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Eye movements provide insights into the conscious use of context in prospective memory☆

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ABSTRACT

Prior research examining the impact of context on prospective memory (PM) has produced mixed results. Our study aimed to determine whether providing progressive context information could increase PM accuracy and reduce costs to ongoing tasks. Seventy-two participants made ongoing true/false judgements for simple sentences while maintaining a PM intention to respond differently to four memorised words. The context condition were informed of the trial numbers where PM targets could appear, and eye-tracking recorded trial number fixation frequency. The context condition showed reduced costs during irrelevant contexts, increased costs during relevant contexts, and had better PM accuracy compared to a standard condition that was not provided with context. The context condition also made an increasing number of trial number fixations leading up to relevant contexts, indicating the conscious use of context. Furthermore, this trial number checking was beneficial to PM, with participants who checked more frequently having better PM accuracy.

1. Introduction

Prospective memory (PM) is the term given to the type of task that requires individuals to remember to perform a deferred task action. PM is vital for everyday functioning since it allows individuals to plan for future contingencies. Triggers for PM tasks can be either time-based or event-based (Kliegel, McDaniel, & Einstein, 2008). Time-based PM involves remembering to perform an action at a certain time, while event-based PM requires a deferred action be performed after a target event occurs. A typical event-based paradigm requires participants to respond to a PM target event embedded within an ongoing task (Einstein & McDaniel, 1990). For example, when the ongoing task is to judge whether a string of letters is a word or not (lexical decision), a PM task may require the participant to press an alternate response key when a word containing the syllable 'tor' is presented.

There is a large literature showing that PM demands can slow ongoing task response time (RT) compared to when participants perform ongoing tasks alone, referred to as PM costs (Smith, 2003). Costs may be the result of individuals directing conscious resources away from the ongoing task towards the PM task in order to detect targets (Guynn, 2003; Marsh, Hicks, & Cook, 2006; Smith, 2003), or could also reflect participants delaying their ongoing task responses to allow more time to detect PM targets (Heathcote, Loft, & Remington, 2015; Loft & Remington, 2013). Regardless of the exact underlying mechanisms, costs can be functionally related to PM accuracy, where increased costs are associated with increased PM accuracy (e.g. Loft & Yeo, 2007; Smith, 2003). Thus in some cases, changes in the conscious processing of ongoing task stimuli in response to PM task demands can benefit

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eventual PM performance.

Real world PM tasks are often associated with predictable and familiar environmental contexts which potentially allow individuals to alter their conscious processing of their environment to facilitate PM more precisely (Smith, 2017). An example of a PM task in which the environmental context signals when the PM task becomes relevant is remembering to post a letter at a letterbox on the way home. In this case it would be most beneficial to delay costs to the ongoing activities (driving) until approaching the context where performing the PM task becomes relevant (the post office). Prior research has shown that informing participants as to when a PM target could potentially appear (relevant context) or could not appear (irrelevant context) can reduce costs in irrelevant contexts (e.g., Loft, Finnerty, & Remington, 2011; Lourenço, White, & Maylor, 2013; Marsh, Hicks et al., 2006; Marsh, Cook, & Hicks, 2006; Smith & Loft, 2014). As reviewed by Smith and Loft (2014), studies that have clearly demarcated the blocks of trials which could contain a PM target event from those that could not, have produced the greatest reduction in costs compared to when relevant and irrelevant context trials have alternated randomly within blocks.

In contrast to block by block or randomly alternating manipulations of context, Smith, Hunt, and Murray (2017) used a paradigm that allowed participants to track context within a single ongoing task block. In the Smith et al. study, participants saw photographs taken on their campus and were asked to remember to complete 'errands' at specified campus locations, such as remembering to buy test forms at the bookstore. Photographs were shown either in order (as though participants were walking around campus, allowing them to anticipate the temporal proximity of PM relevant contexts by using the progressive contextual information) or were randomly presented. The results showed that the ordered condition had reduced overall costs relative to the random condition. Smith et al. also compared RTs for sets of seven trials immediately before the target locations to more distant sets of trials and found that RTs increased in the ordered condition as the PM errand locations were approached (i.e., costs increased as the target location neared).

In addition to reducing costs, providing context may also provide benefits to PM performance. However, prior research examining the impact of context on PM performance has produced mixed results. Ball, Brewer, Loft, and Bowden (2015; blocked context manipulation) and Cook et al. (2005; blocked context manipulation) reported a benefit to event-based PM and time-based PM, respectively, while Loft et al. (2011) reported a benefit to event-based PM in a simulated air traffic control task when participants were informed as to which regions of the air traffic control display PM target aircraft could or could not approach. Kuhlmann and Rummel (2014; randomly alternating context manipulation) and Smith et al. (2017; Experiment 2, progressive context manipulation) reported trends towards improved event-based PM. In comparison, Smith et al. reported no PM benefit in their first and third experiments when providing progressive context cueing, and Lourenço et al. (2013; event-based PM randomly alternating context manipulation) and Marsh, Hicks et al. (2006; Experiment 2, time-based PM, blocked context manipulation) reported no benefits to PM.

Based on these studies, there is no clear pattern regarding what type of PM task (event-based, time-based) or manipulation of context (blocked, randomly alternating on a trial-by-trial basis, progressive context) is most likely to produce PM accuracy improvements. However, it is apparent that to date PM performance has only been significantly facilitated when blocks of trials which could contain a PM target event are clearly demarcated from those that could not (i.e., blocked design). Finally, regardless of whether context has produced a PM advantage or not, many studies have found that costs increased in relevant PM contexts for those participants provided with context information compared to those not provided context (Ball et al., 2015; Kuhlmann & Rummel, 2014; Lourenço et al., 2013; Marsh, Hicks et al., 2006).

Clearly, further research is required to examine the impact of context on PM performance and costs. We were specifically interested in emulating the ecologically valid conditions identified by Smith (2017; Smith et al., 2017) in which individuals can use progressive contextual information to anticipate the temporal proximity of relevant PM contexts. The goal of the current study was to examine the extent to which individuals could use progressive context to reduce costs and improve PM accuracy. For the ongoing task in our experiment participants made a true/false judgement for short sentences. The event-based PM task required an alternate response when one of four memorised target words appeared in these sentences. Trial numbers were used to provide contextual information about the occurrence of the target events. Participants in a context condition memorised the trial number ranges (e.g. 25–30, 50–55, etc.) that could include a PM target word whereas participants in a standard condition were not made aware of the relevance of the trial numbers. Context in this study was therefore cued in a similar way to a time-based PM task since participants could consciously use the trial numbers to judge temporal proximity to relevant PM contexts. At the same time, by providing target intervals (the sets of trials during which targets could appear) we also established relevant (inside the target interval) and irrelevant (outside the target interval) PM contexts. This allowed us to compare, in the same ongoing task, performance for relevant and irrelevant contexts while also examining how participants use progressive contextual information in the irrelevant context as they approach the relevant context where the PM target could appear.

The current study also used eye-tracking to examine more closely how participants utilized the predictive contextual cues. Fixations in particular can be used to determine the object of conscious attention and to some extent the degree to which attention is allocated (Hoffman & Subramaniam, 1995; Posner, Snyder, & Davidson, 1980). While eye-tracking is relatively novel in the PM literature, several previous studies have used it to investigate attention allocation to PM task demands. Shelton and Christopher (2016) showed that participants who spent more time fixating on the area where an event-based PM target could appear had better PM performance, while Hartwig, Schnitzspahn, Kliegel, Velichkovsky, and Helmert (2013) and West, Carlson, and Cohen (2007) demonstrated that maintaining a PM intention during a visual search task changed the ongoing task scanning patterns of participants. However, the current study is the first study of which we are aware in which eye-tracking has been applied to investigate the conscious use of progressive context to support PM.