ELSEVIER

Neuropsychologia 44 (2006) 197–207

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

The effects of working memory demands on the neural correlates of prospective memory

Robert West *, Ritvij Bowry, Jason Krompinger [1]

Department of Psychology, University of Notre Dame, 118 Hagger Hall, Notre Dame, IN 46556, USA

Received 14 December 2004; received in revised form 3 May 2005; accepted 5 May 2005
Available online 3 June 2005

Abstract

Event-related brain potentials (ERPs) were used to examine the reciprocal costs of working and prospective memory loads on the neural correlates of the realization of delayed intentions and the detection of target stimuli. The electrophysiological data revealed several interesting results: (1) distinct modulations of the ERPs were elicited by working memory targets and prospective memory cues, (2) working memory load modulated the amplitude of the N300 elicited by prospective memory cues, (3) prospective memory load was associated with a broadly distributed sustained modulation that began shortly after stimulus onset, and (4) brain–behavior correlations between the neural correlates of prospective memory and working memory varied with the working memory demands of the ongoing activity. These findings appear to indicate that attentional processes associated with the detection of prospective memory cues are sensitive to the working memory demands of the ongoing activity and that different processes may support prospective memory depending on the working memory demands of the ongoing activity.

Keywords: Prospective memory; Working memory; ERPs

1. Introduction

Prospective memory entails the formation and later realization of intentions that must be delayed for some period of time (Meacham & Leimen, 1975). For instance, remembering to attach a file to an email message before sending it, remembering to take a medication with a meal, or remembering to pick up one's child from school, are all examples of prospective remembering. In every day settings, the delay between the formation and realization of an intention could be as brief as a few minutes or as long as several hours. While the time scale of prospective remembering can vary widely across intentions, one common element of prospective remembering across various delays is that individuals are engaged in some ongoing activity leading up to, and often including, the event that serves as the prospective memory cue (Einstein & McDaniel, 1990; Ellis, 1996). This ongoing activity makes it unlikely that individuals will actively rehearse the intention in short-term or working memory during the delay. Consistent with this observation, Marsh and Hicks (1998) demonstrated that occupying the articulatory loop of working memory during the ongoing activity had little effect on the accuracy of prospective memory. In contrast, occupying the central executive of working memory or dividing attention with a demanding secondary task can disrupt the efficiency of prospective memory (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh & Hicks, 1998; Marsh, Hancock, & Hick, 2002; McGann, Ellis, & Milne, 2002).

Complimenting work examining the influence of the working memory demands of the ongoing activity on prospective memory, recent evidence indicates that adding a prospective memory component to a task can significantly slow performance of the ongoing activity (i.e., a prospective interference effect; Marsh, Hicks, Cook, Handen, & Pallos, 2003; Smith, 2003). For instance, response time in the lexical decision task is slowed by 100–300 ms when a prospective

* Corresponding author. Tel.: +1 574 631 7257; fax: +1 574 631 8883.
E-mail address: west.19@nd.edu (R. West).
[1] Present address: University of Pennsylvania, Philadelphia, PA, USA.

0028-3932/$ – see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2005.05.003

memory component is added to the task relative to when lexical decisions are performed in isolation (Marsh et al., 2003; Smith, 2003). Smith (2003) argued that the prospective interference effect resulted from the recruitment of preparatory attentional processes that occupy working memory capacity, thereby, reducing capacity that would otherwise be allocated to the ongoing activity. Consistent with this idea, Smith observed that the magnitude of the prospective interference effect was correlated with the accuracy of prospective memory and with individual differences in working memory capacity. Also, the size of the prospective interference effect is dramatically reduced when a single prospective memory cue is used relative to when there are multiple prospective memory cues (Marsh et al., 2003), indicating that the resource demands of preparatory attentional processes may covary with the number of prospective memory cues that must be maintained in memory.

Work incorporating event-related brain potentials (ERPs) conducted over the last several years has made significant progress in identifying the neural correlates of prospective memory (for a review see West, Herndon, & Ross-Munroe, 2000). The presentation of a prospective memory cue that elicits a prospective response is consistently associated with two modulations of the ERPs (i.e., N300, prospective positivity). The N300 reflects a phasic negativity over the occipital-parietal region of the scalp that peaks between 300–400 ms after the onset of a prospective memory cue (West, Herndon, & Crewdson, 2001). In some studies the N300 is associated with a positivity over the midline frontal region of the scalp that may be slightly delayed relative to the occipital-parietal modulation (West & Ross-Munroe, 2002). The N300 is elicited by cues that are defined by letter case (West et al., 2001), color (West and Ross-Munroe, 2002) and word identity (West & Krompinger, 2005). These findings have been taken to indicate that the N300 is not strongly associated with the perceptual characteristics of the prospective memory cues. The N300 is greater in amplitude for prospective hits (prospective memory cues that elicit a prospective response) than prospective misses (prospective memory cues that fail to elicit a prospective response) leading to the suggestion that the N300 is associated with the detection of prospective memory cues (West and Krompinger, 2005; West and Ross-Munroe, 2002). The time course of the N300 is similar to that of the N2 component of the ERPs over the occipital-parietal region. However, evidence from two studies indicates that the N300 can be dissociated from subcomponents of the N2 that are associated with the processing of unexpected stimuli or the selection of target stimuli. West et al. (2001) demonstrated that the enhancement of the N2 elicited by unexpected stimuli was similar in amplitude over the right and left hemispheres, while the amplitude of the N300 was greater over the right hemisphere than the left hemisphere. West and Wymbs (2004) observed that the amplitude of the N2pc, associated with target selection (Luck & Hillyard, 1994), was greater over the hemisphere that was contralateral to the visual field in which the target was presented; in contrast, the amplitude of the N300 was greater over the right hemisphere regardless of whether the prospective memory cue was presented in the right or left visual field.

The prospective positivity reflects a sustained modulation over the parietal region of the scalp between 500 ms and 1000–1200 ms after the onset of a prospective memory cue (West et al., 2001) that is greater in amplitude for prospective hits than prospective misses (West and Krompinger, 2005). Initial work led to the suggestion that the prospective positivity was associated with the retrieval of an intention from memory (West and Ross-Munroe, 2002). However, more recent evidence has demonstrated that the prospective positivity can be dissociated from the old–new effect that is associated with retrieval processes underlying recognition memory (West and Krompinger, 2005). This finding is not consistent with the interpretation of the prospective positivity as a correlate of memory retrieval and may indicate that the prospective positivity is associated with post-retrieval processes that may be related to the need to coordinate the ongoing and prospective components of the task once an intention is retrieved from memory (West and Krompinger, 2005).

The neural correlates of the prospective interference effect have not been explored in previous studies using ERPs. Evidence from one study using positron emission tomography indicates that the prospective interference effect may be associated with activation of the frontal polar cortex (Burgess, Qualye, & Frith, 2001). In this study activation in the frontal polar cortex was observed when a prospective memory load was added to the ongoing activity regardless of whether or not a prospective memory cue was encountered during task performance. This finding led Burgess et al. to propose that the frontal polar cortex participates in a neural system that supports the maintenance of an intention during the ongoing activity.

Given our limited knowledge of the neural correlates of the prospective interference effect, one goal of the current study was to determine whether or not the ERPs would be sensitive to this effect. If the prospective interference effect arises from a reduction in the allocation of working memory resources to performance of the ongoing activity (Smith, 2003), the addition of a prospective memory load might be expected to result in a reduction in the amplitude of the P3 component of the ERPs for target stimuli presented during the ongoing activity. This prediction is motivated by evidence from a number of studies demonstrating that the amplitude of the P3 component is sensitive to variation in the working memory or attentional demands of the task (Kok, 2001). For instance, the amplitude of the P3 is smaller under divided attention conditions than under full attention conditions (Mangun & Hillyard, 1990) and decreases as memory set size increases during visual search (Kramer, Schneider, Fisk, & Donchin, 1986; Strayer and Kramer, 1990). These and other findings led Kok (1997) to propose that the amplitude of the P3 may serve as an index of the availability of attentional capacity for target processing.