Late frontal brain potentials distinguish true and false recognition

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Brain potentials associated with true and false recognition were recorded using a paradigm consisting of categorized color photographs. Two ERP components were identified. A parietal component was most positive for both true and false recognition, less positive for rejection of lures, and least positive for rejection of novel items. A later frontal component was more positive for false recognition, rejection of lures, and misses than for true recognition and rejection of novel items. The authors suggest that the parietal component may reflect the extent to which test items engender recollection of the gist representation of the study list, while the late frontal component may reflect the engagement of effortful post-retrieval processes. *NeuroReport* 14:1717–1720 © 2003 Lippincott Williams & Wilkins.

Key words: ERPs; Event-related potentials; False memory; False recognition; Frontal activity; Gist; Memory; Photographs

INTRODUCTION

False recognition of non-studied items that are related to studied items (lures) has recently been used to understand memory in healthy [1] and memory-impaired populations [2,3]. Event-related potential (ERP) studies of false recognition have identified a parietal component (~300–800 ms) believed to reflect brain processes related to recollection [4–9], and a late, frontally based component (~800–2000 ms) thought to reflect post-retrieval processing when the contents of memory must be evaluated for particular features, source information, and other details [5,6,9–13].

Curran and colleagues [5] found greater late frontal positivity for studied and semantically related lure words compared to new words for good performers. The authors suggested that these subjects engaged in post-retrieval evaluation processes when considering studied and lure words, but that such processing was not necessary for rejection of new words. To evaluate further the role of the late frontal effect, we used a false recognition paradigm consisting of categorized color photographs. Such stimuli have the advantage of being able to engender vivid, detailed memories in false recognition paradigms [14,15], more so than the words and black and white line drawings used previously in ERP false-recognition studies. We predicted that using a false-recognition paradigm of color photographs would allow participants to correctly identify studied items and reject novel items without engaging in post-retrieval processes, but that such processes would still be needed when considering lure items. We also expected that the parietal component would reflect recollection of the retrieved memory trace.

SUBJECTS AND METHODS

Written informed consent was obtained in 23 healthy right-handed participants (10 female; mean age 22 ± 2 years) who were paid \$25/h. The study was approved by the human subjects committees of Harvard University, Cambridge, MA, and Brigham and Women's Hospital, Boston, MA. Two participants were excluded as outliers due to poor behavioral performance and one due to technical difficulties.

Stimuli consisted of 25 categories of 21 colored photographs each (e.g. cars, dogs) [16]. At study, 12 pictures from each category were intermixed and presented in a pseudorandom order on a color monitor for 1.5 s, followed by a 500 ms interval. A + sign then prompted a like/dislike judgment by joystick, followed by a 500 ms interval before the next trial. Participants studied list A or B, counterbalanced such that items presented at study to group A were lures to group B, and vice versa. There were six blocks of 50 pictures.

At test, participants saw 500 pictures (nine of 12 studied items, nine related lures from each category, and 50 unrelated novel pictures). Each item followed a 750 ms fixation point and was presented for 1.5 s, followed by a 500 ms interval. A + sign prompted a yes/no button press to the question: Did you see this picture before during the study phase?, followed by a 500 ms interval before the next trial. There were 10 blocks of 50 pictures.

ERPs were recorded at test from 29 scalp sites: three midline (Fz, Cz, Pz) and 26 lateral (arranged in four coronal rows from anterior to posterior: (a) F7/8, AF7/8, FP1/2; (b)T3/4, FC5/6, F3/4, FC1/2; (c)CP5/6, C3/4, CP1/2; (d)T5/6, P3/4, O1/2). The electrodes were referenced to the left mastoid; impedances were reduced to $< 15\,k\Omega$. Electrodes were placed below the left eye (LE) and at the lateral canthi of both eyes (HE) to monitor for eye blinks and horizontal movements. The ERPs were amplified, and 2500 ms of recorded data was digitized (100 Hz) beginning 100 ms before stimulus onset. Trials with amplifier blocking or eye movements were excluded; those with blinks were corrected [17].

RESULTS

Participants made more yes responses to studied items (true recognition, 0.69) than to lures (false recognition, 0.31; $t(20) = 13.90$, s.e.m. $= 0.03$, $p < 0.001$), and more yes responses to lures than to novel items (unrelated false alarms, < 0.01; $t(20) = 11.75$, s.e.m. $= 0.02$, $p < 0.001$).

ERPs were computed for the studied-yes, lures-yes, studied-no, lures-no, and novels-no conditions. Because there were no hemispheric interactions, only the midline analyses are presented. For brevity, only significant main effects of item, main effects of response, and interactions with electrode are reported. The Greenhouse–Geisser procedure was used for all ANOVAs with greater than one numerator degree of freedom. The time periods analyzed (250–600 and 1000–2000 ms) were chosen in order to capture the standard parietal and late frontal components identified previously [5,12]. In order to best capture differences between item types, mean ERP amplitude was measured over the first interval and positive peak amplitude over the second interval.

In the first interval an item (studied-yes, novels-no) × electrode (Fz, Cz, Pz) ANOVA was performed to confirm that the old/new effect reported in previous ERP studies of recognition memory [5,6,9,12] was present in our study. This revealed an effect of item ($F(1,19) = 8.93$, MSE $= 5.22$, $p = 0.008$) and an item × electrode interaction ($F(2,38) = 13.06$, MSE $= 0.97$, $p < 0.0005$), which *post-hoc* *t*-test shows is due to studied-yes being more positive than novels-no at Cz ($t(19) = 2.63$, s.e.m. $= 0.46$, $p = 0.017$) and Pz ($t(19) = 6.05$, s.e.m. $= 0.38$, $p < 0.0005$) but not Fz (Figs. 1a and 2a). Lures-yes were also more positive than novels-no at Cz and Pz as demonstrated by an analogous ANOVA (item: $F(1,19) = 6.69$, MSE $= 9.45$, $p < 0.0005$; item × electrode: $F(2,38) = 14.15$, MSE $= 1.44$, $p < 0.0005$) and *t*-tests (Cz: $t(19) = 2.83$, s.e.m. $= 0.53$, $p = 0.011$; Pz: $t(19) = 4.09$, s.e.m. $= 0.65$, $p = 0.001$). Lures-no were more positive than novels-no at Pz (item × electrode: $F(2,38) = 6.74$, MSE $= 0.85$, $p = 0.002$; Pz: $t(19) = 3.59$, s.e.m. $= 0.31$, $p = 0.002$; Fig. 1). Comparisons between studied-no and novels-no yielded an item × electrode interaction ($F(2,38) = 9.58$, MSE $= 0.94$, $p = 0.002$), although the *t*-tests did not reach significance. Figures 1b and 2b show that yes items (studied-yes and lures-yes) were more positive than no items (studied-no and lure-no) in the first interval. An item (studied, lures) × response (yes, no) × electrode (Fz, Cz, Pz) ANOVA demonstrated an effect of response ($F(1,19) = 16.95$, MSE $= 5.05$, $p = 0.001$). No other effects or interactions reached significance.

In contrast to the first interval, there were no differences between studied-yes and novels-no in the second interval (Fig. 1a). The lures-yes, lures-no, and studied-no conditions show comparable positivity, which is greater than that of the studied-yes condition at Fz (Figs 1b and 2c). An item (studied, lures) × response (yes, no) × electrode (Fz, Cz, Pz) ANOVA showed item × response ($F(1,19) = 6.01$, MSE $= 14.89$, $p = 0.024$) and item × response × electrode

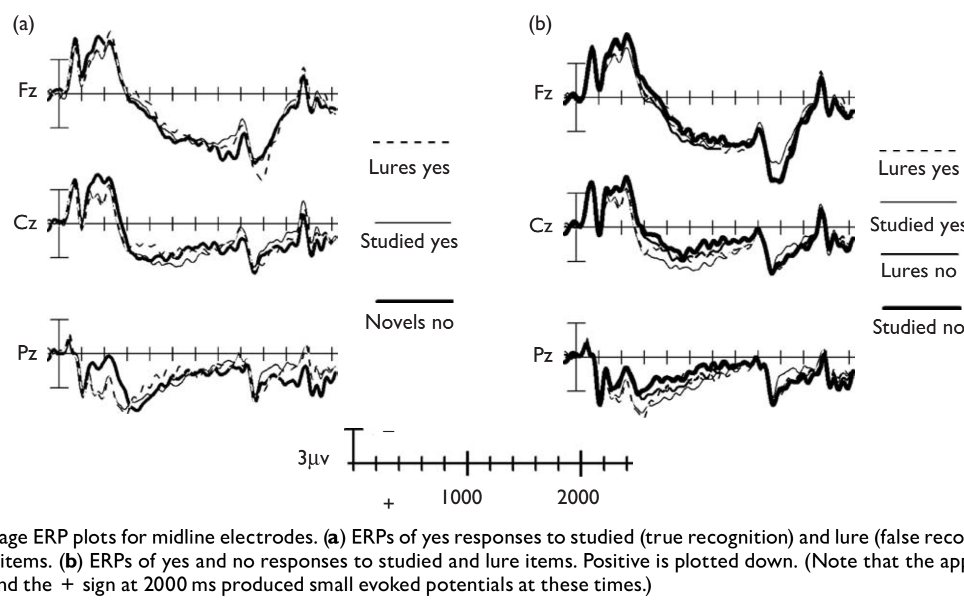

Fig. 1. Grand average ERP plots for midline electrodes. (**a**) ERPs of yes responses to studied (true recognition) and lure (false recognition) items, and no responses to novel items. (**b**) ERPs of yes and no responses to studied and lure items. Positive is plotted down. (Note that the appearance of the blank screen at 1500 ms and the + sign at 2000 ms produced small evoked potentials at these times.)

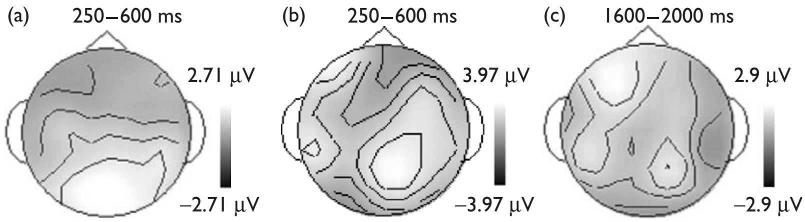

Fig. 2. Topographic distributions of primary ERP differences between selected conditions. (**a**) Yes responses to studied items minus no responses to novel items at 250–600 ms. (**b**) Yes responses to studied and lure items minus no responses to studied and lure items at 250–600 ms. (**c**) Yes responses to lure items (false recognition) minus yes responses to studied items (true recognition) at 1600–2000 ms.

interactions ($F(2,38) = 3.98$, $MSE = 2.26$, $p = 0.034$), and no effects of item or response. *Post-hoc* tests showed that lures-yes was more positive than studied-yes ($F(1,19) = 8.20$, $MSE = 8.45$, $p = 0.010$), and an item × electrode interaction ($F(1,19) = 3.42$, $MSE = 2.15$, $p = 0.047$) was present because the difference between these items was larger in Fz than either Cz ($t(19) = 2.19$, s.e.m. $= 0.703$, $p = 0.041$) or Pz ($t(19) = 2.05$, s.e.m. $= 0.632$, $p = 0.054$; which did not differ). No other comparisons reached significance, although there were trends for studied-no being more positive than studied-yes at Fz ($t(19) = 1.98$, s.e.m. $= 1.20$, $p = 0.063$), and lures-yes being more positive than lures-no ($F(1,19) = 3.46$, $MSE = 11.40$, $p = 0.079$).

DISCUSSION

Waveforms in the first interval showed the standard old/new effect, with studied-yes ERPs being more positive than ERPs to novels-no at Pz, consistent with other studies [5,6,12]. There were no ERP differences between true (studied-yes) and false (lures-yes) recognition or between correct and incorrect rejection of lure and study items. Instead, yes responses were more positive than no responses regardless of item type. Thus, it appears that the parietal component corresponds to processes underlying recognition, regardless of whether that recognition is true or false. Since it is unlikely that the specific lure photographs would spontaneously come to mind as implicit associative responses during the study session (as may occur in paradigms using semantically related words), other explanations must be sought as to why true and false recognition should be the same in this first period.

Previous research has suggested that the parietal old/new effect is related to recollection [4–9,12]. The present results suggest that recollection was present to a similar degree for both correctly and falsely recognized pictures. This raises an important question about the nature of the information that was falsely recollected. One possibility is that false recollection reflects the retrieval of features that are present in both studied and lure pictures (e.g. a white sail on multiple sailboats). Such features could be truly recollected, but would not be diagnostic for separating true from false memories [18]. A second intriguing possibility is that the general meaning, idea, or gist of the categorized items [19,20] is recollected. Pictorial gist information is formed during study from the conceptual and perceptual similarity among studied items. In this experiment, the similarity among stimuli in each category likely enhanced gist formation during study, leading to recollection of a robust gist representation by both studied and lure items at test. This interpretation is consistent with work by Nessler and colleagues [9], who found that ERPs were more similar for true and false recognition when gist influences were increased by encoding instructions focused on conceptual similarity than when instructions focused on item-specific features.

Although it may seem natural to associate gist information with the familiarity component of dual-process recognition memory theories [12,21], the idea that gist information may be associated with recollection in specific circumstances may help to reconcile certain apparent contradictions in the literature. For example, hippocampal activation has been suggested to occur only when retrieval is accompanied by conscious recollection [22,23], yet true and false recognition of lists of semantic associates have been associated with equal hippocampal activation [24]. Exactly what is recollected when gist information is retrieved is a difficult question. While this question will need to be addressed in further studies, one potential answer combines the two possibilities raised above. That is, the gist representation itself may consist of the collection of overlapping features, whether semantic or perceptual, that are present in the items seen during the study session. This collection of features may then be recollected when a similar (but non-studied) lure item is encountered on the recognition test.

Waveforms in the second interval at frontal leads corresponding to recognition and rejection of studied and lure items patterned differently than in the first interval. Here the lures-yes, lures-no, and studied-no conditions show comparable positivity, which is greater than that of the studied-yes condition (Figs. 1b and 2c), and studied-yes and novels-no showed comparable positivity (Fig. 1a). Thus, as predicted, participants were able to correctly reject novel items and identify studied items without increased late frontal positivity, suggesting that post-retrieval processes were less involved in these decisions than when considering lure items (which showed relatively greater positivity). We suggest that in false recognition paradigms subjects engage in post-retrieval processes when old/new discrimination is difficult because the retrieved memory trace of the item is weak. This suggestion is supported by the finding that incorrectly rejected study items show comparable positivity to lure items, and by the work of Rugg *et al.* [25], who found that old/new effects for shallowly studied words were confined to late frontal differences. Thus, in our study the parietal component identified in the first interval may reflect recollection of gist information, whereas the late frontal component in the second interval may reflect engagement of post-retrieval processes related to attempted recollection of the individual item.

CONCLUSION

Our results support the view that late frontal positivity in false recognition studies represents post-retrieval processes that are engaged whenever participants experience difficulty making old/new decisions. Decisions which can be made easily because of either a complete lack of recollection (as in the rejection of the novel items) or clear recollection (as in the recognition of the study items in this picture paradigm) thus require less post-retrieval processing than decisions that are more difficult because they are associated with weak recollection (as in the consideration of the lure items and the incorrect rejection of the study items).

By contrast, the earlier parietal component may be a measure of the extent to which the test item engenders recollection of the gist representation built up by the subject during the study session-regardless of whether the item was studied or not. Future studies using categorized pictures that manipulate item similarity or category size may further elucidate the nature of gist memory, the recollection of this information, and the role of post-retrieval processes in recognition memory.

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