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Research Report

Identifying the ERP correlate of a recognition memory search attempt

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Abstract

Previous recognition memory studies have looked for differences in brain activity during recollection- and familiarity-based responding. Although an ERP component correlated with recollection success has been reported, no analogous component related to search initiation has been found. We argue that such a component has not been discovered because studies have compared trials in which participants have made a search attempt and failed (such as Know responses) with those in which the search attempt is successful (such as Remember responses). In the current study, we compared a task that required judgments of lifetime familiarity (differentiating famous from nonfamous names) with one that required judgments of episodic information (deciding whether a name was seen previously in the experiment). By comparing a task on which familiarity judgments were made with no search attempt to a second task in which a search attempt was likely to occur, we identified a component that may reflect the initiation of a memory search. This effect, maximal between 190 and 235 ms, is correlated with Old judgments in the episodic task. Previous ERP findings (e.g., FN400, parietal old/new effect) were also replicated in the present study.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Recognition memory; Search process; Recollection; Familiarity

1. Introduction

Both behavioral and brain imaging experiments have investigated the processes used in making recognition memory decisions. These lines of research have led to a distinction between theories claiming that recognition is based on a single familiarity process [9,18] and theories claiming it is based on dual processes of familiarity and recollection [14,24]. The familiarity process is thought to involve a single dimension of familiarity along which decisions are made based on the relative familiarity of test items. The recollection process is similar to the process of cued recall, where the information presented at test provides a cue to search memory for confirmation of episodic recognition. While behavioral evidence has been used to argue for both single and dual process models, studies using cognitive neuroscience methodologies such as event-related brain potentials (ERPs) tend to implicate the inclusion of a recollection process in recognition. This question of single vs. dual process is important for understanding memory encoding and retrieval in general.

The first ERP studies of recognition memory identified differences between the processing of items at test that were correctly recognized as Old and those that were correctly recognized as New. Beginning between 300 and 400 ms after stimulus presentation, old words show a more positive ERP waveform than new words. The effect lasts for 400–500 ms and is maximal over the left parietal scalp [11,15]. Smith and Halgren [19] were the first to suggest this old/new effect could be decomposed into two previously studied components, an N400 and a P300. It should be noted that, despite the name, the P300 is typically found much later than 300 ms and

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follows the N400 effect. Although Smith and Halgren concluded that the old/new effects both reflect recollection processes, later studies have contradicted their view [13,15]. Current evidence increasingly indicates that the earlier component is related to a familiarity process, while the later component is related to a recollective process.

The early old/new component was dubbed the FN400 by Curran [2] because it was more frontally distributed than the well-established N400 component. The FN400 is associated with Know responses in the Remember/Know paradigm [6] such that the less familiar an item, the more negative in amplitude is the FN400 component. Consistent with this, Curran [3] used plurality reversed lures to isolate the contribution of familiarity. This paradigm involves presenting both plural and singular words at study, with the plurality of those words sometimes being reversed at test. Therefore, acceptance of plurality reversed lures is thought to indicate the use of familiarity, while acceptance of identical plurality targets and rejection of plurality reversed lures reflect correct recollection of the study context. Curran found that the FN400 was more negative for new items than for studied items and plurality reversed lures. Thus, the FN400 is more negative when items are less familiar but does not distinguish between studied and non-studied items with similar familiarity.

The parietal old/new effect is correlated with phenomenological judgments of recollection (specifically Remember responses), associated with various types of source memory, and affected by variables that likewise impact recollection more than familiarity. Duzel et al. [6] demonstrated that the parietal old/new effect is of greatest magnitude in the Remember/Know paradigm when a Remember response is made. This finding was based on two-step Remember/Know judgments, such that latency for the initial Old response was not significantly different for items that were later judged as Remember or Know. This provides some evidence that the finding was not due to latency jitter as has been previously argued [20]. Also, Curran's [3] reversed plurality experiment showed a more positive parietal old/new effect for studied words than for either reversed plurality lures or new items, with lures and new items evoking highly similar waveforms.

The parietal old/new effect's association with recollection is also demonstrated in source memory experiments, which examine memory for study context. If the encoding process is successful, information about the study context of the item should be available in episodic memory at the time of retrieval. Wilding et al. [23] demonstrated that the parietal old/new effect was indeed not evoked by stimuli that were not correctly identified with their study modality, and further that ERPs to misses and false alarms did not differ from those to correct rejections. These findings indicate that simply making an Old response is not sufficient to produce a parietal old/new effect: a correct source judgment is necessary. Similarly, when an exclusion task is used [8] such that participants must respond Old to only those items that occurred in a particular study modality while excluding items from another modality, both target and non-target items that were correctly identified are associated with the parietal old/new effect.

There are a number of variables that are thought to influence recollection more strongly than familiarity. These variables should influence a recollection-based ERP component, if such a component exists. Normal participants show a larger parietal old/new effect when their memory performance is better. However, hippocampal amnesic participants, who presumably have impaired recollection, do not show this difference in the parietal old/new effect [10]. In addition, high-frequency words have been shown to evoke a weaker parietal effect than low frequency words [16], consistent with the view that high-frequency words are less likely to be recognized based on a recollection process than low-frequency words [14].

All of this evidence makes the parietal old/new effect a good candidate for a neural correlate of recollection, but as Tendolkar et al. [21] and Curran [3] have argued, the component occurs too late in processing to indicate initiation of a search process. Rather, the component probably reflects the outcome of the search process. Because it has been identified with Remember responses and correct source judgments, its amplitude appears to reflect a successful search outcome. As Curran [3] states, for a successful recollection to occur, there should be earlier processes reflecting search and decision. Finding a component that is correlated with such a process would provide further evidence for the use of a recollection process in recognition, as well as information as to what kinds of tasks lead participants to make search-based judgments.

In order to determine why these search and decision processes have not been identified in previous ERP studies of recognition memory, it is helpful to explore the stages of processing that may be occurring during each trial and the temporal ordering of these stages. Familiarity is sometimes assumed to be automatic [8], meaning that upon presentation of a stimulus, the degree of familiarity of that stimulus becomes available without the need for a directed search. Because of this automaticity, familiarity is also thought to be a faster process than recollection. However, it is important to note that even if the degree of familiarity is immediately available, a decision must be made as to whether to accept the item based on its familiarity in a given memory task. This decision process could easily be delayed until after the completion of a recollection attempt and would result in slower response times for Know responses than Remember responses.

Recollection also presumably involves a decision process; however, it is unlikely that a search for episodic information proceeds automatically. In a task where no episodic judgment is required (i.e., lexical decision), recollection may not be attempted. For these tasks, general familiarity is likely the primary source of information used in making the decision. When episodic judgments are the goal of a task (e.g., in source memory, Remember/Know, and exclusion tasks), participants may attempt a memory search and defer their final decision until the search is complete. At that point, they may either respond based on successful recollection or use their familiarity assessment. This proposed model of the integration of recognition memory processes suggests that successful recollection judgments should occur more quickly than familiarity-based judgments, which may wait for recollection failure before proceeding.

ERP findings for episodic memory tasks are somewhat consistent with the model proposed above. The FN400 component, which occurs earlier than the parietal old/new component, is thought to reflect the assessment of familiarity. The parietal old/new component is thought to reflect the confirmation of recollection upon which the response is based. If a recollective search process was initiated by the participant for each stimulus, we would expect the ERP correlate of this process to be evident either before or during the same time frame as the familiarity component. Presumably the automatic familiarity assessment could proceed in parallel with the search process. The lack of previous studies to identify a search initiation component is the only aspect of this model that could be interpreted as inconsistent with the evidence.

We propose that the reason a search initiation component has not been identified in previous studies [2,3,6] is that those studies have only compared conditions in which the search is almost always initiated. That is, when the task is episodic (and particularly when participants are asked to indicate whether they recollect the item), participants will check for recollection before giving a response to an item. Therefore, even on trials where the decision is ultimately based on familiarity, the episodic memory search will still have occurred, and thus its electrophysiological manifestation may be present in all of these ERP waveforms. In fact, this component may even be present when the item is ultimately rejected as New; however, we would expect the component to differ in some way from that for items not rejected as New since participants may sometimes be able to quickly reject an item based on its low familiarity without bothering to assess recollection (e.g., when the memory task is particularly easy). A comparison between episodic recognition and a purely familiarity-based decision-making task has the potential to demonstrate the neural correlates of search initiation, presuming that the search would be initiated in most trials of the episodic task, but in very few trials of the familiarity-based task.

Curran [2] specifically looked for effects of retrieval intention by comparing performance on a lexical decision task to that of a recognition task, but did not find any difference in the old/new components for lexical decision as compared to recognition. However, in Curran's experiment, the lexical decision and recognition tasks were interleaved, such that participants were told at the beginning of the test block whether they would be required to recognize the items or simply identify them as words or nonwords. Because of this task interleaving, participants may have performed some recognition processing, even though it was not required on all trials. Also, because the lexical decision task always followed a study phase, it may have been natural for participants to think about whether they had seen the word previously. In order to avoid these possibilities, our non-episodic task will always be the first task performed, such that an obviously episodic study test procedure will not occur until after the familiarity based task. Participants will not be told about the recognition task or given instructions for the Remember/Know procedure until after the non-episodic task has been completed.

In the current experiment, we used a quick, general impression of the familiarity of a first and last name combination as a "pure" familiarity task. The judgments were based on lifetime experience, rather than episodic encoding. This familiarity task was compared with a typical recognition task where participants were required to determine which first and last name combinations occurred previously in the experiment, rather than in their lifetime. The use of first and last name combinations was designed to allow us to manipulate degree of familiarity by using famous names in comparison with nonfamous names. The famous names that were initially presented in the first phase of the experiment then served as targets in the second phase of the experiment where they were combined with lure names that were also famous. Our goal was to compare the episodic recognition task with the familiarity task in search of correlates of memory search initiation and decision making.

2. Materials and methods

2.1. Participants

Participants were volunteers from the University of Pittsburgh and Carnegie Mellon University communities who were paid $25 for their participation. All participants were right-handed and native English speakers. In addition, all participants were raised in North America, which was required in order to approximately equate their familiarity with the famous names. A total of 28 people participated in the experiment. Three of these participants did not complete the 3-h experiment due to difficulty following directions and impedance control issues. Ten of the remaining 25 participants were excluded due to excessive false alarms (more than 10% of the Remember responses or more than 40% of the Know responses). Of the remaining 15 participants, 9 were male. Their mean age was 24 years (range = 18–38).

2.2. Stimuli

Stimuli were 600 famous names and 600 nonfamous names. Famous names were gathered from celebrity tracking websites and inspected to exclude names that were not well known. Nonfamous names were gathered from recent census data of first and last names ranked by commonality. The names were inspected to exclude different spellings of the same name and then randomly combined to create first and last name pairs. The average syllable and character lengths, respectively, of the famous names were 3.9 and 11.7. For nonfamous names, the average syllable and character lengths were 3.9 and 11.9. Both famous and nonfamous names included 204 female names and 396 male names. Study and test lists for each participant were created by randomly selecting names from each category to be shown in phase 1 (300 famous and 300 nonfamous), with the remaining famous names appearing in phase 2 (300 famous names from phase 1 and 300 new famous names).

All stimuli were presented on a computer screen in yellow on a black background. The maximum horizontal and vertical visual angles subtended were 8° and 2.2°, respectively. All names were centered on the screen with the first name presented directly above the last name, and presented in a sans serif font. EEG recording began 200 ms prior to each stimulus presentation and continued until the blink period. In phase 1, each trial began with a blank screen displayed for a variable amount of time (200–700 ms, randomly determined for each trial) in order to prevent an expectation effect for the stimulus occurring at the same delay on each trial. Following the blank screen, a name was displayed in the center of the screen for 300 ms. Following the stimulus, a blank screen was shown for 1500 ms. After each trial, a cartoon of an eye indicated that the participant should feel free to blink. This blink period lasted for 1200 ms before the next trial began. Participants were required to respond to the stimulus before the blink period began. After every tenth trial, an unlimited break period was given which the participant could end with a key press. In phase 2, the trials proceeded in exactly the same way as phase 1.

2.3. Procedure

Each session began with the completion of a consent form and a handedness questionnaire and was followed by the application of the sensor net. Participants were then seated in front of a computer monitor at a viewing distance of approximately 57 cm.

Each phase was broken into 3 blocks of 200 trials, with a break between each block to check and reduce impedances. In phase 1, participants were instructed to respond to each name with a quick, first impression judgment of whether the name was Familiar or Nonfamiliar. Responses were made by pressing either the 1 or 3 number pad keys. All participants responded using the right hand, with response keys counterbalanced so that all finger/response combinations occurred approximately equally across participants.

After phase 1 was completed, participants were given the Remember/Know instructions for making episodic memory judgments. In phase 2, participants were required to distinguish between names they had seen in the experiment for which they could Remember contextual details about viewing the name in the experiment (Remember), names that seemed familiar from the experiment but for which no contextual details could be recalled (Know), and names that they had not seen in the experiment (New). It is important to note that all names in Phase 2 were famous, so participants were instructed carefully that Know responses should be based on familiarity within the experiment. Responses were made by pressing the 1, 2, or 3 number pad keys. All participants responded using the right hand, with response keys counterbalanced so that all finger/response combinations occurred approximately equally across participants.

2.4. EEG recording and data reduction

Activity from the scalp was collected using a 128-channel Geodesic Sensor Net™ (Electrical Geodesics, Eugene, OR). After soaking in a saline solution, each electrode was adjusted until its impedance was less than 60 kΩ. These adjustments were repeated after each trial block. EEG was recorded with a sampling rate of 1000 Hz and a bandpass of 0.1–200 Hz.

EEGs for each participant were digitally filtered with a 30 Hz lowpass. Trial segments were marked as bad if an eyeblink or eye movement was detected during recording (using a $\pm$ 75 μV threshold). Also, a channel was marked as bad throughout the recording session if it was bad in more than 20% of the trials. Following this artifact detection procedure, a bad channel replacement algorithm was used to replace bad segments with data interpolated from the surrounding good channels. The ERPs were baseline-corrected with respect to the 200-ms pre-stimulus interval. We also used an average reference procedure where each channel was computed as the difference between itself and the average of all channels.

Because we were interested in the processes behind accurate memory judgments, all ERPs reported will be based on correct responses. The mean number of trials included in each condition per participant and standard deviations (in parentheses) for phases 1 and 2 were: famous names judged as Familiar = 208 (28); nonfamous names judged as Nonfamiliar = 253 (33); new famous names judged as New = 239 (46); famous names from phase 1 that were judged Familiar in phase 1 and either Remembered = 92 (52) or Known = 71 (47) in phase 2. We did not analyze phase 2 recognition judgments for famous items rejected as Nonfamiliar in phase 1.

3. Results

3.1. Behavioral results

The results for the behavioral measures of the experiment are shown in Table 1, including mean percent correct and correct reaction time for each phase and response type. Accuracy was higher overall in phase 1 than phase 2. This is

Table 1
Mean accuracy and response time (RT) as a function of phase and response type

Response	Percent correct	RT (ms)
Phase 1		
Familiar	79	754
Nonfamiliar	97	808
Phase 2		
Remember	33	1003
Know	28	1100
New	89	907

probably due to the fact that the familiarity judgment task was easier (based on a lifetime of experience) than a recognition task based on incidental single-trial learning. Participants were not aware that the names would be tested later in the experiment. Phase 1 Nonfamiliar judgments were significantly more accurate than Familiar judgments, $t(14) = -5.54$, $p < 0.001$. In phase 2, the hit rate was 61% and the correct rejection rate was 89%. Although this hit rate is somewhat low, the false alarm rate for Remember responses was extremely low (1% of new items), thus we are confident that the Remember responses reflect accurate recollection-based judgments. The false alarms for Know responses (8% of new items) constitute approximately 22% of the total Know responses. This means that the Know responses in this experiment did not demonstrate a strong distinction between signal and noise based on familiarity. A one-way repeated-measures ANOVA on the phase 2 hit rate was significant, $F(2,28) = 68.97$, $p < 0.001$, with a Tukey's HSD showing that the percentage of correct New responses was significantly higher than either correct Remember or Know responses, while Remember and Know did not differ from one another.

We also compared the reaction times (RTs) for correct judgments of each response type in each phase. If the phase 1 task was based on simple familiarity judgments without a recollection attempt, these RTs should be shorter overall than the phase 2 RTs, which we hypothesize will reflect search attempts on most trials. A one-way ANOVA conducted on the average reaction times for the 5 response types was significant, $F(4,56) = 59.76$, $p < 0.001$. Pairwise comparisons using the Tukey's HSD test revealed that Nonfamiliar and Familiar RTs from phase 1 were not significantly different from each other, while all phase 2 RTs were significantly different from each other as well as from all phase 1 judgments. Therefore, phase 2 judgments were significantly slower than phase 1 judgments, as we expected.

3.2. ERP results

Our analyses of the ERP data were designed to reveal topographical areas and temporal periods over which the scalp voltage differed during processing within phase 1, within phase 2, and between the phases. We divided the electrodes into four areas in each hemisphere: Frontal, Parietal, Temporal, and Occipital. Fig. 1 shows the map of the 128 electrode net, highlighting the electrodes that made up the Frontal and Parietal areas, where we found significant effects in the time periods of interest. For each area, we averaged the amplitude of the electrode sites within each region over each indicated time period for each participant. The results of three time periods of interest are reported here: 190–235 ms, 300–400 ms, and 500–800 ms. These time periods were chosen based on prior research findings as well as visual inspection of the channels for differences in the waveforms.

The dependent variable in our analyses is the mean voltage over each time period examined. Fig. 2 plots the voltage for each of the regions where we found statistically significant differences. Post hoc comparisons were conducted using Tukey's HSD test when the sphericity assumption for the ANOVA was met. When the sphericity assumption was violated, we used the modified Bonferroni correction. In order to examine effects within phase 1 responses, individual ANOVAs were run on the phase 1 response types crossed with hemisphere and anterior/posterior recording site. Similarly for phase 2, ANOVAs were run on the three phase 2 response types crossed with hemisphere and anterior/posterior position. In order to look for between task effects, an ANOVA was also run on the five response types from the two phases crossed with hemisphere and anterior/posterior position. Finally, we also conducted ANOVAs in which Remember and Know responses were collapsed into a general Old category to determine whether Old responses overall would be different from New or phase 1 responses. For the collapsed Old responses, ANOVAs included the factors of response type and phase because the response types in both phases could be categorized as New or Old. This was not possible for the Remember/Know ANOVAs because the response types of phase 1 and phase 2 were not compatible. Also, because response type is not a manipulated variable, we must be cautious in interpreting the cause/effect relationships of the variables. All of our conclusions will be based on the finding that a response type correlated with a mean voltage, rather than that the voltage difference was caused by the response.

3.2.1. 190–235 ms

Differences between phases 1 and 2 and within phase 2 were found during the 190- to 235-ms interval (see Fig. 3). There were no significant differences between responses in phase 1 during this time period. When Remember/Know responses were collapsed into an Old category, an ANOVA examining phase 2 responses showed a main effect of response type, $F(1,14) = 6.13$, $p < 0.05$, such that Old responses were more positive than New responses. There was also a main effect of anterior/posterior position, $F(1,14) = 34.81$, $p < 0.001$, such that there was more positivity in the frontal regions than the parietal regions. The ANOVA comparing phase 1 Old and New vs. phase 2 Familiar and Nonfamiliar, with Remember and Know

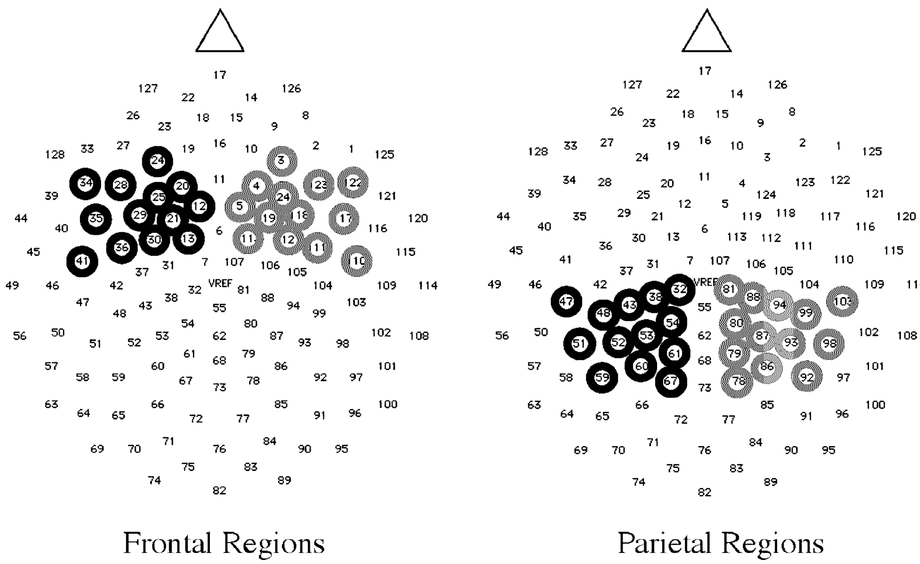

Fig. 1. Plots of the electrodes averaged to create Frontal and Parietal regions. Represented on flattened maps of the 128 electrode net. For each region, black circles indicate the left region and gray circles indicate the right region.

responses collapsed into Old responses, showed a main effect of anterior/posterior position, $F(1,14) = 41.94$, $p < 0.001$, again showing that there was more positivity in the frontal regions than the parietal regions (see Fig. 4). There was also an interaction between response type and phase, $F(1,14) = 12.01$, $p < 0.01$. Tukey's HSD tests revealed that Old responses in phase 2 showed significantly more positivity than both Familiar and Nonfamiliar responses in

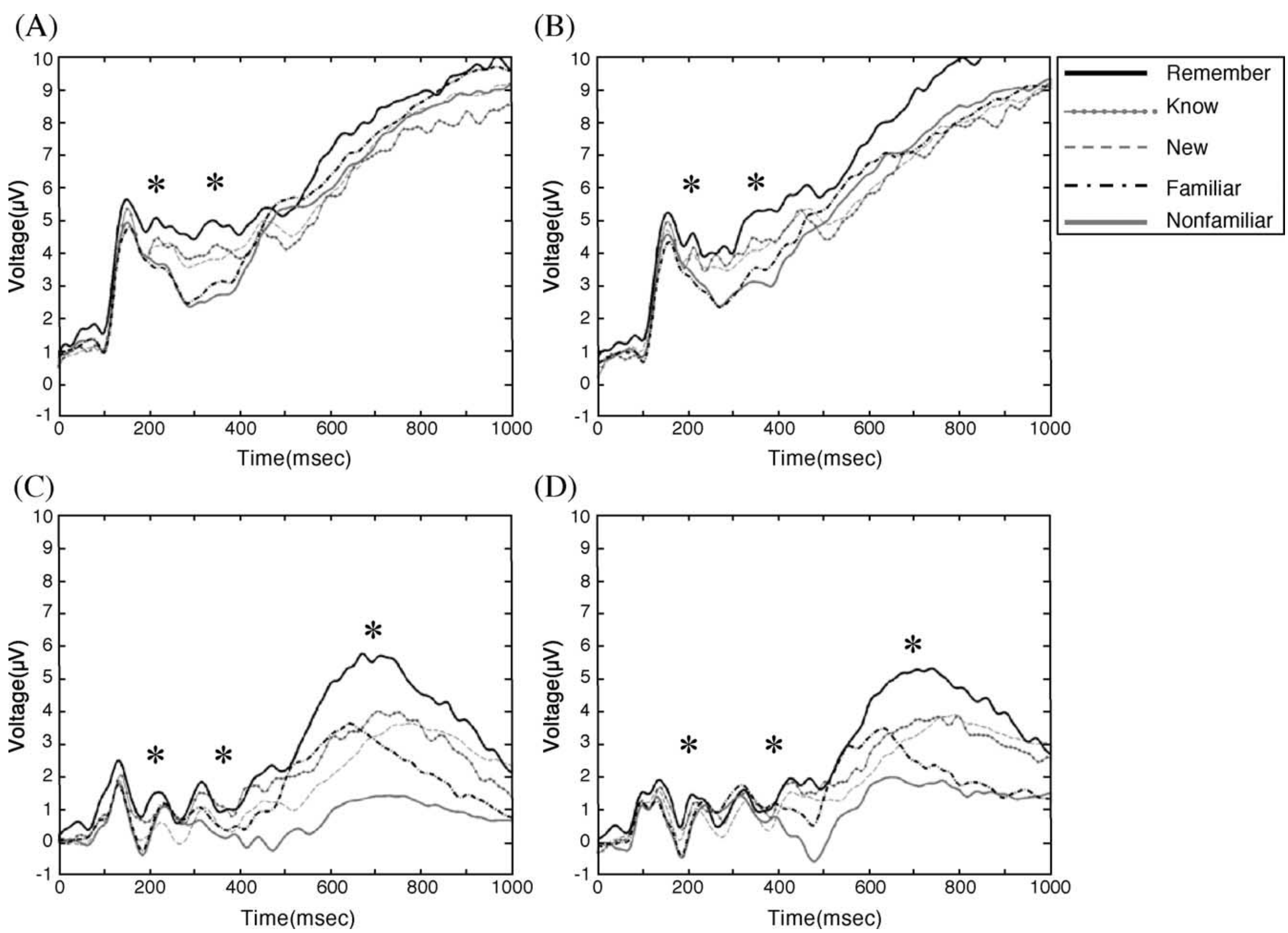

Fig. 2. Grand-average, average-referenced ERPs for correct judgments in phases 1 and 2 of the experiment in each region. (A) Left Frontal, (B) Right Frontal, (C) Left Parietal, (D) Right Parietal. Asterisks illustrate the location of the mean of each analyzed time region.

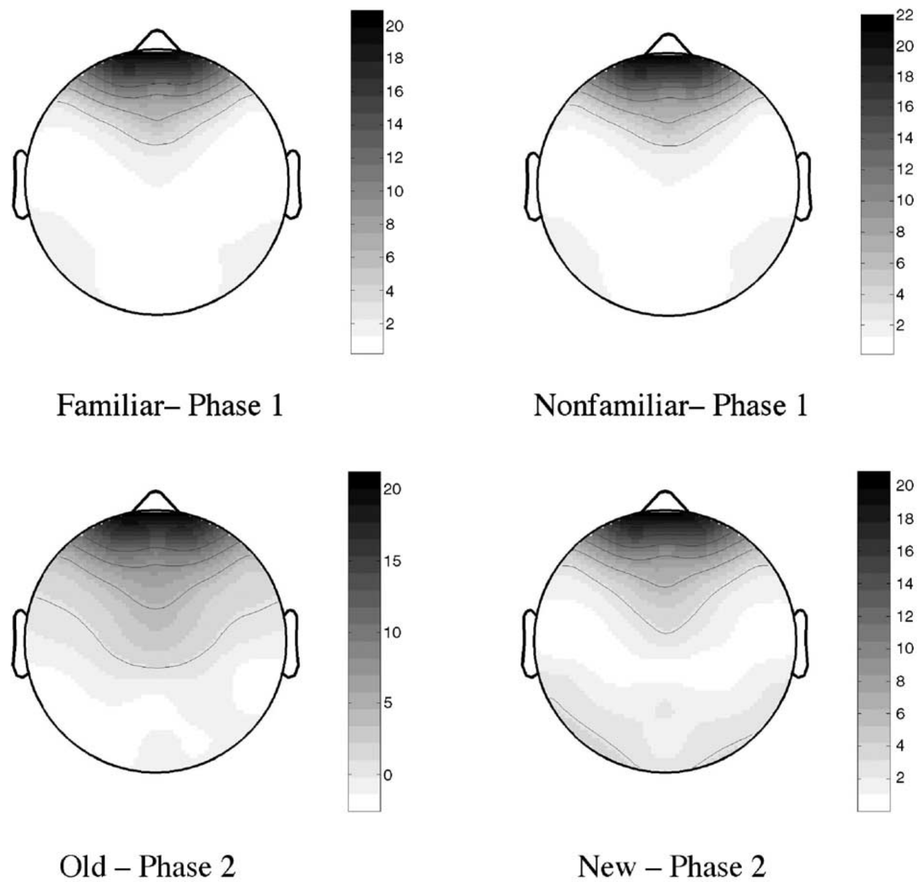

Fig. 3. Topographical maps from phase 1 and phase 2 collapsed between 190 and 235 ms. Tops of the figures represent anterior electrodes and shading scales are shown for each map.

phase 1, while New responses in phase 2 were not different from phase 1 responses.

3.2.2. 300–400 ms

During the 300- to 400-ms poststimulus time period, an FN400 effect [2–4,6] was found. A 2 × 2 × 2 within-subjects ANOVA performed on the phase 1 data, in the right and left frontal and parietal areas, showed a main effect of response type such that famous names judged as Familiar were significantly more positive than nonfamous names judged as Nonfamiliar, $F(1,14) = 8.65$, $p < 0.05$. There was also a significant main effect of anterior/posterior position, such that the frontal areas were more positive than the parietal areas, $F(1,14) = 13.94$, $p < 0.01$. The 3 × 2 × 2 within-subjects ANOVA for phase 2 judgments also showed a main effect of response type, $F(2,28) = 4.03$, $p < 0.05$, a main effect of anterior/posterior position, $F(2,28) = 11.02$, $p < 0.01$, and an interaction between response type and anterior/posterior position, $F(2,28) = 5.39$, $p < 0.05$. A Tukey's HSD test showed that Remember responses in the Frontal regions were more positive than both New responses and Know responses in the Frontal regions. There were no significant effects of hemisphere. A 5 × 2 × 2 ANOVA comparing phase 1 and phase 2 judgments did not reveal any additional effects.

When Remember/Know responses were collapsed into a single category, the ANOVA examining phase 2 differences showed a significant main effect of response type, $F(1,14) = 5.90$, $p < 0.05$, such that Old responses were more positive than New responses. There was also a significant main effect of anterior/posterior position, $F(1,14) = 11.95$, $p < 0.01$, such that frontal areas were associated with more positivity than parietal areas. The ANOVA for between-phase differences compared response type (New/nonfamous vs. Old/famous) with phase of the experiment, hemisphere, and anterior/posterior position. The results showed a main effect of response type, $F(1,14) = 7.83$, $p < 0.05$, such that Old/famous responses were more positive than New/nonfamous responses. There was also a main effect of anterior/posterior position, $F(1,14) = 13.08$, $p < 0.01$. The interaction between phase and anterior/posterior position was significant, $F(1,14) = 5.78$, $p < 0.05$, indicating that the differences between phase 1 and phase 2 occurred in the frontal area, while the phases did not differ in the parietal area during the 300- to 400-ms time period. There was also an interaction between phase of the experiment and hemisphere, $F(1,14) = 8.18$, $p < 0.05$, due to the fact that the difference between phases 1 and 2 was larger in the left hemisphere than in the right hemisphere.

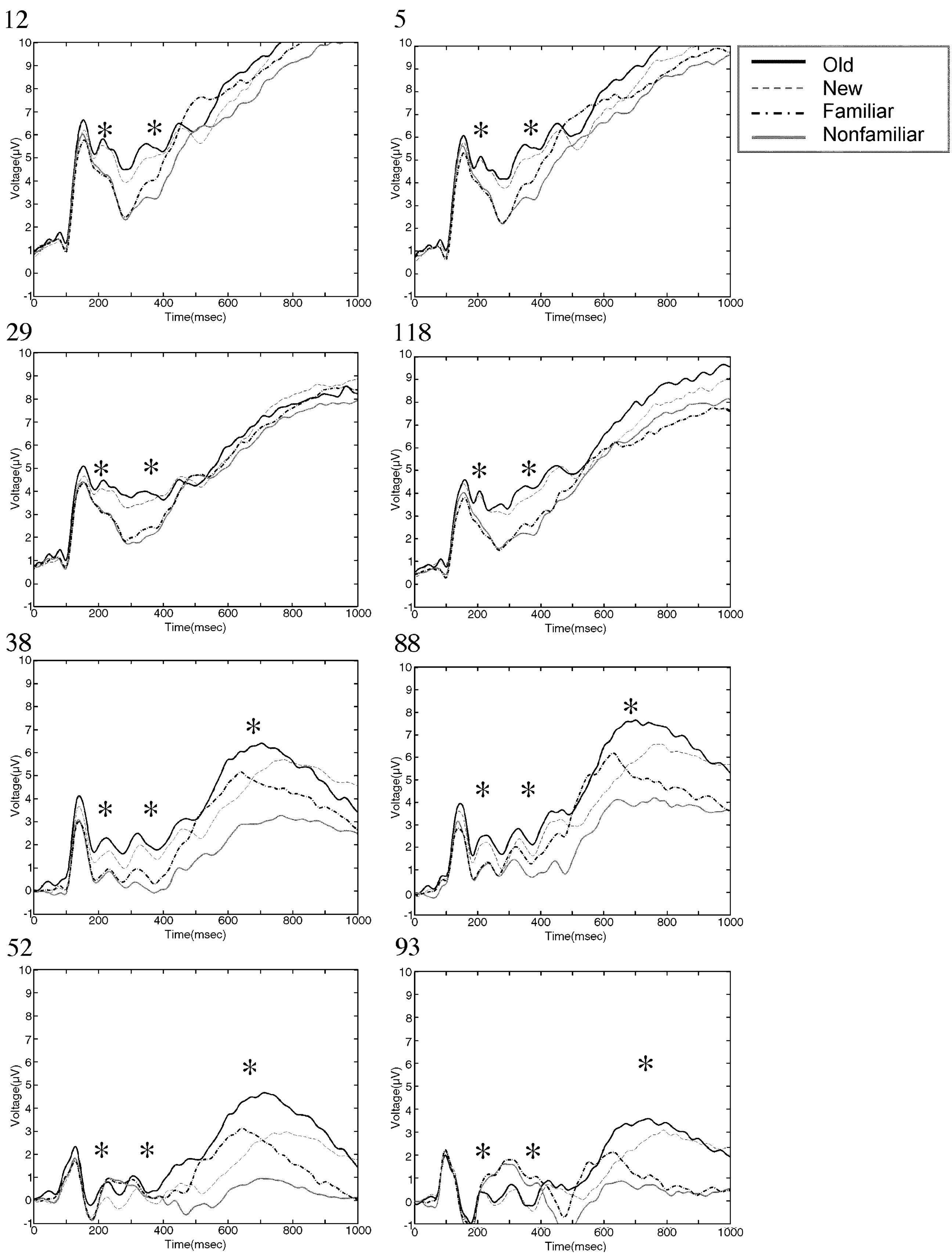

Fig. 4. Grand-average, average-referenced ERPs for correct judgments in phases 1 and 2 of the experiment shown as two individual electrodes from the left and right frontal and parietal regions. Phase 2 Remember/Know data are collapsed to form an Old category. Numbers above each graph indicate the electrode. Asterisks illustrate the location of the mean of each analyzed time region.

3.2.3. 500–800 ms

We also replicated the parietal old/new effect [2,6,10,14,23] occurring 500–800 ms after stimulus onset. An ANOVA examining phase 1 judgments showed a significant main effect of response type, $F(1,14) = 9.35$, $p < 0.01$, and anterior/posterior position, $F(1,14) = 26.07$, $p < 0.001$. There was an interaction between response type and anterior/posterior position, $F(1,14) = 36.37$, $p < 0.001$, indicating that parietal famous judgments were correlated with more positive activity than parietal nonfamous judgments. The phase 2 ANOVA also showed main effects of response type, $F(2,28) = 9.68$, $p < 0.01$, and anterior/posterior position, $F(1,14) = 8.34$, $p < 0.05$. There was a three-way interaction between response type, hemisphere, and anterior/posterior position, $F(2,28) = 3.50$, $p < 0.05$. Tukey's HSD tests revealed that Remember responses were more positive than New responses in both left and right parietal areas. Remember responses were also more positive than Know responses, but in this case the effect was significant in the left parietal and left frontal areas. The difference in Remember and Know judgments was unlikely to be due to latency jitter. The reaction time difference between these conditions was approximately 100 ms, with the standard deviation for Remember responses being 87 ms and for Know being 108 ms. An ANOVA comparing phase 1 and phase 2 did not reveal any additional effects.

We collapsed across Remember/Know judgments to create an Old response category for this effect as well. This allowed us to compare phases 1 and 2 more effectively by including the factors of response type (Old/Famous vs. New/Nonfamous), phase, hemisphere, and anterior/posterior position. The ANOVA revealed main effects of response type, $F(1,14) = 14.06$, $p < 0.01$, and anterior/posterior position, $F(1,14) = 16.75$, $p < 0.01$. In addition, there were interactions between response type and anterior/posterior position, $F(1,14) = 12.02$, $p < 0.01$, indicating an old/new difference in parietal areas, and between phase and anterior/posterior position, $F(1,14) = 7.01$, $p < 0.05$, indicating a difference between phases 1 and 2 in parietal areas. Finally, there was a three-way interaction between response type, hemisphere, and anterior/posterior position, $F(1,14) = 7.02$, $p < 0.05$, such that activity in the right and left hemispheres was approximately equal in frontal areas, but in parietal areas, Old judgments showed more positivity on the left than the right while New judgments showed more positivity on the right than the left.

4. General discussion

The current experiment was designed to compare patterns of voltage changes in the brain during different types of processing in an episodic task, as well as between that episodic task and a task based on more general familiarity. We found differences between the familiarity and episodic tasks, as well as within the episodic task, in the form of a P200 effect. We also replicated the FN400 and parietal old/new effects that previous studies of episodic recognition have linked with different types of processing.

4.1. P200 effect

A 190- to 235-ms P200 effect that distinguished between phase 1 and phase 2 processing was reported. This effect occurred in the frontal and parietal regions of both the right and left hemispheres. Phase 2 Old responses were significantly more positive than either phase 1 Familiar or Nonfamiliar responses, while phase 2 New responses did not differ from phase 1 responses. Within phase 2, Old responses were more positive than New responses. There were no differences within phase 1 for this component. Our prediction was that phase 2 trials would often include memory search attempts and thus that we might find a correlate of these search attempts in phase 2 trials that would not be seen in phase 1. New responses are less likely to show evidence of a search attempt component because they may include fast rejection trials for which no search attempt was necessary. That is, when the familiarity of an item is extremely low, the participant may reject it outright without further memory search [1]. Therefore, it is not surprising that there is a difference between New and Old items in what may be a memory search component.

The argument could be made that this P200 component is actually due to priming. The component was larger for trials in which the name had been seen previously in the experiment. The episodic phase of the experiment always followed the familiarity phase in order to prevent participants from making unnecessary episodic judgments during the familiarity task. Therefore, we cannot be certain that the phase order is not the cause of the P200 effect. A previous study of priming of famous names showed an N200 priming effect from 180 to 220 ms when the name was presented in the same font as the prime [12]. However, the procedure in that experiment involved presenting a prime immediately before a target. In studies using a study test procedure with delayed second item presentations, priming was not found for famous names this early in the ERP waveforms [17].

Schweinberger and colleagues [17] ran a very similar experiment to our current experiment using famous and nonfamous names in an ERP paradigm. Their experiment 2 included two phases. Phase 1 consisted of the same task as phase 1 of our experiment, asking participants to identify names as famous or nonfamous. Phase 2 of the Schweinberger experiment also asked participants to identify names as famous or nonfamous, but it included both new famous and nonfamous names and previously shown famous and nonfamous names. The only difference between their phase 1 and phase 2 was whether some of the names had been repeated. Thus, Schweinberger et al.'s experiment 2 serves as a control for possible priming effects in our experiment. Schweinberger's study found priming of famous names between 500 and 700 ms poststimulus, but no evidence of any earlier priming effects.

Based on the fact that Schweinberger et al. did not find priming effects in the 200-ms range, we believe that our P200 effect is best explained as a correlate of search initiation. This means that the P200 effect may be a correlate of a recollection attempt, with the success or failure of that attempt being reflected in the later parietal old/new effect. The localization of this P200 over the frontal and parietal scalp sites is consistent with the idea that it represents some type of search initiation, as prior studies of memory retrieval have indicated both frontal and parietal regions as important in episodic memory retrieval processes [3,21]. Despite the evidence provided by Schweinberger et al., we must be cautious in interpreting the data from this experiment because the order of the familiarity and episodic tasks was held constant, with the familiarity task always occurring first.

Other studies have found memory retrieval effects during this 200-ms time period [5,7,22]. A study of context effects in recognition reported a frontal effect from 100 to 300 ms, which only occurred when either the target object or context of the object was repeated from the study phase [22]. The authors interpreted this effect as either a priming effect or the first indication that the information being presented was experienced in the past. Thus, the effect could represent some kind of early recognition of the stimulus. If so, this could fit with our argument that participants make an early decision to search when some familiarity or perceptual fluency is present. An alternate way to describe this effect could be as an increase in attention if an item has a certain degree of familiarity. Friedman [7] found a 200- to 300-ms effect that showed an old/new difference with some suggestion that this effect was topographically distinct in the sense that it was more frontally oriented than the FN400 that is associated with familiarity. This effect occurred for both Remember and Know judgments, as well as misses, and did not differ depending on whether the item was episodically primed.

Curran and Dien [5] also found a frontal effect from 176 to 270 ms when items were studied in the same modality in which they were presented at test, but not when study and test modality differed. Although the authors suggest that this effect may be interpreted as a modality-specific priming effect, they note that no such effect was reported in a similar study conducted by Wilding and colleagues [23]. The key difference between these studies is that the study lists of Wilding et al. were almost six times longer than those of Curran and Dien. The similar length of our study (300 names) and test lists (600 names) with those of Wilding et al. make it unlikely that the P2 effect seen in our data is due to priming as may be the case in the Curran and Dien study. Interestingly, Curran and Dien note that P2 old/new effects have not been found in lexical decision tasks—only during explicit recognition tasks. This leads the authors to conclude that “the present early old/new effect is related to intentional retrieval of modality-specific information rather than an implicit perceptual priming mechanism” [[5], p. 985]. These prior findings strengthen our claim that the P200 effect demonstrated in the current experiment reflects an initiation of search.

4.2. FN400 effect

The FN400 effect has been shown by other studies to be correlated with familiarity processes. Our effect is compatible with this idea, primarily because this is the earliest time in the ERP waveform where correct Familiar responses to famous names, which we expect to be high in familiarity, diverge from Nonfamiliar responses to nonfamous names, which we expect to have almost zero familiarity. Also, stimuli to which the participant responded Remember would be expected to be more familiar than those to which the participant correctly responded New, as we found. Our data also show a statistically significant difference between Remember and Know, indicating that stimuli that produced recollection responses were also more familiar. This is not surprising because recollected items are also likely to be highly familiar, but the more reliable recollection process is used to determine the final response. There was no statistical difference between Know and New, but this is likely due to the noisiness of the Know data. As mentioned previously, the large number of Know false alarms seems to indicate that the Know may include some guess responses, which may be based on strategies for equalizing response proportions rather than familiarity. The FN400 effect in phase 1 was significant in both frontal and parietal areas. However, the phase 2 differences occurred exclusively in frontal areas. When Remember and Know responses were collapsed, phase 2 was overall more positive than phase 1 in the parietal areas, with the difference being larger in the left hemisphere. Thus, old names in phase 2, which had been presented previously in the experiment, were differentiated from those that had not been seen in the experiment by frontal effects between 300 and 400 ms. Note that all stimuli in phase 2 were famous names. Therefore, recollection of episodic information was a more reliable method of judging whether names had been presented in the experiment than overall familiarity, as all names had high pre-experimental familiarity.

4.3. Parietal old/new effect

Our parietal old/new effect also fits with previous characterizations of a recollection-based component. Remember responses showed a more positive component from 500 to 800 ms than did either New or Know responses. The component was evident primarily in parietal areas. The fact that Nonfamiliar responses in phase 1 differed from Familiar responses during this time interval was somewhat unexpected. One possibility is that the parietal old/new effect also indexes familiarity to some degree. That is, the activity associated with viewing familiar items was more positive than that for viewing extremely unfamiliar items like our nonfamous names. It is also possible that participants infrequently experienced a recollection when viewing famous names, whereas it would be almost impossible for them to experience a recollection when viewing the nonfamous names. However, given the main effect of phase, such that phase 2 was significantly more positive than phase 1 during this time interval, we would expect that recollection experiences were rare in phase 1, as we intended.

4.4. Conclusions

This study comparing lifetime familiarity judgments with episodic familiarity and recollection judgments shows evidence for an early (190–235 ms) component that correlates with search initiation. This correlate of search initiation may allow us to assess in future research whether search is occurring during a given task, although the question remains as to whether the component indexes only episodic searches vs. more general memory searches. This component occurs before the FN400, which is thought to index familiarity, and the parietal old/new effect, which is thought to reflect successful recollection. It is widely accepted that familiarity assessments occur more quickly than recollection; however, it is also evident that recollection-based judgments are often faster than familiarity-based judgments, as the reaction times in this experiment show. This is thought to be the result of participants' waiting for the completion of the recollection attempt (the confirmation of which is correlated with the 500- to 800-ms effect) before proceeding with the familiarity-based response. (Although the timing of the effect may be due to the instructions of the Remember/Familiar procedure.) Overall, the finding of an early search initiation in a recognition task as compared to a familiarity task provides more support for the perspective that a recollection process is involved in recognition and that the result of that recollection process is indexed by the later parietal old/new effect.

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