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Research Report

The control of memory retrieval: Insights from event-related potentials

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Abstract

Effective performance on episodic retrieval tasks requires the ability to flexibly adapt to changing retrieval demands ('retrieval orientations'; [M.D. Rugg, E.L. Wilding, Retrieval processing and episodic memory, Trends Cogn. Sci. 4 (2000) 108–115]). We used event-related potentials (ERP) to examine whether maintaining a specific retrieval orientation and changing flexibly between different retrieval demands are mediated by the same brain systems or whether dissociable aspects of cognitive control are involved. Sixteen participants performed two recognition memory tasks. One required mere old/new decisions for words (general task), whereas the other task required the additional retrieval of each word's study font typeface (specific task). Furthermore, the participants either were asked to perform the same task continuously or to switch between the two tasks after every second test word. ERPs elicited by correctly rejected new (unstudied) words were analyzed. This enabled us to examine the ERP correlates of having adapted and maintained a task instruction as required during continuous blocks and of flexibly changing between retrieval demands during alternating blocks. The ERP analysis revealed more positive-going ERP slow waves for alternating blocks than for continuous blocks over bilateral frontal recording sites. This effect started around 250 ms after the test word and extended for several hundred milliseconds. As it was present for trials requiring a switch to the other task or to stay on the same task between 500 and 750 ms and no differences between the latter two trial types were obtained, it can be assumed that it is more related to general coordination requirements in alternating blocks, rather than to the actual control required to switch the retrieval task set. In addition, contrasting ERPs for the two task types revealed more positive-going ERP slow waves in the specific task than in the general task in the continuous blocks at lateral frontal recording sites between 250 and 700 ms. Together, these findings suggest that there are electrophysiologically dissociable aspects of cognitive control, namely for adapting and maintaining a retrieval orientation and for flexibly changing between varying retrieval demands.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Cognitive control; Episodic memory; Event-related potentials; Retrieval orientation; Slow waves; Task switching

1. Introduction

It is widely accepted in neuroscientific research that episodic memory retrieval is controlled by strategic processes such as the initiation of specific search operations, the adaptation of response thresholds, and the enabling of post retrieval evaluation of memory products [19,29,33,38,50]. Neuropsychological studies [53,54] as well as functional brain imaging studies [5,41,42,51,52] suggest that the prefrontal cortex (PFC) plays an important role in the control of episodic memory retrieval. For example, patients with lesions restricted to the frontal lobes show a distinct pattern of memory deficits in the sense that they are less impaired in simple item recognition than in free recall or in source memory tasks [10,14,15,18,53]. These latter tasks require the ability to initiate strategic search operations

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and to evaluate retrieved information in order to determine the memory's source or to make appropriate judgments about the temporal order of past events [20,33]. This view is consistent with neurocognitive models of cognitive control that assume that the PFC exerts control by means of bias signals modulating information processing in more posterior association areas [7,30,47]. Furthermore, a number of fMRI results demonstrated that different aspects of episodic memory control are mediated by distinct areas within the PFC. The site of PFC activation depends on the type of processes (e.g., encoding or retrieval), the type of material (e.g., verbal, visual, or spatial) and the specific demands of the memory task (for reviews, see [8,9,34,35,38]).

Recently, Ranganath and colleagues [39–41] conducted a series of ERP and fMRI experiments that showed the importance of the left lateral PFC for the control of memory retrieval. In a modified recognition memory paradigm, the authors varied the amount of perceptual information of line drawings to be retrieved from episodic memory. During the study phase, the participants had to encode pictures of different objects. The test phase included size-changed versions of previously studied objects as well as old unchanged and new unstudied objects. In a "general" memory test, participants had to indicate whether each presented object was "old" or "new" irrespective of size changes. In a "specific test," the participants should respond "old" only to previously studied objects of unchanged size and "new" to all other objects. Comparing ERPs elicited by correct rejections of new items in blocks with the general and specific memory test, Ranganath and Paller found more positive going waveforms for specific test items than for general ones at left anterior–frontal recording sites starting around 300 ms after onset of the test stimuli [39], A topographically similar, though less left lateralized effect was obtained in a follow up study [40]. A subsequent fMRI study using an analogous experimental design confirmed these findings in showing a region within the left anterior–frontal PFC that was significantly more active in specific test trials than in general test trials [41]. The authors concluded that the (left) anterior PFC is important in allocating processing resources to retrieve perceptual detailed information and to maintain this information in working memory in order to evaluate a possible match with the results of memory retrieval.

According to a recently proposed taxonomy of control processes relevant for memory retrieval, such processes can be conceived as 'retrieval orientation' [45,56,57]. The term 'retrieval orientation' refers to the adaptation of a tonically maintained retrieval strategy that modulates the cognitive processes that are set in train in response to a retrieval cue. The initiation of such task-specific retrieval strategies enables successful memory performance as they allow that different aspects of memory representations are accessed upon presentation of one and the same cue and that different amounts of information are retrieved in pursuit of accurate memory judgments [45]. One way to examine these strategic memory processes is to examine ERPs to correctly rejected new items and varying which aspect of the encoded information is relevant to the retrieval task. In this framework, ERPs to correct rejections are assumed to reflect the consequences of having adapted a particular retrieval orientation, unconfounded by neural activity related to successful retrieval. The abovementioned findings by Ranganath and Paller suggest that neural activity in the anterior PFC is relevant for the adaptation and maintenance of retrieval orientations in the service of successful memory performance.

In addition, there is increasing evidence for an anterior–posterior distinction within the PFC with respect to cognitive control processes [5,6,24,51]. On the basis of these findings, it has been suggested that posterior–frontal regions are involved in context-specific control processes required for the selection of representations according to external, contextual signals. Conversely, anterior regions within the PFC contribute to episodic control processes required for the selection of representations according to the temporal episode in which stimuli occur. These latter processes generalize across informational domains and adjust and integrate processing according to higher-order task goals [23,24,51].

A number of studies in recent years have demonstrated that the ability to switch between different task instructions is associated with switch costs in terms of longer reaction times and higher error rates compared to trials that demand for the repeated execution of the same task [1,17,26,31,43,49]. Switch costs were assumed to reflect cognitive control processes that initiate and configure the cognitive system in order to adopt to a new 'task set' [31,44] or to inhibit persisting activation of the previous 'task set' [1,59]. In this sense, a 'task set' can be "assumed to specify the configuration of perceptual, attentional, mnemonic and motor processes critical for a particular task goal" [[27], p. 5]. Longer reaction times and higher error rates that result from shifting from one task to the other one can be thought of as the costs to establish flexibility on the level of cognitive control [1,4,26,27]. The observation that switch costs are reduced but still present even when tasks alternate in a completely predictable manner and/or task-specifying information is given prior to the task stimulus suggests that a task set cannot be activated in advance, i.e., at some point in the previous trial, but rather is initiated by task onset [44] Therefore, it is reasonable to assume that some of the mechanisms, associated with the affordance to reconfigure the task set at hand, take place in the post-stimulus epoch [1]. Experimental paradigms that compare the repeated performance of the same task with alternated execution of different tasks are therefore useful in measuring the effects of the need to adapt to changing task demands [25].

Ranganath and colleagues found electrophysiological and hemodynamic correlates of the ability to maintain retrieval orientations in bilateral PFC regions. Still an open