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ERP ‘old/new’ effects: memory strength and decisional factor(s)

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Abstract

Event-related potentials (ERPs) were recorded while subjects made old/new recognition judgments on new unstudied words and old words which had been presented at study either once (‘weak’) or three times (‘strong’). The probability of an ‘old’ response was significantly higher for strong than weak words and significantly higher for weak than new words. Comparisons were made initially between ERPs to new, weak and strong words, and subsequently between ERPs associated with six strength-by-response conditions. The N400 component was found to be modulated by memory trace strength in a graded manner. Its amplitude was most negative in new word ERPs and most positive in strong word ERPs. This ‘N400 strength effect’ was largest at the left parietal electrode (in ear-referenced ERPs). The amplitude of the late positive complex (LPC) effect was sensitive to decision accuracy (and perhaps confidence). Its amplitude was larger in ERPs evoked by words attracting correct versus incorrect recognition decisions. The LPC effect had a left > right, centro-parietal scalp topography (in ear-referenced ERPs). Hence, whereas, the majority of previous ERP studies of episodic recognition have interpreted results from the perspective of dual-process models, we provide alternative interpretations of N400 and LPC old/new effects in terms of memory strength and decisional factor(s).
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1. Introduction

A common finding of many event-related potential (ERP) studies of recognition memory is that presentation of old/repeated items elicits more positive-going ERPs than does presentation of new/unrepeated items (reviewed in [23,34,35]). Such ERP ‘old/new effects’ typically onset approximately 300–400 ms post-stimulus, last 300–600 ms and, when words are used as stimuli, are generally of greatest magnitude at left parietal and adjacent centro-parietal electrodes. On the basis of differing scalp topographies (e.g. [43]) and differential sensitivities to manipulation of a number of experimental variables (e.g. word frequency and repetition lag [33]), ERP old/new effects are now assumed to comprise dissociable early and late effects which reflect the modulation of the N400 and a subsequent late positive component (or complex). There are incongruities in the literature over the name given to this late positive component of the ERP old/new effect with P3, P300, P600 and late positive complex (LPC) having been used by different authors. Without attempting to resolve the issue of whether or not these labels all represent the exact same entity, the term LPC will be used here in reference to this ERP component. Further support for the N400-LPC old/new effect distinction is provided by evidence from a number of intracranial ERP studies (e.g. [13]) which indicate that the N400 and LPC are generated by different neural populations.

Over the past decade most authors have interpreted ERP old/new effects from the perspective of dual-process models (e.g. [19,27]) of recognition memory. Generally, these models stipulate that recognition comprises familiarity which is often assumed to be a context-insensitive, automatic process bereft of the phenomenological experience of remembering; and recollection, a context-sensitive, strategic, recall-like process involving the conscious retrieval of specific information about the encoding episode. Attempts to relate components of ERP old/new effects to putative familiarity and recollection processes have sometimes possessed low discriminatory power, and must still be considered speculative until further supporting evidence is obtained. It is also noteworthy that some authors have concluded that results from a number of ERP studies of episodic memory provide scant support for dual-process models [35]. Furthermore, these

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models have been found to be unsatisfactory on a number of grounds (e.g. [17]) and alternative approaches have been posited (e.g. [10,18]). Thus, while the results of many ERP studies of episodic recognition have been interpreted in the context of dual-process models, alternative memory models warrant further consideration in the interpretation of ERP old/new effects.

It has been proposed that a N400 component in ERPs recorded at parietal electrodes is sensitive to implicit memory processes [41], and also that it is unlikely that the N400 old/new effect reflects activity associated with the explicit discrimination of old from new items [23,34]. The latter proposal was made on the basis of the failure of a number of investigations to obtain an N400 old/new effect when the study-test interval exceeds some time between 2 and 15 min (e.g. [25,37]). In addition, a N400-like component with a more frontal distribution, the 'FN400' (following [6]), has been proposed to index familiarity [6,7,41]. However, as noted above, ERP data need not be associated with approaches that distinguish between putative familiarity and recollection processes. For example, an alternative framework is provided by global matching models [16] which assume that the recognition decision is based on the summed strength of all matches between the cue(s) and all traces in a single global memory system. Separate episodic and non-episodic systems are not proposed. Instead the memory system can be cued with both item and contextual information so in contrast to the concept of familiarity the matching operation is generally thought to be context-dependent. Some memory models propose a relatively rapid change of contextual representations over time [15]. Thus, the observed susceptibilities to temporal decay of single item recognition performance (e.g. [14]) and of the N400 old/new effect, may be the consequences of such contextual change. The strength of the global match is a continuous variable, and the same is often thought to be true of dual-process familiarity (e.g. [55]). We will hereafter refer to any such continuous or graded variable (as distinct from a categorical variable, such as recollection) as strength. Differences between this and other notions of familiarity will be highlighted where appropriate. Within the global matching framework a decision criterion is set, as in signal detection theory (SDT) [45], such that strengths above the criterion will result in an old response whereas those below will produce a new response. Proponents of global matching models would thus predict that at least some component of the ERP old/new effect reflects the strength of the memory trace and of the matching operation.

In contrast to the N400, the LPC old/new effect has reliably been observed after longer study-test intervals and is broadly considered to be reflective of long-term episodic recognition processes [23,34]. Indeed the LPC old/new effect has been linked to the recollection component of dual-process recognition models (reviewed in [2]). Alternative interpretations of the cognitive processes reflected in the LPC old/new effect have also been posited. Some have proposed that LPC peak amplitude reflects memory trace strength [5], others discriminability [24], or decision accuracy and/or confidence (e.g. [24,26,28,30,32,46]). Within the SDT framework confidence is conceptualized as distance from the response criterion. Hence it appears that LPC amplitude is potentially influenced not purely by items' old/new status but also by a number of variables incorporating strength, the position of the response criterion, and consequently recognition performance. So a simple old/new (much less, hit-correct rejection) ERP comparison cannot adequately address this issue, as old/new effects may reflect differing levels of item strength or confidence. The effect may also potentially reflect response-related processes when ERPs are conditionalized on response and ERPs associated with differing responses are compared (although there is some evidence that this is not the case, e.g. [38]). Moreover an old/new ERP comparison wherein only correct response trials are chosen for averaging is prone to contamination by item selection artifacts, as only a subset of all available old/new items are considered for comparison.

Thus, we employed a strength manipulation: half of the study words were presented once ('weak') and half presented three times ('strong'), a procedure which provides three distinct levels of strength (new, weak, strong) at test. Excluding repetitions in continuous tasks, the only previous reported examinations of ERPs evoked by words which had already been repeated within a different phase of the experiment were those of Bentin and co-workers [3,5]. However, in those experiments, words were presented first in a study list (and categorical decisions made), second during an episodic recognition task, and for a third time in a subsequent implicit memory task. Here we compare ERPs elicited during an explicit episodic recognition test by words which were new, or which were presented once or thrice in a previous study list. For this new–weak–strong ERP comparison, all available items are considered so this comparison is not subject to item selection artifacts.

Despite the large body of literature investigating ERP old/new effects over the past two decades, most studies have not examined in detail ERPs accompanying erroneous new and old responses (misses and false alarms, respectively). Indeed some authors have concluded that the effects are not found for incorrect recognition judgments to either old or new words (e.g. [1,53,54]). However, visual inspection of ERPs in those papers which have illustrated error response ERPs suggests that this may be an oversimplification, with different ERP patterns evidently obtained between N400 and LPC old/new effects, and between frontal and posterior electrodes. For example, in the results of Rugg et al. [41] (Fig. 1), Wilding et al. [51] (Fig. 3) and Wilding and Rugg [53] (Fig. 2) ERPs for misses exhibited an apparent N400 (but not LPC) old/new effect, at parietal (but not at frontal) electrodes. Van Petten and Senkfor [48] (Figs. 5 and 6) obtained false alarm ERPs which exhibited an apparent N400 old/new effect relative to correct rejection ERPs. Whereas, LPC amplitudes in correct rejection ERPs have

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