their meaning. Nonetheless, in order to rule out this explanation, we repeated the same procedure used in Experiment 2 (all words presented focally), but examined whether the abstract–concrete judgments would be facilitated if the processed word was preceded by a semantically related nontarget. Such evidence for semantic priming would indicate that nontargets were processed to the semantic level. Moreover, evidence for semantic priming would provide additional evidence that attending to levels of processing is functionally distinct from stimulus selection, one eliminating the semantic priming effect while the other not.

This experiment did not involve a PM task because presenting the PM cue as a nontarget presumably directs attention to nontargets. Omitting the PM task therefore made it less likely that nontargets would be processed semantically. Evidence for semantic processing under these conditions would provide especially strong evidence that the present method of presentation did not prevent semantic processing.

Method

Participants

Twenty-three participants took part in this experiment.

Stimuli and Design

One of the distracter words in each triplet was replaced by a word semantically related to the target word. To minimize strategic reading of the distracter words, we included triplets with all possible semantic relations between all the possible word pairs, regardless of their status as a target (e.g., first-to-second, second-to-third, first to third, and no relation).

Procedure

The experiment included one session, identical in structure to Session 2 of Experiment 2. Stimulus presentation was otherwise the same as in Experiment 2.

Results

Recognition Memory

P(HIT)-P(FA) values were .30 (P(HIT) = .34, P(FA) = .04) and -.12 (P(HIT) = .11, P(FA) = .23) for the fully attended and poorly attended conditions, respectively, $t(22) = 8.32$.

Concreteness Judgments

RT

Only 4 of the 12 semantic relation conditions present in this experiment were analyzed. The analyzed conditions were the combination of target-word positioning in the triplet (second or third) and semantic relation to the immediately preceding flanker (related or unrelated). (Note that we could not use triplets in which the target word was presented first because it was not preceded by another word). A semantic priming effect of 13 ms was found both for the second and the third positions of the target word, $F(1, 22) = 4.32$. The RT means for related and unrelated condition were 845 and 858 ms, respectively. In addition, responses to the third target position were quicker than those to the second position by 107 ms, $F(1, 22) = 73.14$. The interaction between the variables had an $F = 0$. It is interesting to note that the RTs in the present experiment were 18 ms quicker than in Experiment 2 (852 vs. 870 ms). This trend is very small, suggesting that participants relied mostly on a spontaneous detection strategy of the PM cue (Einstein et al., in press; Smith, 2003).

Proportion of Errors (PE)

There was no indication of speed–accuracy trade-off. The PE data were analyzed according to the same design as the RT data. The two-way interaction between target and relatedness was significant, $F(1, 22) = 7.00$. For the second target position, PE was .10, and no priming effect was observed, $F(1, 22) = .01$. A significant priming effect was found for the third target position, with PE being higher in the unrelated condition (.15) than in the related condition (.10), $F(1, 22) = 7.39$. Compared with Experiment 2, in which the mean PE was .24, the mean PE was lower in this experiment (.12).

Discussion

Stimulus selection involves mental labeling some stimuli as nontargets and other stimuli as targets. Labeling stimuli as nontargets apparently did not completely block their processing, as indicated by a significant semantic priming effect, with nontargets serving as primes (Experiment 3). However, it had strong effects on later recognition memory, which was practically absent. Critically, PM success was very high when the PM cue was a target but was considerably poorer when it was a nontarget. These results are more similar to Einstein et al.'s (in press) findings than to Hick et al.'s (2005). Hicks et al.'s experiments, however, are more similar to ours in manipulating stimulus selection and therefore are more directly comparable. The difference between their results and ours may be due to the fact that we limited stimulus exposure time, which did not enable the participants to attend to nontargets. In contrast, the stimuli in Hicks et al.'s study remained visible until the lexical decision task was given.

The high rate of PM success in Experiments 1 and 2, coupled with the relatively minor decrement in performance on the ongoing task, as indicated by comparing Experiments 1 and 2 with Experiment 3 are two important markers for the employment of a spontaneous retrieval strategy according to Einstein et al. (in press). According to current theorizing regarding the spontaneous retrieval strategy (see Einstein et al. for an excellent review), full processing of the PM cue is a prerequisite for this cue to elicit a spontaneous retrieval of the PM intention. The present results support this theory in showing that PM performance is impaired when the PM cue is a nontarget. The challenge to the theory is to explain in what sense the nontarget PM cue was poorly processed, given the fact it generated reliable semantic priming effects and given Ste-Marie and Jacoby's (1993) results showing that nontargets elicit spontaneous retrieval. A potential solution to this apparent paradox is to argue that semantic processing and recognition are not all-or-none phenomena, but are gradual or probabilistic in nature. Under this assumption, one could argue that the probability for a sufficiently deep encoding of the nontargets was less than that of the targets.

Another interesting observation is that PM success for focal nontargets (Experiment 2) was .60, a figure quite close that observed by Einstein et al. (in press, Experiment 1) for PM cues (syllables) that were not in the focus of attention (words), .67. (The comparison is partly justified by the fact that PM success for focal PM cues was very similar in the two experiments: .92 in the present study's Experiment 2 vs. .90 in Einstein et al.'s). In this condition, Einstein et al. observed a decrement in ongoing task performance, suggesting that effort was invested in monitoring the PM cue. Future studies should determine whether the investment of such effort improves PM performance. This may not be necessarily so, as researchers using dual-task manipulations often observe no decrement in performance, a situation Norman and Bobrow (1975) referred to as "data limitation" rather than "resource limitation." In retrospective memory, for example, the typical finding is that retrieval efforts have minimal if any influence on retrieval success (e.g., Baddeley, Lewis, Eldridge, & Thomson, 1984; Naveh-Benjamin & Guez, 2000).

Several factors affecting PM success were specified by previous theories, but these factors were equal across targets and nontargets in our experiments. Specifically, these factors include the importance of the PM task (Kliegel, Martin, McDaniel, & Einstein, 2001), the difficulty of the ongoing task (Einstein & McDaniel, 1996), the cue–task association (McDaniel et al., 2004), and the distinctiveness of the PM cue (Brandimonte & Passolunghi, 1994). The contribution of the present work is in showing the consequences of stimulus selection on PM performance. Theories of executive control suggest that task control is largely based on the selection of task-appropriate information as a part of response selection (e.g., Logan & Gordon, 2001). Information deemed as task-irrelevant is therefore blocked from affecting response selection. The advantage is reduced interference and correct response choices. The disadvantage is the potential miss of rare and less anticipated but potentially relevant information, as was observed here. As Goschke (2000) argued, the challenge of executive processing in such conditions is maintaining an optimal balance between these two conflicting demands. Such executive functioning is present also if participants rely on spontaneous retrieval, but is not affected by dual-task manipulations because dual-task coordination and selective attention of a target stimulus are two distinct functions (Pashler, 1991).

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