



Effects of perceptual and semantic cues on ERP modulations associated with prospective memory



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ABSTRACT

Prospective memory involves the formation and execution of intended actions and is essential for autonomous living. In this study ($N = 32$), the effect of the nature of PM cues (semantic versus perceptual) on established event-related potentials (ERPs) elicited in PM tasks (N300 and prospective positivity) was investigated. PM cues defined by their perceptual features clearly elicited the N300 and prospective positivity whereas PM cues defined by semantic relatedness elicited prospective positivity. This calls into question the view that the N300 is a marker of general processes underlying detection of PM cues, but supports existing research showing that prospective positivity represents general post-retrieval processes that follow detection of PM cues. Continued refinement of ERP paradigms for understanding the neural correlates of PM is needed.

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1. Introduction

Prospective memory (PM), in the broadest sense, is the ability to form intentions of action and enact those intentions at an appropriate moment in the future without direct reminders (Meacham, 1982). Beginning with the decision to perform a future action and ending with evaluation of the outcome of that decision, PM is highly relevant to everyday functioning (Ellis, 1996). The prospective function of memory is responsible for recognising stimuli relevant to formed intentions even when attention is focused elsewhere (Ellis and Freeman, 2008).

Translated to the laboratory setting, experimental PM tasks are usually modified dual-task paradigms in which the primary task requires discriminations that tax attention and memory (Hertzog, 2008). Embedded within the primary task is a secondary PM task in which PM cues may appear as part of the ongoing task, or as part of the background context. Electrophysiological studies of PM have generally identified two distinct ERP components, the N300, and prospective positivity (West, 2011). Whereas the N300 has been associated with the detection of a prospective cue in the environment, the prospective positivity has been associated with postretrieval processes occurring after the realisation of a delayed intention (West, 2008). Some recent studies have not identified an N300 component (Wang et al., 2013; Wilson et al., 2013). This warrants investigation of whether different

types of cues might or might not be associated with an N300. The aim of the present study was to explore this question.

Initial cue detection and subsequent post-retrieval processes reflect two theoretically distinct processes inherent in PM tasks. The N300 is a negative deflection in the occipital–parietal region that emerges 300–400 ms after stimulus onset and is associated with the detection of PM cues in the context of an ongoing activity, and the prospective positivity is a positive deflection broadly distributed over central, parietal, and occipital regions of the scalp that emerges between 400 and 1200 ms after stimulus onset and is associated with the retrieval of an intended action from memory (West, 2008). The N300 is also accompanied by a frontal positivity of similar onset but longer duration that distinguishes PM cues from the ongoing task (West, 2011). In a review paper, West et al. (2000) described a programme of research supporting the specific involvement of the N300 in initial PM cue detection. PM cues could be distinguished from PM lures (stimuli that only partially fit the criteria for a PM cue), and the amplitude of the N300 was greater for correct responses to PM cues than for incorrect responses. Further studies demonstrated the N300 is elicited by PM cues defined by different attributes such as word identity and colour (West et al., 2006; West and Krompinger, 2005).

Three studies were located that did not identify an N300 component. For each of these studies the PM cue was not defined by its perceptual features, though still adhered to the general experimental PM task paradigm of embedding a PM task within an ongoing task (McNerney, 2006; Wang et al., 2013; Wilson et al., 2013). Each study used PM cues that consisted of animal words, a cue defined by its semantic category rather than its perceptual features. McNerney observed a negative deflection over the left frontal region that distinguished PM

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cues from the ongoing task. However this effect was not observed in the latter published studies of Wang et al. and Wilson et al. Since changing the nature of the PM cue from a perceptual feature of a word to a semantic feature resulted either in the absence of a discernible N300 component in the ERPs or a change in the location where an effect was observed, further investigation of the neural correlates of PM cue detection is worthwhile.

With regard to ecological validity, it seems probable that in real-world situations prospective cues encountered in the environment might not necessarily be perceptual in nature. A variety of cues might exist that differ in their nature, salience, and relation to the intended action. The extent to which the N300 and prospective positivity reflect the cognitive processes employed in these real-world contexts remains an important target for investigation. It is possible that different types of PM cues might have an effect on the ERP modulations associated with PM processes.

The general aim of this study was to investigate the effect of manipulating the nature of the PM cue on two modulations of the ERPs elicited by PM tasks, namely, the N300 component and prospective positivity. Specifically, the study aimed to directly compare the effect of using PM cues defined by perceptual or semantic features. This was achieved by employing a standard semantic judgement task as the ongoing task, then incorporating a PM component in which the PM cue differed between two groups. In the perceptual group, the PM cue was determined by colour and in the semantic group, the PM cue was determined by semantic category. Consistent with inferences derived from the reviewed literature that suggest the N300 component might only be elicited by PM tasks where the PM cue is perceptual, and that the prospective positivity is likely common to all PM tasks, it was hypothesised that the N300 component would have greater mean amplitudes for PM trials relative to ongoing trials in the perceptual condition but not the semantic condition. It was further hypothesised that the prospective positivity would have greater mean amplitudes for prospective hits relative to ongoing hits in both the perceptual and semantic conditions.

2. Method

2.1. Participants

Thirty-two individuals participated in the study. Data of four participants were excluded from analysis due to excessive EEG artefact or insufficient correct trials to produce a stable average waveform. The mean age of the remaining 28 participants (23 females) was 20.39 years ($SD = 5.06$ years). Participants were undergraduate students at Griffith University and were offered course credit for their involvement. All participants spoke English as their first language, reported no history of neurological disorder or unconsciousness following injury, and possessed normal or corrected-to-normal visual acuity and colour vision. Informed consent was sought prior to participation. The study was conducted with the approval of the Griffith University ethics committee and in accordance with the National Statement on Ethical Conduct in Research Involving Humans (NH&MRC, 2007).

2.2. Design

The experiment employed a mixed factorial design with between-subjects factor of condition (semantic, perceptual) and within-subjects factor of trial (PM, ongoing). Mean amplitudes for the time periods corresponding to the N300 and prospective positivity were measured for correct responses to PM and ongoing trials. Accuracy and RT were also measured. Electrodes and latency windows for each component were selected a priori based on previous research (West, 2007). For the N300, this included electrodes P9, Iz and P10 between 300 and 400 ms. For the prospective positivity, this included electrodes P3, Pz and P4 between 600 and 800 ms.

2.3. Materials and procedure

2.3.1. Stimuli

Word pairs were generated from 90 words selected from the Category Norms for Australians (Casey and Heath, 1988). Ten words were selected from each of nine categories. The same set of stimuli was used for each of the two groups, differing only in instructions to differentiate the semantic and perceptual conditions. Words were randomly paired within and between categories. Semantic PM trials consisted of word pairs from the animal category, where each word was randomly coloured blue, green, red, or yellow. Perceptual PM trials consisted of word pairs in which both were coloured red, with words being from either the same or different categories. Ongoing trials consisted of word pairs where each word was randomly coloured blue, green, red, or yellow and could be from either the same category or different categories so long as neither of these combinations generated a semantic or perceptual PM trial. Since the same set of stimuli was used in both experimental conditions, both types of PM cue were present in both conditions. However, from the perspective of a participant in the perceptual group, a semantic PM cue would appear to be part of the ongoing task, and vice versa for the semantic group.

Word pairs for the 540 ongoing trials were randomly generated with an equal ratio of word pairs from the same category (excluding the animal category), and word pairs from different categories. Word pairs for the 30 perceptual PM trials were randomly generated with an equal ratio of word pairs from the same category and from different categories, the colour of both words always being red. Word pairs for the 30 semantic PM trials were randomly generated with word pairs from the animal category and word colour varying randomly.

The experimental task consisted of 30 blocks of 20 trials, each block consisting of 18 ongoing trials, 1 perceptual PM trial, and 1 semantic PM trial. Perceptual and semantic PM trials were presented in varying locations within the block, but following a minimum of 10 ongoing trials. This ensured participants were fully engaged in the ongoing semantic judgement task before encountering a PM cue. An example of the stimuli and their presentation is provided in Fig. 1.

2.3.2. Procedure

Participants were randomly assigned to either the perceptual or semantic condition. Following fitting of the EEG cap and inspection of EEG signal quality, participants received written instructions that varied only in the definition of a PM cue (perceptual cue, two red words; semantic cue, two animal words). A short practice block of 20 trials containing one PM cue was then administered.

Stimuli were displayed on a 22-inch screen. Words were presented in uppercase text on a black background in Console size 40 font. For both semantic and perceptual groups, the ongoing task consisted of a semantic judgement task where participants determined whether randomly coloured word pairs, presented simultaneously and to the left and right of the screen, were from the same category or a different category. Participants responded using a keyboard by pressing “N” for words from the same category, and “M” for words from different categories. Participants were also instructed to press the “V” key whenever they encountered a PM cue (described as two red words or two animal words depending on group assignment). Participants completed 30 blocks of 20 trials, with a 10-second rest every 10 blocks to minimise fatigue.

2.3.3. Electrophysiological recording and analysis

EEG (band-pass DC – 206 Hz, digitised at 1024 Hz, 24 bit A/D conversion) was recorded continuously using the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands) from an array of 64 electrodes placed according to the standard International 10–20 Positioning System (FPz, AFz, Fz, FCz, Cz, CPz, Pz, POz, Oz, Iz, Fp1, Fp2, AF7, AF3, AF4, AF8, F9, F7, F5, F3, F1, F2, F4, F6, F8, F10, T9, T7, C5, C3, C1, C2, C4, C6, T8, T10, TP9, TP7, CP5, CP3, CP1, CP2, CP4, CP6, TP8,

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