

Eye movements and prospective memory: What the eyes can tell us about prospective memory

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Abstract

In this study we used eye tracking methodology in combination with multi-element displays to examine the processes underlying event-based prospective memory in a visual search paradigm. In the task individuals searched for a different target stimulus (i.e., a letter) on each trial that could be present or absent, and made prospective responses to the letters D or M. The response accuracy data revealed that target hits were more frequent than prospective hits, and that there was no difference in response time for target and prospective responses. The eye tracking data revealed that both first and total fixation durations increased from distractors (stimuli that were neither targets nor prospective cues) to targets to prospective cues when a target or prospective response was made. These measures also revealed that the presence of a target in the display served to disrupt prospective memory. In addition, prospective memory misses resulted from a combination of failures to fixate the prospective cues and failures to engage in strategic processing of the prospective cues. These data demonstrate the utility of eye tracking methods in examining the processes underlying event-based prospective memory.

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1. Introduction

The realization of delayed intentions in our natural environment is embedded in a more or less continuous stream of activities that place varying demands on the processing of relevant and irrelevant information. This complexity can be appreciated when one considers the specific details of the often cited example of prospective remembering to “buy a loaf of bread on the way home from work”. If one lives in an urban environment the realization of this intention often involves navigating an automobile, perhaps during heavy rush-hour traffic, from work to the bakery and then home. In this situation realizing the intention requires recognizing stimuli that are related to the intention, such as the bakery, and retrieving from memory the intention to buy bread at the appropriate time. This must be done while also attending to various task relevant

stimuli, such as other vehicles and traffic signals. In contrast to the rich environment in which the realization of real-world intentions is embedded, laboratory paradigms designed to examine the factors underlying successful prospective memory have typically utilized relatively impoverished displays, and measured performance using a limited set of behavioral measures (i.e., accuracy and response time). For instance, in one popular paradigm prospective memory cues are presented as words in a lexical decision task wherein a single stimulus is presented at fixation on each trial, and individuals judge whether the stimulus is a word, non-word, or prospective cue (Smith, 2003).

Studies utilizing single element displays have done much to foster our understanding of the cognitive processes underlying prospective memory. However, one may wonder whether the processes revealed in these studies generalize to settings in which multi-element displays are used that include a set of stimuli that may or may not be relevant to the prospective and ongoing components of the task (Brooks et al., 2000; Cohen et al., 2003; Uttl and Graf, 2000). In the current study we sought

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to address this issue by embedding a prospective memory task in a visual search task in which search targets, prospective cues, and distractors could be present in the display. As a compliment to commonly used measures of response time and accuracy we also examined various indices of eye movement behavior that provided insight into the extent of processing of individual elements within the display. The eye movement measures allowed us to determine whether disruptions of prospective memory resulted from either the failure to focally attend to the prospective cues or the failure to engage strategic processes that facilitate the realization of delayed intentions. These measures allowed us to examine the influence of the presence of other task relevant stimuli in the display on the success of prospective memory.

1.1. *Eyetracking in multi-element displays*

Eye tracking has been used extensively in studies examining the processes underlying perception, language comprehension and production, and visual search. This research is predicated on the assumption that eye gaze provides an index of online cognitive processing (for a review, see Rayner, 1998). In the perception literature eye fixations serve as a means of determining attentional selection, as it has been shown that attention obligatorily precedes the eyes to a desired location (Deubel and Schneider, 1996; Henderson and Hollingworth, 1998; Hoffman and Subramaniam, 1995; Kowler et al., 1995; Irwin and Gordon, 1998; Shepard et al., 1986). Within studies of language, fixation durations and fixation patterns have been used as a means of evaluating when objects have been identified, when reference has been established, and when object names are phonologically accessed (Eberhard et al., 1995; Griffin, 2001; Griffin and Bock, 2000; Tanenhaus et al., 1995). Past research using eye tracking to investigate the processes underlying visual search has examined how the configuration of the search display impacts the size and direction of saccades (e.g., Viviani and Swensson, 1982; Findlay, 1997; Engel, 1977; Zelinsky et al., 1997), how fixation duration is influenced by the redundancy or consistency of the display (Nattkemper and Prinz, 1984), and how fixation durations change as a function of the similarity between targets and distractors (Rayner and Fisher, 1987a,b). Given such broad application of eye tracking measures across cognitive domains, it seems reasonable to expect that eye tracking methodology may also provide valuable insight into the processes underlying prospective memory.

There are multiple measures that can be obtained from the eye tracking record (for a review see Rayner, 1998). Some of these characterize eye fixations or periods of time in which the eyes are relatively still and the input of visual information takes place. Others characterize the eye movements themselves (in particular, saccades) in which the intake of visual information is actively suppressed (e.g., Matin, 1974). In the current work, we present data for three standard measures of eye movement behavior that enabled us to examine the processes underlying prospective memory: 1) the number of fixations on a given stimulus (i.e., target, prospective cue or distractor) that provides an index of whether or not a given stimulus was focally

attended; 2) the duration of the first fixation on a given stimulus that provides an index of the extent of initial foveal processing that is devoted to the stimulus; and 3) total fixation duration on a given stimulus that provides an index of the full extent of foveal processing that is devoted to the stimulus within a trial.

1.2. *Prospective memory and eye tracking*

The use of eye tracking methods in combination with multi-element displays in which both target and distractor stimuli may be present provides a means of fostering conceptual development in the area of prospective memory. This methodology allows one to examine the influence of the presence of other task relevant stimuli on the realization of delayed intentions, an issue that is of theoretical importance but that has been largely ignored in the extant literature. For instance, eye tracking measures may allow one to test between predictions derived from competing theories of prospective memory such as the automatic associative activation (Guynn et al., 2001) and strategic monitoring (Guynn, 2003; Smith, 2003) accounts.

In the automatic associative activation theory of prospective memory, the realization of a delayed intention is thought to occur when a focally attended prospective cue interacts with a memory trace of the cue-intention association. This interaction results in the intention being delivered to conscious awareness and realized (Guynn et al., 2001). A strong form of this theory leads to the prediction that one source of failures of prospective memory arise from instances where the prospective cue is not focally attended or fixated. With respect to the example of buying bread on the way home from work, the failure to realize this intention would occur when one's attention was focused on some other stimulus while driving by the bakery. Supporting this prediction, Cohen et al. (2003, Exp. 1) observed that the accuracy of prospective memory was reduced when the target stimuli in a visual search task were made perceptually distinct relative to the prospective cues and the distractors. This effect presumably resulted from the salient target capturing attention, thereby resulting in individuals failing to process the prospective cues on some trials. According to the automatic associative activation account, the eye tracking measures should reveal that failures of prospective memory result from instances where individuals fail to fixate the prospective cue.

In contrast to the automatic associative activation theory, strategic monitoring accounts of prospective memory (Guynn, 2003; Smith and Bayen, 2004) lead to somewhat different predictions. Within these theories merely fixating the prospective cue may not be sufficient for a delayed intention to be realized. Instead, individuals must also engage in preparatory processes or item checking in order for a prospective cue to be recognized as such when it is encountered (Guynn, 2003; Smith, 2003). With regard to the example of buying bread, simply looking at the sign for the bakery would not be sufficient for individuals to realize the intention; they would also be required to determine whether this stimulus was relevant to a currently maintained intention. According to this view, whether or not a given stimulus (i.e., prospective cue) was fixated would not dissociate trials in which there were successful prospective

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