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Electrophysiological evidence for flexible goal-directed cue processing during episodic retrieval

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ABSTRACT

A widely held assumption is that memory retrieval is aided by cognitive control processes that are engaged flexibly in service of memory retrieval and memory decisions. While there is some empirical support for this view, a notable exception is the absence of evidence for the flexible use of retrieval control in functional neuroimaging experiments requiring frequent switches between tasks with different cognitive demands. This absence is troublesome in so far as frequent switches between tasks mimic some of the challenges that are typically placed on memory outside the laboratory. In this experiment we instructed participants to alternate frequently between three episodic memory tasks requiring item recognition or retrieval of one of two different kinds of contextual information encoded in a prior study phase (screen location or encoding task). Event-related potentials (ERPs) elicited by unstudied items in the two tasks requiring retrieval of study context were reliably different, demonstrating for the first time that ERPs index task-specific processing of retrieval cues when retrieval goals change frequently. The inclusion of the item recognition task was a novel and important addition in this study, because only the ERPs elicited by unstudied items in one of the two context conditions diverged from those in the item recognition condition. This outcome constrains functional interpretations of the differences that emerged between the two context conditions and emphasises the utility of this baseline in functional imaging studies of retrieval processing operations.

Introduction

Episodic memory allows us to navigate our personal past and to recollect detailed information about specific events. Various models of episodic memory have assumed that this ability is enabled by control processes that specify and initiate memory searches, and process stimuli (either externally experienced or internally generated) in a way that maximises our ability to retrieve relevant information. Burgess and Shallice (1996) proposed a set of control processes involved in autobiographical recollection, one category of which ('descriptors') specify the memory search. Anderson and Bjork (1994) argued that recollection can be influenced by *cue bias* mechanisms which shape the nature of the memory search by influencing the way in which retrieval cues are processed. More specifically, they argued that recollection will suffer if the contextual representation specified as part of the memory search does not match the encoding context (*context bias*). In a similar vein, Mecklinger (2010) argued that cue-bias processes are applied to the internal representation of a retrieval cue in order to optimise the cue–memory trace interaction by constraining or specifying relevant cue features.

Rugg and Wilding (2000) introduced the term 'retrieval orientation' to encapsulate the concept that participants can adopt and maintain episodic retrieval sets that influence the processing of retrieval cues in ways that depend upon the specific retrieval requirements. They argued that contrasting neural activity elicited by unstudied items across memory tests that differ in their retrieval requirements will reveal differences in cue processing that are the consequences of having adopted content-specific orientations (for earlier related work, see Johnson et al., 1993; Wilding, 1999). One of the strengths of this contrast is that differences due to retrieval orientations are not confounded with differences between retrieved content, and this account has influenced a large number of studies designed to understand retrieval cue processing and its neural basis in a series of ERP (Robb and Rugg, 2002; Herron and Rugg, 2003; Hornberger et al., 2004, 2006a; Ranganath and Paller, 1999, 2000; Dzulkifli et al., 2004; Dzulkifli and Wilding, 2005; Bridger et al., 2009; Rosburg et al., 2011, 2013, 2014; Roberts et al., 2014) and fMRI studies (Hornberger et al., 2006b; Woodruff et al., 2006; Morcom and Rugg, 2012). Furthermore, there is evidence that these task-dependent differences in cue processing are associated both with increases in retrieval accuracy (Bridger et al., 2009; Bridger and

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Mecklinger, 2012; Roberts et al., 2014) and with the strategic recollection of task relevant information at the expense of less relevant information (e.g. Herron and Rugg, 2003; Dzulkifli and Wilding, 2005; Morcom and Rugg, 2012). It is therefore reasonable to assume that these effects index processes that influence memory retrieval directly.

One important finding that has been replicated in a number of ERP studies is that task-dependent differences in cue processing have only been observed when retrieval demands are blocked (i.e. when the entirety of each memory test retains the same retrieval demands), and that they are eliminated when participants are asked to make frequent switches between different memory tasks (Wilding and Nobre, 2001; Herron and Wilding, 2006; Johnson and Rugg, 2006; Werkle-Bergner et al., 2005). Wilding and Nobre (2001) asked participants to make Remember/Know judgments on the basis of whether they could remember either phonological or imagery-based associates from encoding, and found neural differences between correct rejections (correctly identified unstudied items) in the two tasks when they were blocked and not when they were mixed. Herron and Wilding (2006) cued participants trial-by-trial to make source memory decisions regarding either study location or encoding task, and found differences between correct rejections only when the tasks were predominantly blocked and not when they alternated frequently. Werkle-Bergner et al. (2005) reported task-dependent ERP differences between correct rejections in a general recognition task and a specific task regarding stimulus font when these tasks were blocked but not when they were mixed. Finally, Johnson and Rugg (2006) cued participants before each test item to identify whether the item had been studied either as a word or as a picture (different elaborative encoding tasks were also completed according to stimulus material), and found differences between correct rejections when these requirements were blocked as opposed to mixed. It has been stated on the basis of these consistent findings that retrieval orientations 'develop over multiple trials and cannot be adjusted merely in response to an instructional cue' (Johnson & Rugg, 2006, pp. 1531) and that 'participants are unable to adjust their retrieval orientation on a trial by trial basis' (Roberts, Tsivilis & Mayes, 2014, pp. 124).

The possibility that the engagement of certain classes of retrieval control process takes a number of trials to develop might be regarded as counter-intuitive, given that memory retrieval is something that is commonly accomplished among and in parallel with other cognitive tasks. Requirements to switch frequently between tasks, therefore, bear at least some similarities with the circumstances under which memory is often used. Moreover, the absence of ERP evidence of this kind is at odds with evidence from other sources that memory control processes are highly flexible. ERPs elicited by preparatory cues that direct participants to prepare to retrieve specific information about upcoming test items vary markedly despite frequent switches between cue-types (Herron and Wilding, 2004, 2006). Moreover, Ecker and Zimmer (2009) reported that ERP correlates of familiarity were modulated by general versus specific retrieval orientations in a task-switching paradigm, and Koutstaal (2006) reported behavioural evidence that participants could flexibly switch between gist-based and specific retrieval orientations when cued trial-by-trial. These findings are consistent with the view that retrieval cues are subject to task-specific processing to some degree in task-switching paradigms. It is possible that ERP studies have thus far failed to detect these differences because they tend to be smaller in magnitude in mixed than in blocked paradigms.

This study was designed to maximise sensitivity to ERP differences in task-dependent retrieval cue processing within a task-switching paradigm. In order to enhance the likelihood of detecting differences elicited by ERPs associated by unstudied test items, retrieval of very different kinds of information was emphasised in two retrieval tasks. One task required the retrieval of elaborative encoding operations whereas the other required the retrieval of perceptual location-based information. This was the same task pairing used by Herron and Wilding (2006), but the paradigm was modified to further constrain participants' retrieval orientations. Preparatory cues started each test trial and varied frequently. The preparatory cues took the form of specific questions regarding encoding context which required simple yes/no answers. This was the approach taken by Johnson and Rugg (2006), but we predicted that combining this form of targeted cue with a pair of retrieval tasks that were more polarised in their contents would increase the likelihood of detecting evidence for flexible task-dependent cue processing.

A further development is the inclusion of a third task requiring item recognition only. A pairwise contrast between ERPs elicited by unstudied items in two specific retrieval tasks does not allow differences observed between the two to be ascribed to a particular task, or to determine whether the differences reflect the engagement of qualitatively different processes (indicative of content-specific processing) or quantitative differences between the same operations that are engaged across the two tasks (see Bridger et al., 2009; Bridger and Mecklinger, 2012; Roberts et al., 2014). Employing a general recognition baseline offers the potential for additional insights into the locus and the functional nature of differences detected between the two specific tasks, the assumption being that there is not an incentive to focus on specific contextual details to the same extent in the recognition task as in the other tasks.

Finally, the paradigm will also allow us to examine ERPs that index processes linked to the adoption of retrieval orientations. This will be achieved by time-locking ERPs to the onset of the preparatory cues indicating which retrieval task to complete (Herron and Wilding, 2004, 2006). In direct contrast with the circumstances under which ERPs elicited by correct rejections have tended to differ, divergences between the ERPs elicited by these cues have been observed when retrieval tasks vary frequently, and not when retrieval tasks are blocked (Herron and Wilding, 2006). These outcomes suggest that the ERPs elicited by different preparatory cues should diverge in this experiment, and if this is accompanied by divergences between the ERPs elicited by new test items, it would offer – for the first time – an opportunity to consider the correspondence between neural signatures of two classes of process linked to retrieval orientations: those engaged during their adoption, and those that are a consequence of an orientation having been adopted.

Material and methods

Participants

Data from 16 participants (14 female) were included, and data from a further 3 participants were excluded because they failed to contribute at least 16 artefact free trials to the conditions of interest. All participants were right-handed native English speakers aged 18–22 (average 20 years). They were paid at a rate of £7.50/h and gave informed consent before participating.

Design

Stimuli were 288 visually presented words (frequency range of 1–10/million, MRC psycholinguistic database, Coltheart, 1981). Each experiment list comprised twelve study-test cycles. Twelve items were presented at study in each cycle, and these were repeated during the subsequent test phase together with a further twelve unstudied items. No items were repeated across cycles. During each study phase, words were blocked into groups of 6. Words in one block required animate/inanimate judgments, while words in the other block required indoor/outdoor judgments. The presentation order of these encoding tasks was counterbalanced. In addition, half of the study words in each block were presented to the left of fixation and half to the right. During each test phase, test items were preceded by preparatory cues which directed participants to prepare to make yes/no memory decisions about the upcoming test item. Two of these cues required participants to retrieve information regarding encoding operations ('Animacy?' and 'In/Out?'), two required them to retrieve information regarding encoding location ('Left?' and 'Right?') and a fifth cue required a recognition judgement ('Old?'). Operations cues