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The Recollection Component of Recognition Memory as a Function of Response Confidence: An Event-Related Brain Potential Study

A dissertation submitted by

David M. Lalor

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Abstract

The aim of the current series of experiments was to further explore the boundary conditions of the recognition memory old/new effect in the context of the recognition/associative recall task (Rugg, Schloerscheidt, Doyle, Cox, & Patching, 1996). The study by Rugg et al. was replicated and extended by manipulating both the semantic relatedness between study items and the timing of recall. Event-related potentials (ERPs) were recorded from 17 scalp electrode sites during performance of a recognition/associative recall task. Forty participants were visually presented with four blocks of 50 word pairs which were either unrelated (Experiments 1 and 2) or weakly semantically related (Experiments 3 and 4). Participants were instructed to form an association between the members of each word pair. At test, the first members of each pair were visually presented intermixed with a similar number of unstudied items. Participants were required to discriminate (i.e., recognise) previously studied items (old) from new items. Participants were also required to recall the study associate for words judged old, and to provide confidence levels for each recognition decision on a 3-point scale. Recall was either immediate (Experiments 1 and 3) or delayed (Experiments 2 and 4). Relative to ERPs to new items, the ERPs elicited by words correctly recognised and for which the associate was correctly recalled exhibited a positive-going shift between 500-800 ms poststimulus onset. The effect was maximal at posterior temporal-parietal electrode sites (the *parietal old/new effect*). Although the effect was not lateralised to the left hemisphere, this result may be due to the variability in encoding strategies employed by the participants. Behavioural data consistently indicated that response confidence is confounded with response category. The ERP results also revealed that the old/new effect is not evident following the experimental control of response confidence, and that immediate recall is associated with a negative-going shift at posterior electrode sites between 800-1100 ms poststimulus onset. Manipulating the semantic relatedness between the word pairs did not influence the distribution of the old/new effect. The results are discussed in terms of the view that the parietal old/new effect reflects neural activity associated with the recollection of specific previous experiences, and may reflect retrieval processes supported by the medial temporal lobe memory system (Moscovitch, 1992, 1994; Squire, 1992; Squire, Knowlton, & Musen, 1993). It is suggested that future research extend the current findings by examining the influence of response confidence in alternative recognition memory paradigms.

Certification of Thesis

I certify that the ideas, experimental work, results, analyses, and conclusions reported in this thesis are entirely my own work, except where otherwise acknowledged. I also certify that the work is original and has not previously been submitted for any other award.

David M. Lalor Date

Endorsement

Associate Professor Gerald Tehan (Supervisor) Date

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The Recollection Component of Recognition Memory as a Function of Response Confidence: An Event-Related Brain Potential Study

Understanding of the cognitive structure and dynamics of human memory has undergone a dramatic transformation over recent decades. Central to this process has been the accumulation of evidence suggesting that memory is not a single entity but rather consists of several dissociable (albeit interacting) systems, each fulfilling specific functions (Graf & Schacter, 1985; Graf, Squire, & Mandler, 1984; Tulving, 1984; Tulving & Schacter, 1990). Many characteristics of these proposed memory systems, including their precise definitions, cognitive functions, neuroanatomy, and the temporal parameters of their component processes have not been clearly delineated.

Forms and measures of memory

The term *implicit memory* was introduced by Graf and Schacter (1985) and refers to an unintentional, unconscious form of retention. That is, implicit memory involves a facilitation in test performance that can be attributed to a prior study episode (i.e., repetition priming). Participants are not required to recollect the study phase and may be unable to do so (Schacter, Chiu, & Ochsner, 1993). This form of memory can be contrasted with *explicit memory* which entails the conscious recollection of previous events (Schacter, 1987, 1992). Typically, explicit memory is assessed via recall and recognition tasks which require intentional retrieval of information from previous experiences, or the successful identification of the previously studied material, respectively. As the task instructions refer the subject to a specific spatiotemporal context, these tasks have been variously described as autobiographical (Jacoby & Dallas, 1981), direct (Johnson & Hasher, 1987), episodic (Tulving, 1972, 1983, 1985), intentional (Jacoby, 1984), declarative (Squire, 1987), or explicit (Graf & Schacter, 1985). An alternative set of tasks which involve no reference to previous events have been described as implicit (Graf & Schacter, 1985), indirect (Johnson & Hasher, 1987), or incidental (Jacoby, 1984). Following Richardson-Klavehn and Bjork (1988), the terms direct and indirect will be used to characterise the classes of memory test that refer the subject to either a target event, or to the current task, respectively. Similarly, the terms explicit versus implicit memory will be employed to refer to the underlying memory phenomenon or systems reputedly accessed by direct and indirect tasks, respectively.

Evidence consistent with the distinction between explicit and implicit forms of memory was provided by two avenues of research including studies concerned with the preserved memory abilities of amnesic patients, and those relating to repetition priming in normal participants. Support for the functional distinction between direct and indirect tasks in normal participants has been provided by studies suggesting that performance on direct tests (e.g., recall and recognition) is subject to a faster rate of decay than does priming on indirect tests (e.g., perceptual identification, Jacoby & Witherspoon, 1982; lexical decision, Bentin & Moscovitch, 1988; picture completion, Mitchell & Brown, 1986; word fragment completion, Tulving, Schacter, & Stark, 1982; reading speed, Kolers, 1976). In addition, altering the format of stimulus presentation between the encoding and test phases (e.g., different presentation modality or type font) influences repetition priming more than recognition (Jacoby & Dallas, 1981; Roediger & Blaxton, 1987). Dissociations have also been observed following depth of processing manipulations at study (e.g., elaborative semantic encoding versus orthographic processing). These studies have consistently revealed that, in contrast to direct tests, indirect tasks are relatively insensitive to variation in depth of processing (e.g., Craik & Lockhart, 1972; Craik, Moscovitch, & McDowd, 1994; Graf & Mandler, 1984).

Considerable neuropsychological evidence suggests that explicit memory processes depend critically on the medial temporal lobe region, including the hippocampus and associated cortical (i.e., parahippocampal, entorhinal, and perirhinal cortices) and midline diencephalic structures (i.e., medial thalamic nuclei) (Markowitsch, 1995; Squire, 1992). This form of memory has been identified as fundamentally relational in nature, as opposed to the item-specificity of implicit memory (Cohen, Poldrack, & Eichenbaum, 1997). Cohen et al. argue that the critical distinction between spared versus impaired memory in amnesia is the ability to relate or bind perceptually distinct aspects of episodes into a compositional representation. Cohen et al. therefore maintain that explicit or declarative memory involves the formation of associations between items and the context in which they were experienced. Conversely, implicit memory performance involves inflexible nonrelational representations reflecting experience-based tuning of modality specific processors. This view of implicit memory bears resemblance to Mandler's (1980) concept of intraitem integration. Intraitem integration results from the presentation of an item which focuses perceptual and intrastructural aspects of the item, independent of the item's relations to the surrounding context. According to Mandler, the outcome of this process is experienced by the subject as a sense of familiarity.

Neuropsychological studies involving indirect memory tests indicate that amnesics exhibit normal performance despite severely impaired direct test performance (Cohen & Squire, 1980; Schacter, 1987; Shimamura, 1986,). For example, Cohen and Squire investigated the ability of amnesic patients and normal control participants to read spatially transformed words. No significant difference was found between the groups in terms of reading rate despite the amnesics inability to consciously recollect either the words read or the experimental episode. This result was consistent with the view that indirect test performance reflects the facilitory influence of prior processing of similar material without the involvement of intentional or recollective memory processes.

An alternative to the implicit/explicit distinction as an explanation of amnesics preserved performance on indirect memory tasks has been proposed by Tulving (1983, 1985) who distinguished between episodic and semantic memory. Episodic memory mediates conscious recollection of previously experienced events; whereas semantic memory involves general symbolic knowledge and facts. The retrieval of semantic memories does not require recall of the contextual details surrounding their acquisition. Tulving (1985) associated episodic and semantic memory with autonoetic and noetic consciousness, respectively. Noetic consciousness enables encoding and flexible manipulation of symbolic knowledge (e.g., the capital of France is Paris). That is, the content of noetic consciousness is fundamentally propositional in nature. Conversely, autonoetic consciousness correlates with episodic memory and is necessary for the knowledge that a recollection was personally experienced in a particular spatio-temporal context (e.g., details of a personal trip to Paris). Tulving argued that knowledge recovered from past events can represent a combination of semantic and episodic aspects of the experience. In the context of a recognition memory task, participants may be able to distinguish between recognised items they "remember" (i.e., recollected items associated with autonoetic consciousness) and those they "know" (i.e., nonrecollected items involving noetic consciousness). In general, Tulving suggested that the contents of recollection vary along two dimensions including episodic trace information and semantic cue information. That is, the quality of conscious awareness accompanying overt memory performance is a function of the relationship between trace and cue information. Tulving (1989) provided neurophysiological support for the distinction between episodic versus semantic recollection via the measurement of regional cerebral blood flow (rCBF). During each 80sec trial in this study, participants were required to engage in either episodic or semantic covert retrieval. Episodic retrieval involved personally experienced events (e.g., a holiday or trip). Semantic retrieval was concerned with general, impersonal knowledge. The results revealed relatively greater activation of anterior cortical (i.e., frontal and temporal) regions during recollection of personal episodes. The retrieval of semantic material was associated with increased posterior (i.e., parietal and occipital) cortical activation. Frontal lobe involvement in episodic recollection was consistent with the impairment found in frontally damaged patients with respect to tasks requiring retrieval of temporally and spatially bound episodes (Squire, 1987). The results of Tulving (1989) therefore suggested that the neurophysiological correlates of conscious recollection vary as a function of the semantic versus episodic nature of the recollected material.

Recognition memory: Behavioural frameworks for the isolation of components

Several behavioural paradigms are currently widely employed as mechanisms for separating the component processes of recognition memory. These tasks include the process dissociation procedure (Jacoby, 1991), and the Remember/Know paradigm (Gardiner, 1988; Gardiner & Java, 1990; Tulving, 1985). Both approaches are founded on dual-process theories of memory retrieval which suggest that recognition decisions may be made on the basis of either conscious recollection of the target event, or feelings of familiarity in the absence of contextual details (Atkinson & Juola, 1974; Mandler, 1980, 1991). The development of these approaches was predicated on views suggesting that the analysis of dissociations between memory tests was limited due to the assumption that direct and indirect tests provide pure measures of explicit and implicit memory processes, respectively (Dunn & Kirsner, 1989; Jacoby, 1991; Reingold & Merikle, 1990). That is, these researchers argued that task dissociations are ambiguous as tasks may not provide process-pure measures of memory. For example, an indirect test (designed to measure implicit memory processes) may be contaminated by a conscious use of memory during performance (Richardson-Klavehn & Bjork, 1988). An advantage of these frameworks therefore is that they were designed to examine the effects of explicit and implicit memory within the same task, thus obviating the need for the restrictive assumption of process-purity within tasks. Prior to the dual-process models, recognition performance was entirely attributed to familiarity-based judgments (Mandler, 1980). The contribution of a retrieval component was strongly implicated following a demonstration by Mandler, Pearlstone, and Koopmans (1969) that recognition performance was positively related to organisational factors. Previous research indicated that although recall varies linearly with the number of categories used to organise a study list (e.g., Kintsch, 1968; Mandler, 1967), recognition was believed to be independent of organisational influences. Recognition was viewed as a fast matching process whereby the to-be-recognised item provided direct access to the memory trace. The results of Mandler et al. suggested that a recall-like component contributed to recognition decisions. Additional support for a retrieval process during recognition was provided by Juola, Fischler, Wood, and Atkinson (1971). These researchers varied the length of the study list and found that recognition decision times varied as a function of list length, thereby implicating the operation of a search (i.e., retrieval) process.

The development of the process dissociation procedure was based on the view that performance on recognition memory tests reflects both consciously controlled recollection, and automatic familiarity components (Jacoby, 1991). Conscious or controlled processes are purported to require intention and limited-capacity attentional resources, whereas automatic or unconscious processes are elicited by environmental stimuli thereby requiring minimal attentional resources (Posner & Schneider, 1975; Schneider & Shiffrin, 1977). The recall or recollection component is relatively sensitive to attentional manipulations and is purported to involve conscious or strategic control (Jacoby, 1991). Jacoby argued that via the process of recollection, participants are able to select either for or against test items depending on the task requirements. Jacoby and his colleagues (Jacoby, 1991; Jacoby, Lindsay, & Toth, 1992; Jacoby, Toth, & Yonelinas, 1993; Toth, Lindsay, & Jacoby, 1992) suggested that the separate contributions of recollection and familiarity to recognition memory performance can be quantified by contrasting test situations whereby both components positively contribute to recognition judgments with situations in which the components work in opposition. Jacoby, Woloshyn, and Kelley (1989) had provided support for the employment of opposition paradigms with respect to the measurement of unconscious memory influences using false-fame tasks. In this series of studies, participants read a list of nonfamous names which were later presented in a fame-judgment test together with famous and new nonfamous names. Participants were fully informed as to the nonfamous nature of the previously presented names. Recollection of these names at test would therefore correctly inform the participants as to their nonfamous nature. Jacoby et al. argued that incorrectly identifying an old (i.e., previously studied in phase 1) nonfamous name as famous must be the result of unconscious, nonrecollective memory influences. By opposing the effects of conscious recollection and automatic familiarity, Jacoby et al. indicated that they were able to isolate unconscious memory influences. In the context of recognition memory performance, the process dissociation procedure was initially described in Experiment 3 by Jacoby (1991). During phase 1 of this experiment participants were required to either read visually presented words or to solve anagrams. Anagrams are words which have had their letters rearranged. During phase 2, the participants repeated aurally presented words. Phase 3 involved a word recognition test which included words from both study phases together with nonstudied items. The recognition test was administered under two instruction conditions. In the *inclusion* condition participants were required to call a test item old if it had appeared in either of the study phases (i.e., the word had been earlier read, heard, or studied as an anagram). In the *exclusion* condition participants responded old only if the test word had been presented during phase 2 (i.e., the word had been earlier heard). Interest was focused on the subject's recognition of words studied during phase 1. Jacoby hypothesised that performance on the inclusion condition was mediated by both conscious and unconscious (automatic familiarity) processes. It was further suggested that these processes act in opposition under exclusion instructions, with familiarity processes facilitating and conscious recollective processes inhibiting recognition of phase 1 words.

Following Mandler (1980), Jacoby (1991) viewed recognition performance as being supported by the independent contributions of recollection and familiarity. Specifically, in the inclusion condition, the probability of correctly recognising a target item as old (O) from phase 1 is $O(I) = R + F - RF$. For the exclusion condition false recognition of phase 1 items was assumed to be on the basis of familiarity in the absence of recollection. The probability of incorrectly recognising a phase 1 word in this condition is $O(E) = F - RF$. Therefore, the probability of item recollection was estimated as $R = O(I) - O(E)$. The probability of responding on the basis of familiarity could subsequently be estimated as $F = O(E) / (1 - R)$.

In order to estimate the contributions of conscious (recollection) and unconscious (familiarity) processes using the formulae outlined above, Jacoby (1991) described three critical assumptions underlying his procedure. Violation of these assumptions would lead to inaccurate estimates of recollection and familiarity. Firstly, Jacoby assumed that familiarity is invariant across both instruction conditions. That is, the probability of recognising an item on the basis of familiarity is the same in the inclusion and exclusion conditions. The second assumption involves the similar invariance of recollective processes across the instruction conditions. Finally, familiarity and recollective processes were assumed to be stochastically independent. The first two assumptions entail the similar notion of the consistency of processes across conditions. However, previous research suggests that the type and amount of information retrieved in order to make memory judgments varies as a function of the type of test (e.g., Dodson & Johnson, 1993; Lindsay & Johnson, 1989). Specifically, Lindsay and Johnson (1989) employed a source monitoring task whereby participants were required to distinguish items that had been seen from items that had been read. These researchers found that source misattributions were more likely to occur during a recognition test than during a source monitoring task. Lindsay and Johnson interpreted this result in terms of variations in response criterion between the two tasks. That is, source monitoring tasks require greater reliance on the recollection of source identifying information relative to the recognition task. Dodson and Johnson (1996) argued that as the inclusion condition of the process dissociation procedure is in essence a yes/no recognition task whereas the exclusion condition is a list discrimination (i.e., source monitoring) task, the results of Lindsay and Johnson do not support Jacoby's (1991) consistency assumption.

A similar violation of consistency was reported by Komatsu, Graf, and Uttl (1995) who examined the invariance of familiarity assumption. In a variation of Jacoby's (1991) Experiment 3, Komatsu et al. manipulated the word frequency of items studied during phase 1. Relative to high-frequency items, words of low-frequency of occurrence in the language are subject to higher recognition accuracy (e.g., Glanzer & Bowles, 1976; Gorman, 1961; Kinsbourne & George, 1974). This effect has been attributed to the greater increment in familiarity (relative to baseline levels) of low-frequency words as a result of the presentation during the study phase (Humphreys, Bain, & Pike, 1989; Mandler, 1980). Moreover, high-frequency nonstudied items are more likely to be misrecognised due to the misattribution of a test item's familiarity to its study phase presentation (Glanzer & Adams, 1985). Variations in such misattributions can be achieved via instructional manipulations which vary the participants' recognition response criterion (Humphreys, 1976). Komatsu et al. hypothesised that the inclusion versus exclusion instructions result in the adoption of a more liberal response criterion. Consistent with this view, Komatsu et al. found that participants were more likely to falsely recognise nonstudied high-frequency words under inclusion, relative to exclusion, instructions. This result was therefore inconsistent with the invariance of familiarity assumption which predicts that familiarity response probabilities are similar across conditions.

Jacoby's (1991) third assumption regarding the independence of recollection and familiarity has been similarly questioned following a series word-stem completion experiments by Curran and Hintzman (1995). These authors argued that if recollection and familiarity are positively correlated, rather than independent, then the influence of familiarity will be underestimated to the extent of such correlation. That is, items associated with high recollection would also tend to be highly familiar. As the estimate of familiarity is based on items involving recollection failure in the exclusion condition, then familiarity is estimated on the basis of a biased set of items. These items will tend to elicit low levels of both recollection and familiarity. The application of Jacoby's formulae will therefore result in the underestimation of familiarity. The extent of this underestimation was expected to increase as recollection increased. To test this hypothesis Curran and Hintzman manipulated presentation duration during the study phase. Previous research had suggested that increasing study time enhances recollection, leaving automatic priming intact (e.g., Jacoby & Dallas, 1981). During testing, the participants were required to complete 3-letter stems with either previously studied words (inclusion condition) or new words (exclusion). In a series of five experiments it was found that presentation duration was positively related to estimates of recollection whereas familiarity was inversely associated with this variable. It was concluded that such artifactual dissociations between recollection and familiarity are a logical consequence of their nonindependence. In addition, Curran and Hintzman found a consistent pattern of item-based correlations across their experiments. In violation of the independence assumption, item-based correlations between estimates of recollection and familiarity were found to be significantly positive.

Further problems with the process dissociation procedure were outlined by Dodson and Johnson (1996). These authors examined Jacoby's (1991) view that familiarity automatically contributes to memory performance (Experiment 1), and that recollection occurs in an all-or-none fashion (Experiment 2). In Experiment 1, Dodson and Johnson employed a similar procedure to that used by Jacoby (1991, Experiment 3). However, the proportion of words that were heard, read, and solved as anagrams was manipulated between-subjects. Specifically, the two-thirds heard test condition included 60 items heard in phase 2, 15 items read in phase 1, and 15 items solved as anagrams in phase 1. In the one-third heard condition, each of the above test item categories contributed 30 items. Attention (divided versus full) was also a between-subjects factor. Dodson and Johnson hypothesised that if familiarity can be used in a controlled (as opposed to an automatic fashion) then participants may vary their recognition decisions in the exclusion condition as a function of the proportion of test items that were previously heard. That is, they would be less likely to identify an item as old on the exclusion task in the one-third heard condition relative to the two-thirds heard condition. The results were consistent with these predictions under conditions of full attention which suggested that familiarity can be an attention-demanding controlled process. This outcome was inconsistent with Jacoby's view of familiarity as an automatic process.

In their second experiment, Dodson and Johnson (1996) manipulated the similarity of the target items relative to studied nontarget items and measured the effect of this manipulation on the misrecollection of nontargets. This manipulation was accomplished during phase 2 by requiring participants to either listen to aurally presented words or to solve word fragments. The fragments were constructed by removing two letters from 5-letter nouns (e.g., "SW__D"). Dodson and Johnson reasoned that solving word fragments requires similar processes to solving anagrams. Therefore, following exclusion instructions, items solved as anagrams may be more likely to be misrecollected as items seen as word fragments than as heard items. Jacoby (1991) implied that recollection is an all-or-none process and that under no circumstances can errors result from recollective experiences. That is, participants either recollect the source of a studied item (i.e., that it was heard or seen as a word fragment during phase 2) or they do not recollect an item's source characteristics. However, Dodson and Johnson found that recollective misattributions on the exclusion condition were positively related to the similarity of target and nontargets. This result suggested that familiarity and recollection do not necessarily work in opposition on the exclusion test. Rather, both processes contributed to the false recognition of phase 1 items. The efficacy of Jacoby's formulae for the estimation of the contribution of recollection to recognition performances was therefore undermined.

In summary, several lines of research suggest that Jacoby's (1991) assumptions regarding recollective and familiarity components of recognition memory are overly restrictive. Moreover, Jacoby's view of familiarity as an exclusively unconscious automatic process is inconsistent with evidence that familiarity can be employed in a controlled fashion. This evidence seriously questions the applicability of the process dissociation framework.

An alternative approach that is purported to separate the components of recollection and familiarity has been developed by Gardiner and his associates (Gardiner, 1988; Gardiner & Java, 1990,1991, 1993; Gardiner & Parkin, 1990). This procedure was originally proposed by Tulving (1985) and requires participants to distinguish between *Remember* and *Know* responses following the recognition of a test item. Remember responses are those accompanied by specific contextual detail regarding the study episode (e.g., an evoked image or personal association elicited by the item at study). That is, Remember responses are associated with recollective awareness regarding any aspect of the encoding (i.e., study) event. Conversely, Know responses were assigned to items which were recognised on the basis of familiarity in the absence of recollective experience. Gardiner, Java, and Richardson-Klavehn (1996) have recently extended the range of options available to participants by including recognition decisions based on a guess. According to Gardiner, Remember responses are associated with explicit recollective processes while Know responses reflect implicit memory phenomenon. In a number of studies, Gardiner and his colleagues have presented evidence that the adoption of this introspective approach to memory provides a means of functionally dissociating subjective states of awareness during recognition performance. Independent variables which have been found to influence Remember responses while simultaneously leaving the proportion of Know responses unchanged include, generate versus read encoding instructions (Gardiner, 1988), retention interval (Gardiner & Java, 1991), word frequency (Gardiner & Java, 1990), levels of processing (Gardiner, 1988), and vocalisation versus silent reading at study (Gregg & Gardiner, 1991). The direction of the effect of these factors is consistent with the view that Remember responses reflect explicit (recollective) processes (Richardson-Klavehn & Bjork, 1988). Variables found to have opposing effects on the relative frequency of Remember and Know responses have also been reported. For example, Gardiner and Java (1990) indicated that relative to words, nonwords are associated with more Know and fewer Remember responses. In addition, Parkin and Walter (1992) found that elderly adults produce a higher proportion of Know responses.

The Remember/Know paradigm has however not escaped criticism as a means of exploring recollective and nonrecollective memory. Donaldson (1996) argued that the published data involving this procedure may be better understood if the mnemonic information is arrayed along a continuum along which participants establish decision criteria for both Remember and Know responses. According to Donaldson, a yes/no criterion distinguishes between old and new items. A second criterion partitions yes responses into strong (in terms of contextual detail retrieved) Remember, and weak Know responses. Donaldson accounted for recognition false positives by including a distribution involving new items along the same continuum as that for the old items. The proportion of this new-item distribution included in the areas of the old-item distribution relating to Remember and Know responses corresponded to the false alarm rates for these responses. On the basis of this strength model, Donaldson predicted that memory measures based on Know responses (which corresponds to the area between the decision criteria) will not be independent of the placement of the yes/no response criterion. That is, a positive correlation is expected between the estimate of Know memory and the conservatism of the decision criterion. He also predicted that measures of recognition memory based on Remember responses should not differ from those calculated on overall responses. This prediction was based on the idea that

Remember responses represent conservative yes responses and that recognition estimates such as d’ or A’ (which adjust hit rates for false alarm rates) are bias, or criterion, free (see Snodgrass & Corwin, 1988). Donaldson tested these predictions in a meta-analysis of published research and via an experiment involving the manipulation of the liberality of the participants’ response criteria through the use of confidence ratings. Donaldson demonstrated that previous research supporting dissociations between Remember and Know responses could be explained in terms of a strength model. That is, functional dissociations involving the effects of various independent variables and Remember versus Know responses were related to the decision criteria adopted by the participants. Moreover, the individual subject data exhibited similar relationships to those in the meta-analysis. Donaldson concluded that the introspective Remember/Know paradigm fails to accurately distinguish recollective from nonrecollective memory.

Event-related Potential Studies of Recognition Memory

The investigation of human memory via purely behavioural measures (e.g., reaction time and accuracy) provides an incomplete means of specifying the brain activity contributing to cognitive processes (Johnson, 1995). As behavioural dependent variables are manifested following the completion of sensory, cognitive, and motor processes, the determination of the relative processing times of these various components is problematic. In addition, behavioural measures provide information relating to neither the neuroanatomy of cognitive processes, nor to the question of their serial versus parallel temporal sequencing. Research involving event-related potentials (ERPs) can address the temporal sequencing and spatial extent of brain activation associated with covert mnemonic processes.

Neural activity underlying cognitive processing is associated with regular fluctuations in the brain's electrical fields which can be recorded via scalp electrodes (Kutas, 1988). ERPs are small voltage fluctuations in the brain's electrical activity that are synchronised (time-locked) to stimuli, responses, or environmental events. Due to the small size of these fluctuations relative to unsynchronised background activity (i.e., the electroencephalogram, or EEG), ERPs are obtained by averaging EEG samples involving repetitions of an eliciting event. The averaging process increases the signal-to-noise ratio by cancelling EEG fluctuations that are randomly temporally related to the event-related activity (Rugg, 1995). That is, over a large number of trials, electrical fluctuations that are unrelated to the current task tend to cancel when subjected to an averaging process. The resulting average ERP reflects activity that is consistently associated with task performance. A major strength of ERP methodology involves the capacity for real-time analysis. For example, the latency, amplitude, and scalp distribution of the ERP components can be tracked on a millisecond timebase. Due to their high temporal resolution relative to alternative neuroimaging techniques (e.g., fMRI, PET), ERPs are well suited to provide insights into the neural processes associated with the retrieval of information from long-term memory. ERPs are widely employed as a noninvasive measure of the physiological activity associated with cognitive function in the study of attention, language processing, and memory

(Johnson, 1995).

Memory retrieval processes have been extensively studied using ERP methodology. Numerous studies of memory retrieval measuring ERPs have demonstrated that brain electrical activity differs between *old* (i.e., previously studied) and *new* (i.e., previously unstudied) words during recognition memory testing (e.g., Curran, 1999, 2000; Friedman, 1990; Heit, Smith, & Halgren,1988,1990; Johnson, Pfefferbaum, & Kopell, 1985; Neville, Kutas, Chesney, & Schmidt, 1986; Paller & Kutas, 1992; Paller, Kutas, & McIsaac, 1995; Rugg, 1990; Rugg, Cox, Doyle, & Wells, 1995; Rugg & Doyle, 1992; Rugg & Nagy, 1989; Rugg, Schloerscheidt, & Mark, 1998; Sanquist, Rohrbaugh, Syndulko, & Lindsay, 1980; Smith, 1993; Smith & Guster, 1993; Wilding, Doyle, & Rugg, 1995; Wilding & Rugg, 1997). That is, ERPs involving words that are correctly recognised as old are more positive than ERPs to correctly rejected new words (for reviews, see Johnson, 1995; Rugg, 1995). This ERP *old/new effect* typically involves a posterior-maximum phasic positive shift which commences approximately 400-500 ms poststimulus onset and lasts for 400-600 ms. The effect is very robust, is morphologically similar across a variety of tasks, and has an asymmetric distribution in favour of left temporo-parietal electrode sites. That is, the effect is strongly lateralised in the left hemisphere which is consistent with neuropsychological evidence suggesting that long-term verbal memory predominantly relies on the left hemisphere (Smith, 1989). The old/new effect has not been observed with respect to both old items incorrectly rejected as new (misses), and new items incorrectly recognised as old (false alarms). Smith and Guster (1993) established that the old/new effect is unrelated to several potentially confounding variables, including the proportion of study items included in the test list and the target versus nontarget nature of previously studied words. In addition, the effect is not related to the necessity to assign old and new items to separate response classifications (Rugg, Brovedani, & Doyle, 1992). Several authors have noted that as the old/new effect precedes reaction time by several hundred milliseconds, it may reflect processes that are functionally related to recognition memory discriminability (e.g., Halgren & Smith, 1987; Smith & Guster, 1993). It has been further suggested that the effect represents neural activity associated with processes which are either contributing to, or contingent upon, the correct categorisation of previously experienced test items (Rugg, 1995). However, the precise nature of the cognitive processes associated with the old/new effect is currently not fully understood.

Functional interpretations of the old/new effect have been largely restricted to dual-process theories of recognition memory. As stated previously, dual-process models distinguish between two bases (i.e., sources of information) for making recognition judgments, including recollection and familiarity (Atkinson & Juola, 1973, 1974; Jacoby & Dallas, 1981; Hintzman & Curran, 1994; Mandler, 1980). Recollection has been conceptualised as the successful outcome of a conscious, effortful, search process. That is, the test item acts as a cue for the search for a recent episode involving that particular item. Successful retrieval of the event enables the subject to correctly identify the item as ‘old’ as the search process yields contextual information regarding the previous encounter with the item. In contrast, recognition based on familiarity is devoid of contextual detail regarding the target event. According to Mandler (1980), familiarity is an automatic (unconscious) process. Jacoby (1991) associated familiarity and recollection with implicit and explicit processes, respectively. Jacoby and colleagues further argue that familiarity based recognition decisions occur when a test item is processed relatively ‘fluently’ (Jacoby & Dallas, 1981; Whittlesea, 1993). According to this view, fluency-based recognition decisions are supported by processes related to those underlying priming and other manifestations of implicit memory (Schacter, 1992; Tulving & Schacter, 1990).

Rugg and his colleagues have argued that the old/new effect reflects the familiarity component of recognition memory (Rugg, 1990; Rugg & Doyle, 1992; Young & Rugg, 1992). This view is based on Rugg’s (1990) findings that the old/new effect was restricted to low- as opposed to high-frequency words. Rugg interpreted this outcome in terms of the greater relative increase in perceptual fluency of low- versus high-frequency words. That is, the frequency with which a word is experienced in the language has been found to be a strong determinant with respect to the processing efficiency of the particular word across a variety of cognitive tasks, including identification time (Forster, 1976) and lexical decision (Gordon, 1983, 1985). Low-frequency words tend to be associated with longer reaction times. Several researchers have argued that the effect of word frequency reflects the speed with which words ranging in frequency access their stored lexical representations (Forster, 1976; McClelland & Rumelhart, 1981). Perceptual fluency is a nonconscious process that involves the facilitation in the identification of recently encountered material (Jacoby & Dallas, 1981). Jacoby and Dallas proposed that the ease with which an item can be identified (i.e., perceptual fluency) is related to both word frequency and recency of presentation. Perceptual fluency of low-frequency words was postulated to increase to a relatively greater degree than high-frequency words following study, and that this increase in relative fluency leads to an experience of familiarity. However, the role played by perceptual fluency in recognition decisions is not clear. Several studies reported relatively spared recognition performance compared to recall in amnesic patients (Hirst et al., 1986; Hirst, Johnson, Phelps, & Volpe, 1988). These results are consistent with the view that amnesics are able to recognise test items on the basis of spared implicit (i.e., primed perceptual fluency) processes. Conversely, a recent evaluation of recall and recognition in amnesics over an extensive range of retention intervals revealed proportionate impairment of recognition relative to recall (Haist, Shimamura, & Squire, 1992). Moreover, amnesics have been found to perform at chance levels on recognition tests despite intact repetition priming (Cave & Squire, 1992; Squire, Shimamura, & Graf, 1985). These results are inconsistent with the view that recognition should be relatively spared in patients experiencing severe anterograde amnesia due to the contribution of implicit memory processes which may facilitate performance during a test of recognition memory.

An alternative interpretation of the old/new effect has however been proposed. For example, Gardiner and Java (1990), employing the Remember/Know procedure, found that the recognition advantage of low-frequency words was restricted to Remember responses. It was concluded that low-frequency words are subject to better recognition due to their higher levels of recollection. This conclusion is consistent with suggestions that the greater distinctiveness of low-frequency words may increase their level of attention at study (Gregg, 1976), or the degree of elaborative encoding they receive (Schmidt, 1991), which may enhance the probability of recollection of these items. Smith (1993) similarly investigated the source of the old/new ERP difference using the Remember/Know paradigm. Following a study phase, during which participants were required to classify words from a range of frequency classes as either “interesting” or “uninteresting”, a Remember/Know recognition test was presented. The results revealed that Remember items elicited greater positivity than Know items approximately 500 to 700 ms following word onset. Both Remember and Know items exhibited enhanced positivity relative to new items from 400 to 700 ms postword onset. Conversely, previously studied words that were not recognised did not exhibit the old/new effect. Smith therefore concluded that the ERP difference between correctly recognised and unrecognised old items was related to retrieval processes as opposed to an implicit priming process. As both classes of recognition responses were associated with old/new effects, Smith’s data are consistent with the operation of two memory-related processes. However, the similar scalp distribution of electrophysiological activity associated with Remember and Know responses suggests that these response categories do not isolate qualitatively different ERP effects. Smith suggested that the old/new effect may index the focus of consciousness on the product of the retrieval process. According to Smith, the quantitative (as opposed to qualitative) activity differences between Remember and Know responses may reflect the retrieval of less specific contextual information concerning the target study episode for Know, relative to Remember responses. This conclusion is consistent with the view that familiarity may involve explicit memory. The proposal that familiarity reflects implicit memory processes and should therefore be spared in amnesia has not gone unchallenged. Moscovitch (1992, 1994) has suggested that familiarity is an explicit process and therefore relies on medial temporal and midline diencephalic structures which support declarative memory. Moscovitch argues that both familiarity and recollection are consequent upon the successful retrieval of episodic information. However, recollection occurs when additional contextual detail surrounding the target event is both retrieved and integrated with the target item’s prior presentation. This integration process is dependent upon the prefrontal cortex. Familiarity is therefore viewed as the result of only partially successful retrieval of episodic information. However, given the criticisms levelled at the Remember/Know procedure in terms of the dependence of nonrecollective memory estimation on decision criteria, Smith’s (1993) data do not provide an unambiguous separation of the ERP waveforms associated with recollective and nonrecollective memory.

Smith and Halgren (1989) also argued that the old/new effect reflects recollective processes. These researchers obtained ERP recordings during a recognition task from patients who had undergone either left (L) or right (R), anterior temporal lobectomy (ATL), in addition to age- and education-matched control participants. The surgery involved unilateral removal of the hippocampal formation and associated cortical and limbic structures. Anatomical models of memory characterise these areas as critical for the formation of long-term memories (Squire,1992; Zola-Morgan & Squire, 1993). Smith and Halgren found that LATL patients were significantly impaired on recognition of repeatedly presented words relative to both control and RATL participants. In addition, the word-repetition effect on ERPs was observed in both the control and RATL groups. However, this effect was eliminated in the LATL group. As the LATL participants did exhibit a normal level of improvement in reaction time and accuracy across test blocks, Smith and Halgren concluded that the contribution of the familiarity component was intact in these participants. It has been argued that repeated exposure to items indexes the strength/familiarity component of the dual-process model (Atkinson & Juola, 1973; Mandler, 1980). Therefore, Smith and Halgren reasoned that the ERP old/new effect must reflect recollective experience.

Paller and Kutas (1992) examined the cognitive source of old/new ERP effects in the absence of recognition judgments. Participants were required to process words either semantically (i.e., by forming an image of each word), or nonsemantically (i.e., by counting the number of times the letter “e” appeared in each study item). All words were tested using an indirect perceptual identification task (i.e., identifying briefly presented words; 33 - 50 ms). The results revealed that the magnitude of repetition priming was unrelated to the encoding manipulation. However, recall and recognition were superior for imaged words relative to nonsemantically encoded words. These results were consistent with previous research (see Richardson-Klavehn & Bjork, 1988). Of prime interest in this study however was that ERPs evoked at test varied as a function of the study condition. Specifically, imaged words elicited more positive ERPs relative to new words between 400 and 800 ms postword onset. Moreover, ERPs to imaged words were significantly more positive than words from the orthographic task from 500 to 800 ms. A difference waveform was obtained by subtracting the activation associated with correctly identified words from the letter-counting task from the activity elicited by imaged words. This waveform exhibited laterality effects with a greater positivity over the left hemisphere. In addition, the deflection onset was 250 ms earlier at frontal locations. These characteristics of the difference waveform resembled previously described old/new ERPs (e.g., Neville et al., 1986; Rugg, 1995; Rugg & Doyle, 1992; Smith, 1993). Paller and Kutas concluded that as the words from the imagery task were subject to higher levels of recall and recognition, the difference waveform may be interpreted as an ERP template for conscious recollection of the study episode.

Paller, Kutas, and McIsaac (1995) (Experiment 2) employed a similar design to that reported by Paller and Kutas (1992), however participants in this ERP study were required to perform an indirect lexical decision task at test. That is, participants viewed a series of letter strings and decided as quickly as possible whether each string constituted an English word. The test items included equal proportions of orthographically and phonologically legal nonwords, words from the image task, words from a nonsemantic syllable counting task, and new nonstudied words. Paller et al. found that while recognition performance was influenced by the encoding condition, priming on the lexical decision task was not. Specifically, recognition accuracy was higher for words previously imaged whereas the degree of facilitation in lexical decision reaction time was similar for both categories of previously studied words relative to nonstudied items. The ERPs evoked at test were more positive for studied than for new words beginning approximately 300 ms postword onset. Following Paller and Kutas (1992), Paller et al. attempted to isolate the ERP correlate of recollective processes by comparing the activation associated with words from the syllable task with that evoked by words encoded during the image task. Between 500 and 800 ms after word onset, the ERP amplitude was larger for previously imaged words. This pattern of electrophysiological activity replicated the characteristics of the recollection template reported by Paller and Kutas (1992). Paller et al. similarly concluded that as this ERP effect mirrored the encoding task effect on recognition performance, it may be interpreted as an index of recollection. Ostensibly, this outcome attested to the robustness of the results outlined by Paller and Kutas, as the recollection template was not sensitive to the method of indirect testing employed.

Several criticisms may be raised regarding the conclusions reported by Paller and Kutas (1992) and Paller et al. (1995). Firstly, conscious recollection was not a prerequisite for successful perceptual identification or lexical decision at test. Although performance on indirect tests may be contaminated by explicit memory (e.g., Jacoby, 1991; Schacter, Bowers, & Booker, 1989), neither Paller and Kutas nor Paller et al. offered objective evidence that recollection occurred at the point of successful indirect test performance. Secondly, in order to obtain the recollection template, activity associated with orthographically encoded items was subtracted from that elicited from imaged words. However, the items previously studied via the orthographic task were subject to above-chance recognition performance. This waveform may therefore also include trials that involved recollection experiences during the latency regions examined by both Paller and Kutas, and Paller et al. Therefore, the resulting subtracted waveform may not provide a pure reflection of recollection-related activity.

Rugg, Schloerscheidt, Doyle, Cox, and Patching (1996) reported an alternative method for segregating recollected from nonrecollected items (see also, Donaldson & Rugg, 1999). In this study, the operational definition of recollection involved the ability to retrieve associative information relating to the test item. During the study phase, a series of unrelated word pairs was presented visually and participants were instructed to form the words into a meaningful sentence. At test, the first word from each pair was presented along with an equal number of nonstudied words. The participants were required to classify each item as old or new. For recognised items, the participants were further required to recall the item's study associate. Successful associative retrieval was regarded as evidence that recollection of the study episode occurred at the point of recognition. Rugg et al. argued that if the ERP old/new effect reflects successful episodic retrieval then the effect should be larger for items associated with recollection than for those that can be recognised but for which contextual detail cannot be retrieved. Rugg et al. suggested that the latter class of items may have been recognised on the basis of familiarity or partial recollection. The ERP results were consistent with these predictions. From approximately 400 ms postword onset the waveforms for recognised items (including recognised/recalled and recognised/unrecalled words) became more positive than the waveform for new items. Consistent with previous research, the old/new effect was maximal over the left temporo-parietal regions. Moreover, the effect was larger and more temporally sustained for ERPs elicited by recognised/recalled compared to recognised/unrecalled items. Rugg et al. concluded that the ERP old/new effect reflects successful episodic retrieval processes that are dependent on the medial temporal lobe.

The current series of experiments aim to further characterise the ERP correlates of recollection. Following Rugg et al. (1996), the two theoretical bases of recognition memory will be separated according to whether contextual information associated with correctly recognised test items can be retrieved. That is, recollection will be operationalised as the ability to recall the words associated with the correctly recognised test items during the study phase. Successful retrieval of contextual information accompanying recognised target items strongly suggests that recollection occurred during the recognition of the particular item. Conversely, retrieval failure despite successful recognition suggests that the recognition decision was based either on familiarity or incomplete recollection. That is, the recognition decision was made in the absence of complete recollection of the study episode. Waveform subtraction will be employed to isolate the ERP activity associated with recollection. This commonly used technique enhances the ability to associate patterns of activity with specific cognitive processes (Johnson, 1995). Specifically, the averaged waveform accompanying items subject to successful recognition but unsuccessful recall of the contextual material will be compared with both the new item ERP and the waveform involving test items subject to both successful recognition and contextual retrieval.

Evidence concerning the implicit versus explicit nature of familiarity-based recognition decisions may also be provided via an examination of the scalp distribution of activity associated with the two classes of recognition response. Smith (1993) found quantitative as opposed to qualitative differences in activity between familiarity- and recollection-based responses. This outcome was consistent with the view that familiarity reflects explicit processes (Moscovitch, 1992, 1994). In the proposed experiments qualitative differences between the classes of response will be revealed through interactions between electrode site and response class. It is possible that participants may treat the recognition task effectively as a cued-recall test. Such demand characteristics may influence the old/new effect. In order to explore the influence of demand characteristics, the order of administration of the recognition and recall tests will also be manipulated. Specifically, half of the participants (i.e., Experiments 1 and 3) will receive the recall test immediately following the recognition of a particular item, while the remaining participants (i.e., Experiments 2 and 4) will receive the recall test following the completion of the recognition test.

A further aim of this project is to further explore the boundary conditions associated with the old/new effect by examining the impact of manipulating the preexperimental semantic relationship between the study pairs on the pattern of old/new effects. This manipulation will require two sets of materials, including unrelated word pairs and weak associates. Varying the degree of cue-target semantic association may increase the extent to which the task relies on retrieval from long-term semantic memory. Following Tulving (1989) it is possible that the degree of semantic relatedness of the items will be positively related to the magnitude of the old/new effects involving recollected items. Conversely, unrelated word pairs may require a greater episodic retrieval contribution at test which may be reflected in greater frontal activity (e.g., Van Petten, Luka, Rubin, & Ryan, 2002). Temporal and spatial variations in the old/new effects for recollected items across these conditions will provide electrophysiological support for Tulving’s view regarding the functional distinction between episodic and semantic memory.

Confidence and EEG

Of additional interest in the current study is the question of the potential mediating effect of response confidence with respect to the magnitude of the old/new effect. Previous research suggests that decision confidence is positively associated with the magnitude of the P300 ERP component in a variety of cognitive tasks (see Hillyard, Squires, Bauer, & Lindsay, 1971; Rohrbaugh, Donchin, & Eriksen, 1974; Rushkin & Sutton, 1978). That is, more confident decisions are associated with a positive shift in the ERP record. In addition, Paller, Kutas, and Mayes (unpublished) obtained confidence measures during a recognition memory test of words. These researchers obtained ERPs by averaging separately as a function of response confidence. They found that words recognised with a greater degree of confidence elicited ERPs that were more positive than those based on ERPs formed from low confidence trials only. Although the ERP results obtained by Paller et al. were associated with the encoding phase of the recognition memory task, the results do suggest a positive association between response confidence and the EEG record. With respect to the test phase of a recognition memory test, to date, the most comprehensive examination of the potential influence of response confidence was conducted by Rugg and Doyle (1992). In this study, ERPs were recorded while participants performed a recognition memory test involving high- and low-frequency words. Half of these words had been presented previously in an incidental lexical decision task. Participants in this study were required to provide confidence ratings following each recognition decision. The results revealed that for low-frequency words, the ERP waveform associated with correctly recognised words deviated in a positive direction from the new item waveform in the post 500 ms stimulus onset latency region. The distribution of the effect was consistent with the previously reported old/new effect. Rugg and Doyle attempted to control for the potentially extraneous variable of response confidence by conducting a second analysis following the selection of confident responses only when forming the ERP waveforms for the critical response categories. The results revealed that the pattern and distribution of the old/new effect was not influenced by response confidence. That is, the pattern of ERP differences involving the recollected and new item waveforms was similar when the waveforms were formed using confident responses only when compared with the pattern observed when the waveforms pooled across confidence levels. It is possible however that given the limited range of response options available to the participants in the Rugg and Doyle study (i.e., *confident* versus *nonconfident*) that many trials involving new words that were associated with medium levels of response confidence were nevertheless assigned to the confident category. That is, it is possible that the new item and the recollected waveforms were confounded with response confidence despite the procedure employed by these researchers to control for this potentially confounding factor. Such contamination of confidence levels across the conditions employed in this study may have obscured any underlying EEG effects associated with variations in response confidence. When measuring response confidence, the current studies will therefore provide participants with a wider range of options regarding their level of confidence associated with each trial. That is, after each test trial, participants will be required to rate the confidence associated with their decision on a 3-point scale ranging from high confidence (i.e., 3) to low confidence (i.e., 1).

It is possible that the ERP old/new effect is at least partially mediated by the influence of response confidence. For example, if ERPs formed from recollected and new items vary with respect to average response confidence, then experimentally controlling for this potentially confounding factor may vary the pattern of ERP results typically observed in recognition memory paradigms, reviewed earlier. There is reason to suspect that such a confounding may be present given the various operational definitions of *recollection* employed in previous recognition memory ERP research. For example, in the study by Rugg et al. (1996), recollection was operationalised as the ability to both recognise a previously studied word and to correctly retrieve the item's study associate. Trials (and the associated ERP waveform) associated with these performance characteristics are likely to involve a high level of response confidence regarding the initial recognition decision. As the new item waveform is based on the average of *all* successfully rejected new items, the average level of response confidence for this waveform may be lower than that observed in the recollected ERP waveform, which is based on a restricted category of successful recognition trials. That is, the recollected waveform is formed from trials involving both successful recognition of the test item *and* retrieval of the studied associate. Such trials are likely to involve a high degree of confidence regarding the recognition decision. Alternatively, the new item waveform may be based on a greater number of trials associated with low response confidence regarding the status of previously unstudied test items. This argument is similarly applicable to the alternative paradigms employed by researchers to measure the construct of recollection (e.g., process dissociation and the Remember/Know task). For example, the operational definition of recollection according to the process dissociation procedure involves successful recognition of the test item *and* correct allocation of the item to its original encoding context. It is likely that such trials would involve a high level of confidence regarding the recognition decision at test.

The current experiments will examine the possible influence of response confidence by requiring participants to rate their recognition decisions during the test phase. ERPs will subsequently be derived using two approaches. Initially, ERPs will be formed without regard for the level of confidence associated with the decision. This approach is consistent with the current strategy undertaken in recent ERP recognition memory research. The second approach will involve controlling for the potential influence of confidence by restricting the selection of trials to those involving highly confident responses. Any difference observed in the pattern of ERP results (i.e., old/new effects) between these two approaches can therefore be attributed to the effect of differential response confidence between the critical categories employed in recognition memory ERP research (i.e., recollected versus new item waveforms).

Experiment 1

The primary aim of Experiment 1 was to replicate and extend the findings of Rugg et al. (1996) by examining the influence of response confidence in the context of the recognition/associative recall task. It was expected that the old/new effect would be replicated when ERP waveforms were formed without regard to the levels of response confidence. That is, the ERP waveform associated with recollected trials is expected to deviate in a positive direction from the new item waveform, particularly at left temporo-parietal electrode sites. It is also hypothesised that higher levels of reported confidence will be observed during recollected trials relative to new item trials. If differential levels of confidence *are* observed between the recollected and new item response categories, then controlling for this factor may serve to reduce the magnitude of the old/new effect, given the association between increasing confidence and positivity in the EEG record identified in previous research.

Method

Participants

Ten undergraduate students from the University of Southern Queensland participated in this experiment in return for course credit. Data from one subject was discarded due to equipment failure. The mean age of the remaining nine participants (seven of whom were female) was 24.2 years (range: 18 – 33 years). All participants were right-handed (as defined by writing hand), had normal or corrected-to-normal vision, and spoke English as their first language. Participants were tested individually and gave informed consent prior to participation. The study was approved by the USQ ethics committee.

Stimulus Materials and Presentation

The critical stimuli consisted of 200 word pairs of weak associates that were selected from the Palermo and Jenkins (1964) associative norms. For each pair, the probability that the cue (referred to as the A item) elicited the target (B) ranged from .005 to .015. An additional eight word pairs were selected according to the same selection criteria to act as buffer items in the study lists. Two hundred similarly open-class words were selected as foils (i.e., new words) during the recognition/recall test phase. All stimuli varied in length between four and six letters and ranged in frequency between 1 and 41 counts per million according to the Kucera and Francis (1967) corpus. The new items (mean 7.51 counts per million, range 1- 41) and the critical A items from the word pairs (mean 7.85, range 1 – 38) did not differ significantly with respect to word frequency, $t(398) = .41$, $p > .05$.

In addition to the experimental word lists, a practice list was also produced, following the same selection procedure as for the experimental lists. The practice stimuli included 16 word pairs, which were presented during the practice study phase, and 32 test items (including the 16 A items from the practice study phase and 16 foil items).

As Experiments 1 and 2 involved unrelated word pairs (following Rugg et al ., 1996) the AB pairs were rearranged such that the semantic and associative relationship between the words was essentially nonexistent. (The originally selected pairs of weak associates were employed during the study phases of Experiments 3 and 4.) The subsequent list of to-be-studied word pairs was held constant for all participants. That is, the word pairings did not vary across participants. The study and test stimuli are presented in the appendix. The 200 critical word pairs were then randomly allocated into one of four study lists. Each list contained 52 word pairs including 50 pairs that were randomly selected without replacement from the 200 critical pairs and 2 buffer pairs. That is, each study list began and ended with a buffer word pair. The order of presentation of the experimental stimuli during both the study and test phases was randomly determined for each subject. With respect to the test phase, although the presentation order of the stimuli (including new items and previously studied A items) was determined randomly, such determination was subject to the constraint that no more than three items of a particular class (i.e., new or A items) should be presented consecutively. The presentation order of the study lists was rotated across participants using the random starting order with rotation technique (see Shaughnessy & Zechmeister, 1997).

All stimuli were presented in central vision on a computer monitor as white upper-case letter strings on a black background. During each study phase, the 52 pairs in a particular study list were presented visually in the centre of the computer screen (e.g., “GLUE CHAIR”). Pairs were exposed for 5000 ms with a stimulus onset asynchrony of 6000 ms. Test trials began with a fixation point (i.e., “*”) that appeared in the centre of the screen for 500 ms terminating 100 ms prior to test word onset. The participants were instructed to fixate upon this point in anticipation of the forthcoming test item. The test item was then exposed for 300 ms followed by a blank screen (e.g., “GLUE”). A “?” appeared 2500 ms after word onset. The participants were instructed to withhold their response until the appearance of the “?”. At a viewing distance of approximately 60 cm, the study and test stimuli subtended a maximum vertical visual angle of approximately 0.8^{o}, and a maximum horizontal angle of approximately 1.9^{o}.

Procedure

Participants were initially fitted with an ERP recording cap (see below) and seated in front of the display monitor in a dimly lit recording room. Each subject participated in four study-test phases. During each study phase, the 52 pairs in a particular study list were presented visually in the centre of a computer screen (e.g., “GLUE CHAIR”). Participants were instructed to encode each target in the context of the cue (i.e., to remember the words as a pair), and were fully informed as to the nature of the subsequent recognition/recall tests. Participants were provided with the opportunity to practice both the study and test phases of the experiment using the 16 practice word pairs and the 32-item practice test.

The test phase associated with each study block occurred immediately following the study phase and involved the presentation of 100 single items, including 1 buffer and 99 experimental items. Each test block began with the buffer item which was a foil item. Responses involving buffer items were not included in the behavioural or ERP results. The participants were informed that 50 of the experimental items constituted the A words from the previously studied word pairs. The remaining test items had not been presented previously. The participants were required to verbally indicate whether each item had been presented during the study phase following the appearance of the “?” (i.e., “old” versus “new”). At this point, the participants were also required to indicate the degree of confidence associated with each recognition decision. Confidence ratings were provided on a 3-point scale, ranging from 3 (*highly confident*) to 1 (*low confidence*). For words judged old, the participants were further required to recall the item’s studied associate (e.g., “CHAIR”). If the studied associate could not be recalled, then the participants were instructed to respond “don’t know”. The participants’ responses were recorded by the experimenter. At the completion of each response, the experimenter initiated the next trial.

In order to maximise the signal-to-noise ratio of the ERP recordings (by minimising the number of trials containing artifact) it was requested that participants minimise muscle tension and eye movements during the test phase. Specifically, participants were requested to remain relaxed and as still as possible during the test trials and to restrict blinking to the period during which the question mark was displayed on the computer screen.

ERP Recording

Scalp EEG was recorded during the recognition test from 17 tin electrodes which were embedded in an elasticated head cap (Electro-cap). Electrode locations were based on the international 10-20 system (Jasper, 1958). The montage included three midline sites (Fz, Cz, Pz); left and right frontal (including Fp1/Fp2, F3/F4, and F7/F8); left and right central, C3/C4; left and right temporal, T5/T6; left and right parietal, P3/P4; and left and right occipital, O1/O2. All electrodes were referred to linked earlobes. The EOG was recorded bipolarly from two additional electrodes placed on the outer canthus of the left eye and above the supraorbital ridge of the right eye. Interelectrode impedance levels were maintained below 5 kΩ and all channels (i.e., including both EEG and EOG) were amplified with a bandpass of 0.03 Hz to 37 Hz (3 dB points). On-line sampling was at a rate of 5 ms per point for a duration of 1200 ms, commencing 100 ms prior to stimulus presentation. When forming ERPs, trials on which one or more channels exhibited baseline drift (i.e., the difference between the first and the last data point during the baseline recording epoch) greater than 100 μV, or on which base-to-peak EEG or EOG amplitude exceeded 100 μV were excluded prior to averaging. Six percent of trials were subsequently deleted from the analysis in Experiment 1 (*SD* = 5). Following previous researchers (e.g., Donaldson & Rugg, 1998, 1999; Paller & Kutas, 1992, Paller et al., 1995; Rugg & Doyle, 1992; Rugg et al., 1996; Rugg et al., 1998) with respect to the maintenance of an acceptable signal-to-noise ratio, a minimum of 16 artifact-free trials were required from each subject in order to form an ERP for each critical response category.

Results

Across all four experiments, both behavioural and ERP data were analysed using repeated measures ANOVA. The degrees of freedom associated with each F ratio were adjusted by the Geisser-Greenhouse correction procedure which aims to protect against Type I error associated with violations of homogeneity of covariance (Howell, 1997; Keselman & Rogan, 1980), and corrected degrees of freedom are reported. Homogeneity of covariance was assessed using the Mauchly sphericity test (see Tabachnick & Fidell, 1996). Pairwise comparisons were performed using Tukey's HSD test and involved a familywise significance level of $p < .05$.

Behavioural data

Table 1 presents the behavioural performance data across the four experiments. As can be seen in Table 1, participants in Experiment 1 correctly recognised a mean of 83% of the previously studied words in the recognition test (i.e., the A items from the studied word pairs), and made false alarms to 19% of the new test items. Eighty one percent of the new items were correctly rejected. The participants correctly recalled 29% of the B items (i.e., the study associates of the A items) following the successful recognition of the test item. The remaining trials attracted a "don't know" response. The discrimination measure '$P_{hit} - P_{false\ alarm}$' (see Snodgrass & Corwin, 1988) indicated that participants were able to identify previously studied test items at a performance level which was significantly above the chance level of .50, $t(8) = 2.68$, $p < .05$.

Table 1 also presents the mean confidence levels associated with the three critical response categories (i.e., recognised/recalled, recognised/unrecalled, and new items). From Table 1 it can be seen that recognised/recalled items attracted the highest level of reported confidence ($M = 2.99$, $SD = 0.01$) while new items were associated with the lowest level of confidence ($M = 2.26$, $SD = 0.57$). Intermediate levels of confidence were reported in the recognised/unrecalled category ($M = 2.62$, $SD = 0.19$). A repeated measures ANOVA was conducted in order to assess the reliability of differences in response confidence across the various response categories. The analysis employed the factor of response category (new vs. recognised/recalled vs. recognised/unrecalled) and the results revealed a significant effect involving this factor, $F(1.18, 9.44) = 11.07$, $p < .05$. Subsequent testing revealed that the recognised/recalled items exhibited significantly higher confidence levels than both new items, $t(8) = 3.88$, $p = .005$, and recognised/unrecalled items, $t(8) = 5.81$, $p < .001$. New items and recognised/unrecalled items did not differ significantly with respect to response confidence, $t(8) = 1.99$, $p > .05$.

ERP Data: Pooled Across Confidence

Across all four experiments, separate averaged ERPs were obtained from trials associated with the following performance characteristics: (a) successful cue recognition, given successful recall of the target (recognised/recalled); (b) successful cue recognition, given unsuccessful recall of the target (recognised/unrecalled); and (c) successful rejection of new items (new). These

ERPs were initially formed without regard to the level of confidence associated with the recognition decisions for each trial. In Experiment 1, the mean number of trials contributing to the grand averaged ERPs was 44 (range, 16 – 96), 86 (56 – 135), and 149 (94 – 186) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. No subject in this series of experiments provided a sufficient number of artifact-free trials involving the incorrect identification of new words as old (i.e., false alarms). Therefore, the question of the presence of old/new effects involving false alarms cannot be addressed in this study.

In order to preserve comparability with previous research concerned with the ERP parietal old/new effect (e.g., Rugg & Doyle, 1992; Rugg et al., 1995; Rugg et al., 1996; Rugg et al., 1998; Wilding & Rugg, 1996), the ERPs were quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of two successive latency regions, including 500 - 800 ms and 800 – 1100 ms poststimulus onset. Table 2 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 1, while Table 3 presents similar descriptive statistics with respect to the 800 – 1100 ms latency region. Figure 1 presents the grand averaged ERP waveforms, collapsed across confidence levels, from electrode sites in Experiment 1. As can be seen in Table 2 and Figure 1, recollected items (i.e., recognised/recalled items) elicited an ERP that diverged in a positive direction from the ERP elicited by new items. This effect was evident at all electrode locations, but was most pronounced at left posterior sites (i.e., left temporo-parietal, including P3, C3, T5, and O1) and posterior midline sites (i.e., Cz and Pz). At frontal locations the effect was markedly smaller in magnitude and exhibited a bilateral distribution, as opposed to the left greater than right asymmetry seen at posterior sites. The ERP involving recognised/unrecalled items also exhibited a positive-going shift relative to new items at posterior electrode

sites (see Table 2). Across all experiments, the data from both latency regions were analysed using repeated measures ANOVA, which was conducted separately on the data from midline and lateral electrode sites. Global ANOVAs involving the lateral electrode sites employed the within-subjects factors of response category (recognised/recalled vs. recognised/unrecalled vs. new), hemisphere (left vs. right), and electrode site (frontal vs. posterior). Global ANOVAs involving the midline electrode sites employed the factors of response category (recognised/recalled vs. recognised/unrecalled vs. new) and electrode site (Fz vs. Cz vs. Pz). Main effects involving the factors of hemisphere and site are not reported as they do not relate to the aims of the study, unless they interact with the factor of response category. That is, significant effects that do not involve the factor of response category are not reported. Pairwise comparisons involving the levels of the response category factor were conducted using Tukey’s HSD test to control familywise error at .05 (Howell, 1997).

500-800 ms latency region. ANOVA of the 500-800 ms recording epoch revealed a significant main effect for the response category factor at lateral electrode sites, $F(1.93, 15.41) = 4.05$, $p < .05$. Although the descriptive statistics presented in Table 2 suggest that the size of the old/new effect (i.e., the difference between recognised/recalled and new ERP waveforms) was larger at left-posterior electrode sites (relative to right-posterior sites), the interaction between response category and hemisphere was not significant, $F(1.93, 15.47) = 1.74$, $p = .21$. The second-order interaction involving the factors of response category, hemisphere,

and site was also not significant, $F(1.47, 11.79) = 2.38$, $p > .05$. However, a significant interaction was found between the factors of response category and electrode site, $F(1.73, 13.87) = 6.20$, $p < .05$. As is evident from Table 2, this result reflects the fact that the magnitude of the old/new effect was considerably larger at posterior electrode sites when compared with frontal sites. Subsidiary ANOVAs revealed no reliable effect of response category at either left-frontal, $F(1.89, 15.16) = 0.53$, $p > .05$, or right-frontal electrode sites, $F(1.52, 12.18) = 1.81$, $p > .05$. However, ANOVAs restricted to posterior sites revealed significant effects of response category at both left-posterior, $F(1.70, 13.60) = 8.63$, $p < .05$, and right-posterior electrode sites, $F(1.34, 10.75) = 5.07$, $p < .05$. Subsequent pairwise comparisons indicated that the recognised/recalled waveform was more positive than the correct rejection waveform at both left-posterior, $F(1, 8) = 14.06$, $p < .01$, and right-posterior sites, $F(1, 8) = 5.43$, $p < .05$. The recognised/unrecalled waveform was also more positive than the new item waveform at both left-posterior, $F(1, 8) = 8.94$, $p < .05$, and right-posterior sites, $F(1, 8) = 5.90$, $p < .05$.

Comparisons between the recognised/recalled and recognised/unrecalled waveforms revealed no significant effects at either left- or right-posterior sites.

The global ANOVA involving the midline data resulted in a significant main effect involving the response category factor, $F(2, 16) = 3.77$, $p < .05$. The interaction between response category and site was not significant, $F(1.54, 12.34) = 2.53$, $p > .05$. The significant effect of response category reflected the greater positivity of the recognised/recalled waveform relative to the new item waveform (see Table 2). Follow-up pairwise comparisons revealed that the recognised/recalled waveform differed significantly from both the recognised/unrecalled, $F(1, 8) = 5.68$, $p < .05$, and the new item waveform, $F(1, 8) = 9.47$, $p < .05$.

800-1100 ms latency region. From Table 3 it can be seen that the correct rejection waveform tended to be more positive than the recognised/recalled waveform during the 800-1100 ms poststimulus onset recording epoch. Notwithstanding this tendency, the global ANOVA involving the lateral electrode sites for the 800-1100 ms recording epoch revealed no significant main effect for the response category factor, $F(1.51, 12.11) = 1.96$, $p > .05$. The first-order interaction effects involving the factors of response category and hemisphere, $F(1.51, 12.09) = 0.36$, $p > .05$, and response category and site, $F(1.71, 13.68) = 2.90$, $p > .05$, were also not significant. Moreover, no second-order interaction involving the three factors was revealed by the analysis, $F(1.67, 13.33) = 0.35$, $p > .05$. However, ANOVA involving the midline data revealed a significant main effect for the response category factor, $F(1.43, 11.44) = 10.31$, $p < .01$. In addition, the interaction between response category and site was also significant with respect to midline sites, $F(2.16, 17.29) = 13.33$, $p < .001$. As can be seen in Table 3 these results reflect the fact that both the recognised/recalled (i.e., recollected) waveform and the recognised/unrecalled waveform tended to be more negative than the new item (i.e., correct rejection) waveform, especially at posterior midline electrode sites (i.e., Cz and Pz) during the 800-1100 ms recording period. The recognised/recalled and recognised/unrecalled waveforms did not differ significantly at either Cz, $t(8) = 1.61$, $p > .05$, or Pz, $t(8) = 1.83$, $p > .05$.

ERP Data: Controlling for Confidence

In order to control for the potentially confounding influence of response confidence, ERPs were again formed into the three critical response categories. However, when forming the ERPs, only highly confident artifact-free responses were included. With respect to the correct rejection ERP, only eight participants provided a sufficient number of trials in order to form a sufficiently reliable waveform (i.e., 16 trials). The mean number of trials contributing to the grand averaged ERPs for highly confident responses was 43 (range, 16 – 95), 63 (30 – 107), and 83 (23 – 165) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. The ERPs were again quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of the two successive latency regions (i.e., 500 - 800 ms and 800 – 1100 ms poststimulus onset). Table 4 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 1, while Table 5 presents similar data relating to the 800 – 1100 ms latency region. Figure 2 presents the grand averaged waveforms, formed from highly confident trials, from electrode sites in Experiment 1. This data was also subjected to repeated measures ANOVA using the factors of response category, site, and hemisphere (with respect to lateral electrodes), and response category and site (with respect to midline electrodes).

500-800 ms latency region. From Table 4 (see also Figure 2) it can be seen that the positive shift associated with the recognised/recalled waveform, relative to the new item ERP, is no longer evident. As outlined previously, this positive shift was statistically reliable with respect to the data that was pooled across response confidence. However, ANOVA of the 500-800 ms data comprising highly confident responses revealed no significant main effect for the response category factor, $F(1.69, 13.51) = 0.21$, $p > .05$. In addition, the first-order interaction effects between response category and site, and response category and hemisphere were also not significant, $F(1.70, 13.58) = 3.00$, $p > .05$; and $F(1.93, 15.43) = 0.20$, $p > .05$, respectively. The second-order interaction between response category, site, and hemisphere was not significant, $F(1.15, 9.16) = 1.21$, $p > .05$.

ANOVA involving the midline electrode sites indicated that the neither the main effect of response category nor the interaction between response category and site were significant, $F(1.43, 10.03) = 0.26$, $p > .05$; and $F(1.60, 11.20) = 0.86$, $p > .05$, respectively.

800-1100 ms latency region. The descriptive statistics presented in Table 5 suggest that the recognised/recalled waveform deviates in a negative direction from that associated with the new item waveform during the 800-1100 ms poststimulus recording epoch. The global ANOVA of this data revealed a significant main effect of response category, $F(1.45, 10.12) = 8.84$, $p < .01$. The interaction between response category and site was also statistically significant, $F(1.95, 13.65) = 6.54$, $p < .05$. Neither the first-order interaction between response category and hemisphere nor the second-order interaction between response category, site, and hemisphere achieved significance, $F(1.05, 7.35) = 0.01$, $p > .05$; and $F(1.23, 8.63) = 1.12$, $p > .05$, respectively. Follow-up ANOVAs restricted to frontal sites revealed no significant influence of the response category factor at either left- or right-frontal electrode sites, $F(1.6, 11.21) = 2.45$, $p > .05$; and $F(1.85, 12.98) = 1.39$, $p > .05$, respectively. However, similar ANOVAs restricted to posterior sites revealed a reliable effect of the response category factor at both left- and right-posterior sites, $F(1.88, 13.19) = 10.70$, $p < .01$; and $F(1.69, 11.81) = 22.75$, $p < .001$, respectively. Follow-up pairwise comparisons involving the levels of response category revealed that the recognised/recalled waveform differed significantly from the new item waveform at both left-, $F(1, 7) = 17.72$, $p < .01$, and right-posterior sites, $F(1, 7) = 32.38$, $p < .001$. That is, the recognised/recalled waveform was significantly more negative than the new item waveform at both posterior electrode sites during the 800-1100 ms recording epoch, after controlling for response confidence. The recognised/unrecalled waveform was also significantly more negative than the new item waveform at both left-posterior, $F(1, 7) = 9.01$, $p < .05$, and right-posterior sites, $F(1, 7) = 40.32$, $p < .001$. However, the recognised/recalled and recognised/unrecalled waveforms did not differ significantly at either posterior electrode site.

The global ANOVA involving the midline sites revealed a significant main effect for the response category factor, $F(1.71, 11.97) = 14.00$, $p < .001$, and a significant interaction between response category and electrode site, $F(2.63, 18.42) = 8.07$, $p < .01$. As is evident in Table 5, the significant main effect of response category arose due to the increased negativity of the recognised/recalled waveform relative to the new item waveform. The significant interaction reflected the fact that this increased negativity was more pronounced at posterior sites (i.e., Cz and Pz, see Table 5). Follow-up comparisons revealed that the recognised/recalled waveform differed significantly from the new item waveform at both Cz, $F(1, 7) = 23.42$, $p < .01$, and Pz, $F(1, 7) = 36.6$, $p < .001$. However, these waveforms did not differ significantly at the midline frontal location, Fz, $F(1, 7) = 3.38$, $p > .05$. The recognised/recalled and recognised/unrecalled waveforms did not differ significantly at either Cz, $t(8) = 1.29$, $p > .05$, or Pz, $t(8) = 2.27$, $p > .05$.

Discussion

The level of recognition performance indicated that participants in Experiment 1 were able to reliably discriminate between previously studied and new items.

Behavioural performance measures, such as the rate of successful recognition and the rate of successful recall of the studied associate, were similar to those reported in previous research involving the recognition/associative recall task (e.g., Donaldson & Rugg, 1999; Rugg et al., 1996). The proportion of recognised words associated with correct recall (i.e., 29%) was somewhat lower than that reported by both Rugg et al. (i.e., 36% correct recall) and Donaldson and Rugg (i.e., 49% correct recall). This difference is likely due to the larger number of study pairs involved in the current study. That is, the current design involved 196 word pairs during the study phase, which is substantially higher than both Rugg et al. and Donaldson and Rugg with 128 and 100 study pairs, respectively. In addition, the false alarm rate observed in the current study (and across all four experiments, as can be seen in Table 1) was higher than the rate of 6% which was reported by Rugg et al. The relatively low rate of false positives reported by Rugg et al. may be due to the provision of a "don't know" response option to participants in this study. From the perspective of the dual-process theories of memory (Atkinson & Juola, 1973; 1974; Mandler, 1980, 1991; Moscovitch, 1992, 1994), successful recognition performance in the current study was based on veridical information concerning the study episode which was derived from either the successful retrieval of the study phase episode involving the test item (i.e., recognised/recalled trials involving *recollection*) or from partial retrieval of the study episode (i.e., recognised/unrecalled trials involving *familiarity*).

As predicted, the ERP results of the current experiment indicated that the recognised/recalled waveform deviated in a positive direction relative to the new item waveform during the 500 - 800 ms poststimulus onset period. This result is consistent with the findings reported by Rugg et al. (1996) using a similar recognition/associative recall task during the test phase of the experiment. The effect was observed when ERPs for the experimental conditions were formed irrespective of the level of response confidence associated with each trial. The effect was most pronounced at posterior electrode sites. Although the effect was absent during the 800 -1100 ms poststimulus onset recording period, the distribution of the old/new effect observed in the current experiment corresponds with that of previously reported recognition memory parietal old/new effects (Rugg, 1995). As outlined in the introduction, evidence concerning the implicit versus explicit nature of familiarity-based recognition decisions may be provided via an examination of the scalp distribution of activity associated with the two classes of recognition response (i.e., recognised/recalled and recognised/unrecalled). Smith (1993) found quantitative as opposed to qualitative differences in activity between familiarity- and recollection-based responses. This outcome was consistent with the view that familiarity reflects explicit processes (Moscovitch, 1992, 1994). The current data provides further support for this view as the distribution of the old/new effects associated with the recognised/unrecalled ERP waveform relative to the new item ERP was similar to that observed with respect to the recollected versus new item ERPs.

In general, the pattern of ERP results obtained in Experiment 1 conforms with those observed previously in a variety of recognition memory paradigms (e.g., Curran, 1999, 2000; Friedman, 1990; Johnson et al., 1985; Paller & Kutas, 1992; Paller et al., 1995; Rugg, 1990; Rugg et al., 1995; Rugg & Doyle, 1992; Rugg & Nagy, 1989; Rugg et al., 1996; Rugg et al., 1998; Sanquist et al., 1980; Smith, 1993; Smith & Guster, 1993; Wilding et al., 1995; Wilding & Rugg, 1997). More specifically, ERP results similar to those observed in the current study have been reported previously in recognition memory studies which have operationalised recollection as the ability to retrieve contextual details regarding the initial encoding of the test item (e.g., Rugg et al., 1996; Wilding et al., 1995; Wilding & Rugg, 1996). For example, Rugg et al. (1996) operationalised recollection as the ability to both recognise a previously studied word, and to retrieve it's studied associate. Rugg et al. found that relative to new words, these *recognised/recalled* words elicited an ERP that deviated in a positive direction at posterior electrode sites between 500-800 ms poststimulus onset. This effect was more pronounced at left temporo-parietal electrode locations. In addition, Wilding et al. (1995) operationally defined recollection as the ability to both recognise a test item as having been previously studied and assign the particular item to it's correct encoding context (i.e., modality of presentation during the study phase). The results of this study were similar to those reported by Rugg et al. and to those observed in the current study. ERPs for correctly recognised words which also satisfy the operational definition requirements for *recollection* to have taken place, tend to deviate positively from the ERP associated with new words from approximately 500 ms poststimulus onset. This effect is more pronounced at posterior electrode sites, and in particular, left temporo/parietal sites. Although the present data revealed no reliable difference between the magnitude of the old/new effect at left-posterior and right-posterior electrode sites, the pattern of descriptive statistics suggests that the effect was lateralised to the left hemisphere. Therefore, the failure to observe a significant interaction between the factors of hemisphere and response category in this study may represent a Type II error. Alternatively, during the encoding phase, many participants in the current study reported using a visual imagery strategy to form associations between the word pairs. Previous ERP studies involving the recognition/associative recall task have involved encoding tasks that are more likely to result in verbal strategies. For example, participants in the Rugg et al. study were required to combine the members of each word pair into a meaningful sentence. Given that the posterior parietal cortex is essential for the encoding of visuospatial information (particularly in the right hemisphere) (Fuster, 1995), and that right inferotemporal cortex has been implicated in visual memory (Milner, 1958), participants employing a strategy of visual imagery may exhibit an old/new effect which is lateralised in the *right* hemisphere. As the current results were averaged across all subjects, it seems not unreasonable that no interaction was observed between the factors of response category and hemisphere if encoding strategies varied across subjects. Future replication and extension of the current design involving, for example, direct manipulation of the encoding task, is therefore necessary in order to establish the reliability of the current result.

The present findings are consistent with the view proposed by Rugg et al. (1996) that when recollection is operationally defined as successful associative recall, within the context of a recognition memory test, the magnitude of the parietal old/new effect varies according to whether successful recollection has occurred. In Experiment 1, the descriptive pattern of the ERP waveforms during the 500-800 ms poststimulus period is consistent with the position of Rugg et al. as the old/new effect was consistently larger with respect to the recognised/recalled waveform compared with the recognised/unrecalled waveform (although the inferential pairwise contrasts indicated that these waveforms were not consistently different). Rugg et al. concluded that when operationalising recollection via an associative recall task, the parietal old/new effect is dependent upon successful recollection in a similar manner to that observed when recollection is operationalised as the ability to retrieve contextual details regarding the original study experience (Wilding & Rugg, 1996; Wilding et al., 1995).

The current study revealed no evidence of the late sustained positivity, maximal at right frontal electrode locations which was reported by Wilding and Rugg (1996) using a source memory task. In this respect, the current results are consistent with those reported by Rugg et al. (1996). Rugg et al. adopted a similar methodology to that employed in the current study and found no right frontal ERP component. Rugg et al. further suggested that, relative to the parietal old/new effect, the right frontal ERP component is more sensitive to task-related factors. These authors suggested that the right frontal effect reflects post-retrieval functions which are selectively involved during contextual discrimination tasks. This view is supported by research indicating that prefrontal cortical lesions selectively impair memory for contextual information (e.g., source memory) as opposed to associative information (e.g., performance on the paired associate subtest of the Weschler Memory Scale) (Janowsky, Shimamura, & Squire, 1989; Stuss, Eskes, & Foster, 1994). The current results also support this conclusion. However, Donaldson and Rugg (1999, Experiment 2) *did* find a late positive shift at right frontal electrode sites. This effect was not evident until 1400 ms poststimulus onset. These researchers employed a similar recognition/associative recall task to that used in the current experiment. One of the limitations of the current experiments involves the restricted recording epoch of 1100 ms. Future research should aim to replicate this finding by extending the recording epoch beyond the 1400 ms poststimulus interval.

Late Negative Wave

As stated previously, analysis of the 800 - 1100 ms data revealed no evidence of the parietal old/new effect. In this respect, the current result is consistent with the findings of Rugg et al. (1996). However, during this recording epoch, a negative shift was observed at posterior electrode sites with respect to both classes of recognised items (i.e., the recognised/recalled and recognised/unrecalled) relative to the new item waveform. This effect was maximal at midline central and parietal electrode sites(i.e., Cz and Pz). A similar negative shift with an identical spatial distribution has been previously identified by Rugg et al. (1996) using a similar recognition/associative recall task to that employed in the current study. Moreover, using a source memory task, both Rugg et al. (1998) and Wilding and Rugg (1997) reported a similar late negative shift with respect to recollected items relative to new items. Wilding and Rugg reported that the amplitude of the negative-going wave covaried with mean reaction time rather than the study status of the eliciting item. The negative shift was also most pronounced in ERPs elicited by false alarms. In addition, Rugg et al. (1996) suggested that as the effect did not differ between the recognised/recalled and recognised/unrecalled waveforms, it can be distinguished from the temporally overlapping parietal old/new effect. Both Rugg et al. (1996) and Rugg et al. (1998) suggested that the functional significance of the effect may be due to response-related factors such as variability in reaction time across the different classes of test item as opposed to mnemonic factors.

Response Confidence and the Old/New Effect

The previous discussion involved the analysis of ERP waveforms formed without regard for the level of response confidence associated with each trial. As very few studies explicitly incorporate a measure of response confidence, this strategy is consistent with previous research involving the old/new ERP effect in recognition memory. However, analysis of the behavioural data involving the levels of response confidence across the various conditions in the current study (i.e., recognised/recalled, recognised/unrecalled, and new) indicated that confidence levels varied reliably across the conditions. That is, trials involving both correct recognition of the test item and successful retrieval of the item's studied associate were associated with substantially higher levels of response confidence than trials involving the successful identification of new items. (The confidence level associated with the recognised/unrecalled waveform was midway between the new item and recognised/recalled waveform across all four experiments, as can be seen in Table 1.) This result indicates that the new item waveform included many trials involving low levels of response confidence. As can be seen in Table 1, the mean confidence rating for the recognised/recalled category was extremely high across all four experiments with all means exceeding 2.90 on the 3-point confidence rating scale. This suggests that almost every trial contributing to the recognised/recalled waveform attracted the highest possible confidence rating. Therefore, in the current study, reliable differences in response confidence found between the experimental conditions indicate that the factor of condition is *confounded* with response confidence. After experimentally controlling for the potentially mediating effect of response confidence by forming ERPs for the various conditions from highly confident responses only, the pattern of ERP results differs from those described in the previous section. That is, when the analyses were restricted to highly confident responses only, the pattern of ERP results from the current experiment differed from those reported previously. No evidence of the parietal old/new effect was observed with respect to either the 500-800 ms or the 800-1100 ms poststimulus recording epoch. However, the late negative shift associated with recollected items was more pronounced when ERPs were formed from highly confident trials only.

The pattern of ERP results observed in the current experiment differed from those reported by Rugg and Young (1992). In one of the few studies involving the influence of response confidence, Rugg and Young found that, in a recognition memory test for low-frequency words, the magnitude of the ERP old/new effect was not reduced when ERP waveforms for the response conditions were formed exclusively from confident responses. The contrasting pattern of ERP results observed in Experiment 1 may be due to the different methods used to operationalise response confidence between these studies. When compared with the results reported by Rugg and Young, the current data suggests that the use of 3-option measurement of the subject's response confidence provides a more precise measure of this construct. That is, participants in the study by Rugg and Young were simply required to categorise each response as either *confident* or *nonconfident*. It is possible that many responses in the *confident* category included both trials involving the conscious recollection of the study episode (which the ERP in this category purports to measure) *and* trials involving a sense of familiarity without conscious recollection. The resulting ERP formed from these trials may therefore not provide a pure measure of recollection. The current results indicate that when participants are able to more precisely define their degree of confidence at the point of recognition (by providing a wider variety of response options) and

ERPs can be formed which control for differential confidence levels across experimental conditions, then the old/new effect is not evident.

The current results cannot be generalised beyond the recognition/associative recall task and future research involving alternative recognition memory paradigms is required in order to establish the external validity of the influence of response confidence on the magnitude of the parietal old/new ERP effect. However, as outlined previously, there is reason to suspect that such a confounding of response confidence and experimental condition may have been present in earlier research involving the ERP old/new effect, given the various operational definitions of *recollection* employed. For example, Rugg et al. (1996) employed a similar methodology to the current study. These researchers operationalised recollection as the ability to both recognise a previously studied word and to correctly retrieve the item's study associate. Trials (and the associated ERP waveform) associated with these performance characteristics are likely to involve a high level of response confidence during the initial recognition decision. The new item waveform is based on the average of *all* successfully rejected new items. Therefore, the average level of response confidence for this ERP waveform may be lower than that for the recollected waveform, which is based on a restricted category of successful recognition trials. Specifically, the recollected waveform is formed from trials involving both successful recognition of the test item *and* retrieval of the studied associate. These trials are likely to involve a high degree of confidence in terms of the recognition decision. The new item waveform however, may be based on a greater number of trials involving low response confidence with respect to the status of previously unstudied test items. The reliable difference in confidence between the recollected and new item waveforms observed in the current study, supports this view. This argument is similarly applicable to the alternative paradigms employed by researchers to measure the construct of recollection (e.g., process dissociation and the Remember/Know task). For example, the operational definition of recollection according to the process dissociation procedure involves successful recognition of the test item *and* correct allocation of the item to its original encoding context. For test items identified as *old*, Rugg et al. (1998) required participants to indicate in which of two voices items had been presented during the study phase. It is likely that such trials would involve a high level of confidence regarding the recognition decision at test.

In summary, the results of the current study suggest that response confidence is an important factor with respect to the magnitude of the old/new ERP effect. As outlined in the introduction, Experiment 2 was designed to replicate and extend Experiment 1 by investigating whether the recognition memory old/new effect and the potential effect of response confidence are influenced by the delayed recall of the studied associate. That is, the experimental design of Experiment 1 was modified so that the requirement to retrieve the studied associate of test items judged old was delayed until the completion of the recognition test.

Experiment 2

Method

Participants

Seven undergraduate students from the University of Southern Queensland participated in this experiment in return for course credit. The mean age of the participants (including five females) was 25.1 years (range: 18 – 34 years). All participants were right-handed (as defined by writing hand), had normal or corrected-to-normal vision, and spoke English as their first language. Testing was conducted individually and all participants gave informed consent prior to participation. The study was approved by the USQ ethics committee.

Stimulus Materials and Presentation

Stimulus materials were identical to those utilised in Experiment 1. The presentation of the experimental stimuli during the recognition test was also as for Experiment 1. During the delayed recall test, previously studied A items were presented in central vision on a computer monitor as white upper-case letter strings on a black background. A different random presentation order of the A items was determined for each participant. Test trials began with the presentation of the test item for 300 ms followed by a blank screen. EEG was not recorded during these trials.

Procedure

Procedural conditions during the study phase and the recognition test were similar to Experiment 1 with the single exception that participants were not required to retrieve the studied associate of recognised items during the recognition test. The delayed recall test occurred immediately following the recognition test. For each test item, the participants were required to recall the item's studied associate. If the studied associate could not be recalled, then the participants were instructed to respond "don't know". The experimenter recorded all participants' responses. Following the completion of each response, the experimenter initiated the next trial.

ERP Recording

EEG recording and artifact detection procedures were similar to those described previously in Experiment 1. A mean of 11% of trials were rejected due to artifact detection in Experiment 2 (*SD* = 9).

Results

Behavioural data

Participants in Experiment 2 correctly recognised a mean of 90% of the previously studied words in the recognition test (i.e., the A items from the studied word pairs), correctly rejected 83% of the new items, and made false alarms to 17% of the new test items. The participants correctly recalled 33% of the B items (i.e., the study associates of the A items) following the successful recognition of the test item, with the remaining trials attracting a "don't know" response. An independent-samples t-test revealed that the level of recall did not differ between Experiments 1 and 2, $t(14) = -.99$, $p > .05$. The discrimination measure '$P_{hit} – P_{false\ alarm}$' (see Snodgrass & Corwin, 1988) indicated that participants were able to identify previously studied test items at a performance level which was significantly above the chance level of .50, $t(6) = 4.87$, $p < .01$. Table 1 also presents the mean confidence levels associated with the three critical response categories (i.e., recognised/recalled, recognised/unrecalled, and new items). From Table 1 it can be seen that recognised/recalled items attracted the highest level of reported confidence ($M = 2.93$, $SD = 0.10$) while new items were associated with the lowest level of confidence ($M = 2.25$, $SD = 0.29$). The level of reported confidence in the recognised/unrecalled category ($M = 2.58$, $SD = 0.13$) was midway between the remaining response categories. A repeated measures ANOVA was conducted in order to assess the reliability of differences in response confidence across the various response categories. The analysis employed the factor of response category (new vs. recognised/recalled vs. recognised/unrecalled) and the results revealed a significant effect involving this factor, $F(1.60, 9.61) = 42.70$, $p < .001$. Subsequent testing revealed that the recognised/recalled items exhibited significantly higher confidence levels than both new items, $t(6) = 8.25$, $p < .001$, and recognised/unrecalled items, $t(6) = 6.65$, $p = .001$. New items and recognised/unrecalled items also differed significantly with respect to response confidence, $t(6) = 4.06$, $p < .01$.

ERP Data: Pooled Across Confidence

Separate averaged ERPs for the response categories were initially formed without regard to the level of confidence associated with the recognition decisions. The mean number of trials contributing to the grand averaged ERPs was 72 (range, 21 – 116), 48 (29 – 61), and 122 (72 – 174) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. As in Experiment 1, ERPs were quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of two successive latency regions, including 500 - 800 ms and 800 – 1100 ms poststimulus onset. Table 6 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 2, while Table 7 presents similar descriptive statistics with respect to the 800 – 1100 ms latency region. Figure 3 presents the grand averaged waveforms, collapsed across confidence levels, from electrode sites in Experiment 2. As can be seen in Table 6 and Figure 3, recollected items (i.e., recognised/recalled items) elicited an ERP that diverged in a positive direction from the ERP elicited by new items. This effect was evident at all electrode locations, but was most pronounced at left posterior sites (i.e., left temporo-parietal, including P3, C3, T5, and O1) and posterior midline sites (i.e., Cz and Pz). At frontal locations the effect was markedly smaller in magnitude and exhibited a bilateral distribution, as opposed to the left greater than right asymmetry seen at posterior sites. The ERP involving recognised/unrecalled items also exhibited a positive-going shift relative to new items at posterior electrode sites (see Table 6).

500-800 ms latency region. ANOVA of the 500-800 ms recording epoch revealed a significant main effect for the response category factor at lateral electrode sites, $F(1.89, 11.34) = 4.16$, $p < .05$. Although the descriptive statistics presented in

Table 6 suggest that the size of the old/new effect (i.e., the difference between recognised/recalled and new ERP waveforms) was larger at left-posterior electrode sites (relative to right-posterior sites), the interaction between response category and hemisphere was not significant, $F(1.62, 9.70) = 1.00$, $p > .05$. The second-order interaction involving the factors of response category, hemisphere, and site was also not significant, $F(1.36, 8.18) = 0.36$, $p > .05$. However, a significant interaction was found between the factors of response category and electrode site, $F(1.41, 8.48) = 31.17$, $p < .001$. As is evident from Table 6, this result reflects the fact that the magnitude of the old/new effect was considerably larger at posterior electrode sites when compared with frontal sites. Subsidiary ANOVAs revealed no reliable effect of response category at either left-frontal, $F(1.77, 10.63) = 1.90$, $p > .05$, or right-frontal electrode sites, $F(1.87, 11.20) = 3.42$, $p > .05$. However, ANOVAs restricted to posterior sites revealed significant effects of response category at both left-posterior, $F(1.90, 11.40) = 6.42$, $p < .05$, and right-posterior electrode sites, $F(1.81, 10.84) = 8.31$, $p < .01$. Subsequent pairwise comparisons indicated that the recognised/recalled waveform was more positive than the correct rejection waveform at both left-posterior, $F(1, 6) = 10.40$, $p < .05$, and right-posterior sites, $F(1, 6) = 12.75$, $p < .05$. The recognised/unrecalled waveform did not differ significantly from the new item waveform at both left-posterior, $F(1, 6) = 4.23$, $p > .05$, and right-posterior sites, $F(1, 6) = 4.24$, $p > .05$. Comparisons between the recognised/recalled and recognised/unrecalled waveforms revealed no significant effects at either left- or right-posterior sites.

The global ANOVA involving the midline data resulted in a significant main effect involving the response category factor, $F(1.61, 9.64) = 5.74$, $p < .05$. The interaction between response category and site was also significant, $F(2.38, 14.28) = 3.90$, $p < .05$. The significant effect of response category reflected the greater positivity of the recognised/recalled waveform relative to the new item waveform (see Table 6). The significant interaction between response category and site reflects the fact that the greater positivity associated with the recognised/recalled waveform was more pronounced at posterior midline sites (i.e., Cz and Pz).

800-1100 ms latency region. Table 7 presents the descriptive statistics relating to the critical response categories during the 800-1100 ms poststimulus onset recording epoch. The global ANOVA involving the lateral electrode sites for the 800-1100 ms recording epoch revealed no significant main effect for the response category factor, $F(1.43, 8.58) = 1.00$, $p > .05$. The first-order interaction effects involving the factors of response category and hemisphere, $F(1.66, 9.93) = 0.87$, $p > .05$, and response category and site, $F(1.54, 9.25) = 0.20$, $p > .05$, were also not significant. However, the second-order interaction involving the three factors was statistically significant, $F(1.58, 9.51) = 7.89$, $p < .05$.

ANOVA involving the midline data revealed no significant main effect for the response category factor, $F(1.37, 8.21) = 0.92$, $p > .05$. In addition, the interaction between response category and site was also not significant, $F(1.98, 11.87) = 1.10$, $p > .05$.

ERP Data: Controlling for Confidence

In order to control for the potentially confounding influence of response confidence, ERPs were again formed into the three critical response categories. However, when forming the ERPs, only highly confident artifact-free responses were included. The mean number of trials contributing to the grand averaged ERPs for highly confident responses was 68 (range, 21 – 114), 30 (21 – 38), and 53 (16 – 106) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. The ERPs were again quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of the two successive latency regions (i.e., 500 - 800 ms and 800 – 1100 ms poststimulus onset). Table 8 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 2. Table 9 presents similar data relating to the 800 – 1100 ms latency region, while Figure 4 presents the grand averaged waveforms, based on highly confident responses, from electrode sites in Experiment 2. This data was also subjected to repeated measures ANOVA using the factors of response category, site, and hemisphere (with respect to lateral electrodes), and response category and site (with respect to midline electrodes).

*500-800 ms latency region***.** ANOVA of the 500-800 ms data comprising highly confident responses revealed no significant main effect for the response category factor, $F(1.40, 8.37) = 0.45$, $p > .05$. In addition, the first-order interaction effects between response category and site, and response category and hemisphere were also not significant, $F(1.71, 10.26) = 0.10$, $p > .05$; and $F(1.30, 7.82) = 3.48$, $p > .05$, respectively. The second-order interaction between response category, site, and hemisphere was not significant, $F(1.28, 7.7) = 1.18$, $p > .05$. In addition, ANOVA of the midline electrode sites revealed no significant effect of response category, $F(1.42, 8.53) = 0.67$, $p > .05$, and no interaction between response category and site, $F(1.62, 9.72) = 0.06$, $p > .05$.

800-1100 ms latency region. The descriptive statistics presented in Table 9 suggest that the recognised/recalled waveform deviates in a negative direction from that associated with the new item waveform during the 800-1100 ms poststimulus recording epoch. The main effect of the response category factor was not significant, $F(1.67, 10) = 0.54$, $p > .05$. The interaction between response category and site was also not statistically significant, $F(1.61, 9.69) = 1.37$, $p > .05$. Moreover, neither the first-order interaction between response category and hemisphere nor the second-order interaction between response category, site, and hemisphere achieved significance, $F(1.38, 8.30) = 1.61$, $p > .05$; and $F(1.72, 10.32) = 3.55$, $p > .05$, respectively. The global ANOVA involving the midline sites revealed no significant main effect of the response category factor, $F(1.79, 10.72) = 0.56$, $p > .05$, and no significant interaction between response category and electrode site, $\underline{F}(1.12, 12.70) = 3.34$, $\underline{p} > .05$.

Discussion

As in Experiment 1, participants in Experiment 2 were able to discriminate between previously studied and new test items at above chance levels. The level of recognition performance and the rate of successful recall of the studied associate, were similar to those reported in Experiment 1 and in related previous research (e.g., Donaldson & Rugg, 1999; Rugg et al., 1996). Although the descriptive statistics in Table 1 suggests that the level of successful recall of the B items was higher in Experiment 2 than in Experiment 1 (i.e., 33% vs. 29%), these measures were not reliably different. Dual-process theories of memory suggest that successful recognition of the test items in Experiment 2 was based on information concerning the study episode (Atkinson & Juola, 1973; 1974; Mandler, 1980, 1991; Moscovitch, 1992, 1994). Dual-process theories suggest that this information was derived from either a sense of conscious recollection of the study episode (operationalised via recognised/recalled trials) or from a sense of familiarity regarding the test item associated with partial retrieval of the study phase (recognised/unrecalled trials).

As expected, the ERP results of Experiment 2 replicated those observed in Experiment 1 with respect to the 500-800 ms poststimulus recording interval. At posterior electrode sites, the recognised/recalled waveform deviated in a positive direction relative to the new item waveform during this recording period. This result is consistent with Rugg et al. (1996) despite the change in methodology between Experiment 2 and Rugg et al. That is, the participants in the current study were not required to recall the studied associate of test items identified as old during the recognition test phase. The pattern of ERP results was observed when waveforms were formed irrespective of the level of response confidence for each trial. As in Experiment 1, the effect was most pronounced at posterior electrode sites and the topographical distribution of the old/new effect corresponds with that of previously reported recognition memory parietal old/new effects (see Johnson, 1995; Rugg, 1995).

Examination of the scalp distribution of EEG activity associated with the two classes of recognition response may provide evidence concerning the implicit versus explicit nature of familiarity-based recognition decisions. Consistent with the results of Smith (1993) who found a similar pattern but greater magnitude of the old/new effects for recollection-based responses relative to familiarity-based responses, the current data revealed a similar distribution of the old/new effects associated with the recognised/unrecalled and recognised/recalled ERP waveforms. This outcome is consistent with the view that familiarity reflects explicit processes (Moscovitch, 1992, 1994).

The pattern of ERP results observed in Experiment 2 is consistent with those reported previously in recognition memory research (e.g., Curran, 1999, 2000; Friedman, 1990; Johnson, Pfefferbaum, & Kopell, 1985; Paller & Kutas, 1992; Paller et al., 1995; Rugg, 1990; Rugg, Cox, Doyle, & Wells, 1995; Rugg & Doyle, 1992; Rugg & Nagy, 1989; Rugg et al., 1996; Rugg et al., 1998; Sanquist, Rohrbaugh, Syndulko, & Lindsay, 1980; Smith, 1993; Smith & Guster, 1993; Wilding et al., 1995; Wilding & Rugg, 1997).

Late Negative Wave

As was the case in Experiment 1, analysis of the 800 - 1100 ms data revealed no evidence of the parietal old/new effect. In this respect, the current result is consistent with the findings of Rugg et al. (1996). In addition, the results of Experiment 2 revealed no evidence of the negative shift at posterior electrode sites with respect to both classes of recognised items (i.e., the recognised/recalled and recognised/unrecalled) relative to the new item ERP waveform. The current results are therefore inconsistent with those observed Experiment 1 and those previously reported by Rugg et al. (1996) using a similar recognition/associative recall task to that employed in the current study. The results of Experiment 2 suggest that methodological differences across studies may account for the variability in findings related to the late negative wave. The only methodological difference between the present study and relevant previous studies (e.g., Rugg et al., 1996; Rugg et al., 1998; Experiment 1) was that during the recognition test in Experiment 2, the participants were not required to retrieve the studied associate of recognised test items. One of the aims of Experiment 3 and 4 therefore is to replicate and extend the results of Experiments 1 and 2 in the context of weakly semantically related word pairs. If a similar pattern of results is observed in Experiments 3 and 4 then this would suggest that the methodological differences are more likely to account for the discrepant findings involving the late negative wave.

Response Confidence and the Old/New Effect

Analysis of the levels of response confidence across the levels of the response category data indicated that confidence levels differed significantly across the conditions. Trials involving both correct recognition of the test item and successful retrieval of the item's studied associate involved higher levels of reported response confidence than trials involving the successful identification of new items. The new item waveform therefore included many trials involving low levels of response confidence. Significant differences in response confidence found between the experimental conditions in Experiment 2 indicate that the factor of condition is *confounded* with response confidence.

After forming ERPs for the response conditions using highly confident responses only, the pattern of ERP results differed from those reported previously. No evidence of the parietal old/new effect was observed with respect to either the 500-80 ms or the 800-1100 ms poststimulus recording epoch. This result is consistent with that observed in Experiment 1. Moreover, no evidence of the late negative shift observed in Experiment 1 was found after controlling for confidence.

In support of the findings of Experiment 1, the ERP results in Experiment 2 differed from those reported by Rugg and Young (1992). These researchers found that the size of the ERP recognition memory old/new effect was unaffected by the experimental control of response confidence. As outlined previously, the conflicting pattern of ERP results between these studies may be due to the different operational definitions of response confidence. Participants in the study by Rugg and Young categorised each response as either *confident* or *nonconfident*. Given the relatively constrained range of response options available, it is possible that many responses in the *confident* category included both trials involving the conscious recollection of the study episode (which the ERP in this category purports to measure) *and* trials involving a sense of familiarity without conscious recollection. The resulting ERP formed from these trials may therefore not provide a pure measure of recollection. The current results indicate that when participants are able to more precisely define their degree of confidence at the point of recognition (by providing a wider variety of response options) and ERPs can be formed which control for differential confidence levels across experimental conditions, then no evidence of the old/new effect is found.

In summary, the results of Experiment 2 further support the view that response confidence is an important mediating factor in terms of the magnitude of the old/new ERP effect. An additional aim of Experiment 2 was to investigate whether the delayed recall of the studied associate influences the recognition memory old/new effect. As can be seen in Table 6, the pattern of ERP effects during the 500-800 ms poststimulus recording epoch was similar to that observed in Experiment 1. That is, when ERP waveforms were formed without regard to response confidence, the recognised/recalled waveform deviated in a positive direction from the new item waveform during the 500-800 ms recording period. However, during the 800-1100 ms recording epoch, the late negative shift observed in Experiment 1 was absent. Therefore, Experiment 3 aims to replicate and extend Experiment 1 by employing weakly semantically related word pairs with a view to further exploring the boundary conditions of the recognition memory old/new effect. If the effect of response confidence is robust then it is expected that the pattern of ERP results will replicate those observed in Experiment 1. With respect to the emergence of the late negative wave, if the requirement to retrieve the studied associate at the point of recognition is the important determinant, then the negative shift should be observed in Experiment 3.

Experiment 3

Method

Participants

Ten undergraduate students from the University of Southern Queensland participated in this experiment in return for course credit. The mean age of the participants (six of whom were female) was 22.8 years (range: 17 – 33 years). All participants were right-handed (as defined by writing hand), had normal or corrected-to-normal vision, and spoke English as their first language. All participants were tested individually and gave informed consent prior to participation. The study was approved by the USQ ethics committee.

Stimulus Materials and Presentation

The critical stimuli consisted of the 200 word pairs of weak associates that were selected from the Palermo and Jenkins (1964) associative norms. For each pair, the probability that the cue (referred to as the A item) elicited the target (B) ranged from .005 to .015. Buffer, practice, and new items were identical to those utilised in previous experiments. Stimulus presentation conditions during the recognition/recall test were identical to those described previously in Experiment 1.

Procedure

Procedural conditions during the study phase and the recognition/recall test were similar to those described in Experiment 1.

ERP Recording

EEG recording and artifact detection procedures were identical to those employed in Experiment 1. A mean of 11% of trials were rejected due to artifact detection in Experiment 3 ($SD = 12$).

Results

Behavioural data

Table 1 presents the behavioural performance data across the four experiments. Participants in Experiment 3 correctly recognised a mean of 88% of the previously studied words in the recognition test (i.e., the A items from the studied word pairs). Participants correctly rejected 84% of new test items and made false alarms to 16% of these items. The participants correctly recalled 53% of the B items. The level of recall was significantly higher than that reported previously for both Experiment 1 ($t[17] = 3.62$, $p < .05$), and Experiment 2 ($t[15] = 2.59$, $p < .05$). The discrimination measure '$P_{hit} - P_{false\ alarm}$' (see Snodgrass & Corwin, 1988) indicated that participants were able to identify previously studied test items at above the chance level of .50, $t(9) = 4.45$, $p < .01$.

Table 1 also presents the mean confidence levels associated with the three critical response categories (i.e., recognised/recalled, recognised/unrecalled, and new items). The recognised/recalled items attracted the highest level of reported confidence (M = 2.98, SD = 0.02) while new items were associated with the lowest level of confidence (M = 2.23, SD = 0.42). Intermediate levels of confidence were reported in the recognised/unrecalled category (M = 2.43, SD = 0.30). A repeated measures ANOVA was conducted in order to assess the reliability of differences in response confidence across the various response categories. The analysis employed the factor of response category (new vs. recognised/recalled vs. recognised/unrecalled) and the results revealed a significant effect involving this factor, $F(1.31, 9.17) = 32.50$, $p < .001$. Subsequent testing revealed that the recognised/recalled items exhibited significantly higher confidence levels than both new items, $t(9) = 5.82$, $p < .001$, and recognised/unrecalled items, $t(7) = 8.44$, $p < .001$. New items and recognised/unrecalled items also differed significantly with respect to response confidence $t(7) = 2.70$, $p < .05$.

ERP Data: Pooled Across Confidence

Separate averaged ERPs were obtained from trials associated with the following performance characteristics: (a) successful cue recognition, given successful recall of the target (recognised/recalled); (b) successful cue recognition, given unsuccessful recall of the target (recognised/unrecalled); and (c) successful rejection of new items (new). These ERPs were initially formed without regard to the level of confidence associated with the recognition decisions. The mean number of trials contributing to the grand averaged ERPs was 78 (range, 25 – 180), 53 (20 – 92), and 123 (58 – 193) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. With respect to the recognised/unrecalled waveform, only eight participants contributed a sufficient number of artifact-free trials (i.e., 16) in order to form a sufficiently reliable ERP. Again, the ERPs were quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of two successive latency regions, including 500 - 800 ms and 800 – 1100 ms poststimulus onset. Table 10 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 3, while Table 11 presents similar descriptive statistics with respect to the 800 – 1100 ms latency region. Figure 5 presents the ERP waveforms, collapsed across confidence levels, from electrode sites in Experiment 3. As can be seen in Table 10 and Figure 5, recollected items elicited an ERP that diverged in a positive direction from the ERP elicited by new items at posterior electrode sites. This effect was most pronounced at left posterior sites (i.e., left temporo-parietal, including P3, C3, T5, and O1) and posterior midline sites (i.e., Cz and Pz). The data from both latency regions were analysed using repeated measures ANOVA, which was conducted separately on the data from midline and lateral electrode sites. Global ANOVAs involving the lateral electrode sites employed the within-subjects factors of response category (recognised/recalled vs. recognised/unrecalled vs. new), hemisphere (left vs. right), and electrode site (frontal vs. posterior). Global ANOVAs involving the midline electrode sites employed the factors of response category (recognised/recalled vs. recognised/unrecalled vs. new) and electrode site (Fz vs. Cz vs. Pz).

500-800 ms latency region. ANOVA of the 500-800 ms recording epoch revealed a significant main effect for the response category factor at lateral electrode sites, $F(1.65, 11.57) = 5.45$, $p < .05$. The recognised/recalled waveform was more positive than the new item waveform. The interaction between response category and site was also significant, $F(1.90, 13.28) = 4.48$, $p < .05$. The descriptive statistics presented in Table 10 suggest that this interaction arose due to the fact that the size of the old/new effect (i.e., the difference between recognised/recalled and new ERP waveforms) was larger at posterior electrode sites (relative to frontal sites). The interaction between response category and hemisphere was not significant, $F(1.44, 10.07) = 2.46$, $p > .05$. The second-order interaction involving the factors of response category, hemisphere, and site was also not significant, $F(1.83, 12.83) = 0.54$, $p > .05$.

Subsidiary one-way ANOVAs revealed no reliable effect of response category at either left-frontal, $F(1.51, 10.60) = 1.42$, $p > .05$, or right-frontal electrode sites, $F(1.69, 11.82) = 0.44$, $p > .05$. Subsidiary ANOVAs involving the effect of response category restricted to posterior sites revealed a significant effect of this factor at both left-posterior, $F(1.41, 9.90) = 12.00$, $p < .01$, and right-posterior electrode sites, $F(1.96, 13.75) = 4.03$, $p < .05$. Subsequent pairwise comparisons indicated that the recognised/recalled waveform was more positive than the correct rejection waveform at both left-, $F(1, 9) = 31.14$, $p < .001$ and right-posterior electrode sites, $F(1, 9) = 14.51$, $p < .01$. The recognised/unrecalled waveform was also significantly more positive than the new item waveform at the left-posterior, $F(1, 7) = 5.81$, $p < .05$, but not the right-posterior site, $F(1, 7) = 2.79$, $p > .05$. Similarly, the recognised/recalled ERP was significantly more positive than the recognised/unrecalled waveform at the left-posterior site, $F(1,7) = 11.29$, $p < .05$, but not the right-posterior recording site, $F(1, 7) = 1.21$, $p > .05$.

The global ANOVA involving the midline data revealed a significant main effect involving the response category factor, $F(1.88, 13.17) = 4.11$, $p < .05$. The interaction between response category and site was not significant, $F(2.14, 14.97) = 2.73$, $p > .05$. Subsequent pairwise comparisons revealed that the recognised/recalled waveform was significantly more positive-going than both the recognised/unrecalled, $F(1, 7) = 3.95$, $p < .05$, and the new item waveforms, $F(1, 7) = 4.77$, $p < .05$.

800-1100 ms latency region. From Table 11 it can be seen that the recognised/recalled waveform tended to be more negative than the correct rejection waveform during the 800-1100 ms recording epoch. However, the global ANOVA involving the lateral electrode sites for the 800-1100 ms recording period revealed no significant main effect for the response category factor, $F(1.66, 11.59) = 2.86$, $p > .05$. The first-order interaction effects involving the factors of response category and hemisphere, $F(1.16, 8.13) = 1.33$, $p > .05$, and response category and site, *F*(1.78, 12.47) = 2.49, *p* > .05, were also not significant. Moreover, no second-order interaction involving the three factors was revealed by the analysis, *F*(1.93, 13.48) = 3.28, *p* > .05. However, ANOVA involving the midline data revealed a significant main effect for the response category factor, *F*(1.68, 11.79) = 5.38, *p* < .05. The interaction between response category and site was not significant, *F*(2.35, 16.44) = 1.29, *p* > .05. As can be seen in Table 11 these results reflect the fact that both the recognised/recalled and the recognised/unrecalled waveforms tended to be more negative than the new item (i.e., correct rejection) waveform during the 800-1100 ms recording period at midline sites. The recognised/recalled and recognised/unrecalled waveforms were not significantly different at either Cz, *t*(7) = -.17, *p* > .05, or Pz, *t*(7) = .04, *p* > .05.

ERP Data: Controlling for Confidence

ERPs were again formed into the three critical response categories using only highly confident artifact-free responses. With respect to the correct rejection ERP, nine participants provided a sufficient number of trials in order to form a sufficiently reliable waveform (i.e., 16 trials). Ten participants contributed to the recognised/recalled waveform, while eight participants provided sufficient trials for a sufficiently reliable recognised/unrecalled ERP. The mean number of trials contributing to the grand averaged ERPs for highly confident responses was 76 (range, 25 – 180), 29 (16 – 41), and 55 (19 – 178) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. The ERPs were again quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of the two successive latency regions (i.e., 500 - 800 ms and 800 – 1100 ms poststimulus onset). Table 12 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 3, while Table 13 presents similar data relating to the 800 – 1100 ms latency region. Figure 6 displays the ERP waveforms involving highly confident responses from electrode sites in Experiment 3. This data was subjected to repeated measures ANOVA using the factors of response category, site, and hemisphere (with respect to lateral electrodes), and response category and site (with respect to midline electrodes).

500-800 ms latency region. From Table 12 it can be seen that no consistent pattern of differences are evident across the critical response categories. Accordingly, ANOVA of the 500-800 ms data comprising highly confident responses revealed no significant main effect for the response category factor, $F(1.41, 8.47) = 0.25$, $p > .05$. In addition, the first-order interaction effects between response category and site, and response category and hemisphere were also not significant, $F(1.34, 8.04) = 4.15$, $p > .05$; and $F(1.45, 8.71) = 0.82$, $p > .05$, respectively. The second-order interaction between response category, site, and hemisphere was also not significant, $F(1.49, 8.92) = 0.22$, $p > .05$.

ANOVA involving the midline data revealed that the main effect of response category was not significant, $F(1.27, 7.59) = 0.21$, $p > .05$. The interaction between response category and site was also not significant, $F(2.46, 14.75) = 2.83$, $p > .05$.

800-1100 ms latency region. The descriptive statistics presented in Table 13 suggest that the recognised/recalled waveform deviates in a negative direction from that associated with the new item waveform during the 800-1100 ms poststimulus recording epoch. The global ANOVA of this data revealed a significant main effect of the response category factor, $F(1.52, 9.13) = 10.83$, $p < .01$. Although the data in Table 13 suggests that the negative shift associated with the recognised/recalled waveform is more pronounced at posterior electrode sites, the interaction between response category and site was not statistically significant, $F(1.15, 6.91) = 1.83$, $p > .05$. Neither the first-order interaction between response category and hemisphere nor the second-order interaction between response category, site, and hemisphere achieved significance, $F(1.70, 10.22) = 2.56$, $p > .05$; and $F(1.80, 10.79) = 1.96$, $p > .05$, respectively.

The global ANOVA involving the midline sites revealed a significant main effect of the response category factor, $F(1.70, 10.23) = 14.81$, $p < .001$, and a significant interaction between response category and electrode site, $F(1.92, 11.52) = 6.17$, $p < .05$. As is evident in Table 13, the significant main effect of response category arose due to the increased negativity of the recognised/recalled waveform relative to the new item waveform. The significant interaction reflected the fact that this increased negativity was more pronounced at posterior sites (i.e., Cz and Pz, see Table 13). Follow-up comparisons revealed that the recognised/recalled waveform differed significantly from the new item waveform at both Cz, $F(1, 8) = 28.09$, $p < .001$; and Pz, $F(1, 8) = 26.83$, $p < .001$. However, the recognised/recalled and recognised/unrecalled waveforms did not reliably differ at either Cz, $t(7) = .54$, $p > .05$, or Pz, $t(7) = .61$, $p > .05$.

Discussion

Recognition performance levels indicated that participants in Experiment 3 reliably discriminated between old and new items. The rate of successful recognition was similar to that reported in relevant previous research (e.g., Donaldson & Rugg, 1999; Rugg et al., 1996). The proportion of recognised words associated with correct recall (i.e., 53%) was substantially higher than those reported in Experiments 1 and 2. This difference is likely due to the benefit provided to participants by the preexisting relationship between the study pairs. That is, the effectiveness of the previously studied A words to elicit the associated B words (and hence satisfy the current operational definition of *recollection*), was enhanced by the use of word pairs with a preexisting semantic relationship. This outcome is consistent with previous research involving the cued-recall paradigm (see Humphreys, 1976, 1978; Thomson & Tulving, 1970).

The electrophysiological results of Experiment 3 were consistent with expectations and mirrored those reported previously in Experiment 1. The recognised/recalled waveform exhibited a positive shift relative to the new item waveform during the 500 - 800 ms poststimulus recording period. The effect was observed when ERPs were formed irrespective of the level of response confidence associated with each trial and was most pronounced at posterior electrode sites.

The ERP results were consistent with those reported by Rugg et al. (1996) using a similar recognition/associative recall task at test.

As in Experiments 1 and 2, the pattern of differences between the two recognition response category ERPs and the new item waveform could be described as quantitative rather than qualitative. More specifically, the magnitude of the parietal old/new effect was larger for the recognised/recalled waveform compared with the recognised/unrecalled waveform. This result is consistent with the reported findings of Smith (1993) and supports the proposal that the familiarity component of recognition memory may reflect explicit memory processes (Moscovitch, 1992, 1994). The current data provides further support for this view as the distribution of the old/new effects associated with the recognised/unrecalled ERP waveform relative to the new item ERP was similar to that observed with respect to the recollected versus new item ERPs.

The general pattern of ERP results in Experiment 3 is consistent with those obtained in Experiments 1 and 2, and conforms with previously reported findings in a variety of recognition memory paradigms (e.g., Curran, 1999, 2000; Friedman, 1990; Johnson et al., 1985; Paller & Kutas, 1992; Paller et al., 1995; Rugg, 1990; Rugg et al., 1995; Rugg & Doyle, 1992; Rugg & Nagy, 1989; Rugg et al., 1996; Rugg et al., 1998; Sanquist et al., 1980; Smith, 1993; Smith & Guster, 1993; Wilding et al., 1995; Wilding & Rugg, 1997). Of more specific interest to the current design, ERP results similar to those observed in Experiment 3 have been reported previously in recognition memory studies that have operationalised recollection as the ability to accurately retrieve contextual details regarding the encoding phase. These details have involved source judgments (e.g., Wilding et al., 1995; Wilding & Rugg, 1996), and the retrieval of a studied associate of the test item (e.g., Rugg et al., 1996).

Consistent with Experiments 1 and 2, the results of Experiment 3 revealed no reliable difference between the magnitude of the old/new effect at left-posterior and right-posterior electrode sites. As discussed previously, this finding may be related to the variability in encoding strategy employed by participants (i.e., visual imagery versus verbal strategies). Future replication of the current design involving direct manipulation of the encoding strategy, is therefore required in order to establish the reliability of the current result.

Consistent with Experiments 1 and 2, no evidence of the late sustained positivity, maximal at right frontal electrode locations, was found in Experiment 3. The current results are therefore also consistent with those reported by Rugg et al. (1996). Rugg et al. adopted a similar methodology to that employed in the current studies and found no right frontal ERP component. Rugg et al. further suggested that, relative to the parietal old/new effect, the right frontal ERP component is more sensitive to task-related factors. These authors suggested that the right frontal effect reflects post-retrieval functions which are selectively involved during contextual discrimination tasks (see also Van Petten et al., 2002). This view is supported by research indicating that prefrontal cortical lesions selectively impair memory for contextual information (e.g., source memory) as opposed to associative information (e.g., performance on the paired associate subtest of the Weschler Memory Scale) (Janowsky et al., 1989; Stuss et al., 1994). The current results also support this conclusion. Conversely, using the recognition/associative recall task, Donaldson and Rugg (1999, Experiment 2) reported a late positive shift at right frontal electrode sites. This effect was not evident until 1400 ms poststimulus onset. Therefore, one of the limitations of the current experiments involves the restricted recording epoch of 1100 ms. Future research should aim to replicate the findings reported by Donaldson and Rugg by extending the recording epoch beyond the 1400 ms poststimulus interval.

Late Negative Wave

Analysis of the 800 - 1100 ms data revealed no evidence of the parietal old/new effect which is consistent with the results of Rugg et al. (1996). However, a negative shift was observed at posterior electrode sites with respect to both classes of recognised items (i.e., the recognised/recalled and recognised/unrecalled) relative to the new item waveform during this recording epoch. The effect was maximal at midline central and parietal electrode sites(i.e., Cz and Pz). This negative shift was also observed in Experiment 1 and has been previously identified by Rugg et al. (1996) using a similar recognition/associative recall task. Both Rugg et al. (1998) and Wilding and Rugg (1997) reported a similar late negative shift with respect to recollected items relative to new items using a source memory task.

Response Confidence and the Old/New Effect

Analysis of the behavioural data involving the levels of response confidence across the response conditions in Experiment 3 indicated that confidence levels varied reliably across the conditions. Trials involving both correct recognition of the test item and successful retrieval of the item's studied associate were associated with significantly higher levels of response confidence than trials involving the successful identification of new items. This result mirrors that observed in Experiments 1 and 2 and suggests that the factor of condition is *confounded* with response confidence. After controlling for the effect of response confidence by forming ERP waveforms for the response conditions from highly confident responses only, the pattern of ERP results revealed no evidence of the parietal old/new effect with respect to either the 500-800 ms or the 800-1100 ms poststimulus recording epoch. However, consistent with Experiment 1, the late negative shift associated with recollected items was more pronounced when ERPs were formed from highly confident trials.

The pattern of electrophysiological results observed in Experiment 3 differed from those reported by Rugg and Young (1992) in a recognition memory test involving low-frequency words. These researchers found that the magnitude of the ERP old/new effect was not affected following the experimental control of response confidence. As discussed previously in the context of Experiments 1 and 2, the contrasting pattern of ERP results observed in Experiment 3 may be due to the different methods used to operationalise response confidence between these studies. Participants in the study by Rugg and Young categorised each response as either *confident* or *nonconfident*. It is possible that many responses in the *confident* category included both trials involving the conscious recollection of the study episode *and* trials involving a sense of familiarity without conscious recollection. The resulting ERP formed from these trials may therefore not provide a pure measure of recollection. The results of Experiment 3 provide further support for the view that when participants are able to more precisely define their degree of confidence at the point of recognition (by providing a wider variety of response options) and ERPs can be formed which control for differential confidence levels across experimental conditions, then the old/new effect is not evident. This issue will be addressed further in the General Discussion.

To summarise, the results of Experiment 3 provide further support for the view that response confidence is an important factor in terms of the magnitude of the old/new ERP effect. A primary aim of Experiment 4 was to replicate and extend Experiment 3 by investigating whether the recognition memory old/new effect and the previously observed effect of response confidence are influenced by the delayed as opposed to immediate recall of the studied associate, utilising weakly associated word pairs. Experiment 4 also provides an opportunity to further examine the previously reported late negative wave. No evidence of this negative shift was found in Experiment 2 which also involved delayed recall of the B items. Therefore, if the requirement to retrieve the studied associate during the recognition test is an important determinant for the emergence of the late negative wave, then this wave should be similarly absent in Experiment 4.

Experiment 4

Method

Participants

Nine undergraduate students (seven female) from the University of Southern Queensland participated in this experiment in return for course credit. The mean age of the participants was 24.7 years (range: 18 – 45 years). All participants were right-handed (as defined by writing hand), had normal or corrected-to-normal vision, and spoke English as their first language. Testing was conducted on an individual basis and all participants gave informed consent prior to participation. The study was approved by the USQ ethics committee.

Stimulus Materials and Presentation

Stimulus materials were identical to those employed in Experiment 3. The presentation of the experimental stimuli during the recognition test was also as for Experiment 3. Presentation of test stimuli during the delayed recall test was similar to that described previously in Experiment 2. The order of presentation of test stimuli was randomly determined for each participant. EEG was not recorded during the delayed recall test trials.

Procedure

Procedural requirements during the study phase and the recognition test were similar to Experiment 2. That is, during the recognition test, participants were not required to retrieve the studied associate of recognised test items. Also similar to Experiment 2, the delayed recall test occurred immediately following the recognition test. During this test, participants were instructed to recall the item's studied associate, or to respond "don't know" if the studied associate could not be recalled.

ERP Recording

EEG recording and artifact detection procedures were similar to those described in Experiment 1. A mean of 12% of trials were rejected due to artifact detection in Experiment 4 (*SD* = 9).

Results

Behavioural data

Participants in Experiment 4 correctly recognised a mean of 87% of the previously studied words in the recognition test (i.e., the A items from the studied word pairs), correctly rejected 81% of the new items, and made false alarms to 19% of the new test items. The participants correctly recalled 53% of the B items (i.e., the study associates of the A items) following the successful recognition of the test item, with the remaining trials attracting a "don't know" response. The level of recall performance was significantly higher than that observed in both Experiment 1 ($t[16] = 4.33$, $p < .05$), and Experiment 2 ($t[14] = 3.05$, $p < .05$). Conversely, the level of recall did not differ between Experiments 3 and 4 ($t[17] = -.03$, $p > .05$. Both recognition performance ($F[3, 31] = 1.15$, $p > .05$) and the correct rejection of new items (*F*[3, 31] = .11, $p > .05$) did not differ across the four experiments. The discrimination measure ‘$P_{hit} – P_{false\ alarm}$’ (see Snodgrass & Corwin, 1988) indicated that participants were able to identify previously studied test items at a performance level which was significantly above the chance level of .50, $t(8) = 3.49$, $p < .01$.

Table 1 presents the mean confidence levels associated with the three critical response categories. From Table 1 it can be seen that recognised/recalled items attracted the highest level of reported confidence (*M* = 2.89, *SD* = 0.10) while new items were associated with the lowest level of confidence (*M* = 1.89, *SD* = 0.45). Medium levels of confidence were reported in the recognised/unrecalled category (*M* = 2.29, *SD* = 0.32). A repeated measures ANOVA was conducted in order to assess the reliability of differences in confidence across the response categories. The analysis employed the factor of response category (new vs. recognised/recalled vs. recognised/unrecalled) and the results revealed a significant effect involving this factor, $F(1.43, 11.46) = 39.71$, $p < .001$. Follow-up testing revealed that the recognised/recalled items exhibited significantly higher confidence levels than both new items, $t(8) = 6.97$, $p < .001$, and recognised/unrecalled items, $t(8) = 6.93$, $p < .001$. New items and recognised/unrecalled items also differed significantly with respect to response confidence, $t(8) = 4.00$, $p < .01$.

ERP Data: Pooled Across Confidence

Separate averaged ERPs were obtained from trials associated with the following performance characteristics: (a) successful cue recognition, given successful recall of the target (recognised/recalled); (b) successful cue recognition, given unsuccessful recall of the target (recognised/unrecalled); and (c) successful rejection of new items (new). These ERPs were initially formed without regard to the level of confidence associated with the recognition decisions. The mean number of trials contributing to the grand averaged ERPs was 90 (range, 34 – 135), 44 (22 – 65), and 132 (67 – 185) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. Consistent with relevant previous research (e.g., Rugg & Doyle, 1992; Rugg et al., 1995; Rugg et al., 1996; Rugg et al., 1998; Wilding & Rugg, 1996), the ERPs were quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of two successive latency regions, including 500 - 800 ms and 800 – 1100 ms poststimulus onset. Table 14 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 4. Table 15 presents similar descriptive statistics with respect to the 800 – 1100 ms latency region and Figure 7 displays the grand averaged ERP waveforms, averaged across confidence, for all electrode sites in Experiment 4. As can be seen in Table 14, recollected items (i.e., recognised/recalled items) elicited an ERP that diverged in a positive direction from the ERP elicited by new items. This effect was evident at all electrode locations, but was most pronounced at left posterior sites (i.e., left temporo-parietal, including P3, C3, T5, and O1) and posterior midline sites (i.e., Cz and Pz). At frontal locations the effect was markedly smaller in magnitude and exhibited a bilateral distribution, as opposed to the left greater than right asymmetry seen at posterior sites. The ERP involving recognised/unrecalled items also exhibited a positive-going shift relative to new items at posterior electrode sites (see Table 14).

500-800 ms latency region. ANOVA of the 500-800 ms recording epoch revealed a significant main effect for the response category factor at lateral electrode sites, $F(1.59, 12.73) = 6.46$, $p = .015$. The interaction between response category and hemisphere was not significant, $F(1.79, 14.29) = 0.70$, $p > .05$. However, a significant interaction was found between the factors of response category and electrode site, $F(1.33, 10.67) = 5.25$, $p < .05$. The second-order interaction involving the factors of response category, hemisphere, and site was not significant, $F(1.38, 11.08) = 1.99$, $p < .05$. As is evident from Table 14, the interaction between response category and site reflects the fact that the magnitude of the old/new effect was considerably larger at posterior electrode sites when compared with frontal sites. Subsidiary ANOVAs revealed no reliable effect of response category at either left-frontal, $F(1.50, 11.98) = 2.08$, $p > .05$, or right-frontal electrode sites, $F(1.91, 15.31) = 1.51$, $p > .05$. However, ANOVAs restricted to posterior sites revealed significant effects of response category at both left-posterior, $F(1.39, 11.09) = 8.59$, $p < .01$, and right-posterior electrode sites, $F(1.33, 10.63) = 6.50$, $p < .05$. Subsequent pairwise comparisons indicated that the recognised/recalled waveform was more positive than the correct rejection waveform at both left-posterior, $F(1, 8) = 34.46$, $p < .001$, and right-posterior sites, $F(1, 8) = 18.58$, $p < .01$. The recognised/unrecalled waveform did not differ significantly from the new item waveform at both left-posterior, $F(1, 8) = 5.29$, $p >$

.05, and right-posterior sites $F(1, 8) = 4.12$, $p > .05$. Similarly, comparisons between the recognised/recalled and recognised/unrecalled waveforms revealed no significant effects at either left- or right-posterior sites, $F(1, 8) = 2.43$, $p > .05$; and $F(1, 8) = 2.40$, $p > .05$, respectively.

The global ANOVA involving the midline data resulted in a significant main effect involving the response category factor, $F(1.44, 11.51) = 4.79$, $p < .05$. The interaction between response category and site was also significant, $F(2.75, 21.97) = 3.07$, $p < .05$. The significant effect of response category reflected the greater positivity of the recognised/recalled waveform relative to the new item waveform (see Table 14). The significant interaction between response category and site reflects the fact that the greater positivity associated with the recognised/recalled waveform was more pronounced at posterior midline sites (i.e., Cz and Pz).

800-1100 ms latency region. Table 15 presents the descriptive statistics relating to the critical response categories during the 800-1100 ms poststimulus onset recording epoch. The global ANOVA involving the lateral electrode sites for the 800-1100 ms recording epoch revealed no significant main effect for the response category factor, $F(1.78, 14.22) = 0.12$, $p > .05$. The first-order interaction effects involving the factors of response category and hemisphere, $F(1.17, 9.33) = 0.34$, $p > .05$; and response category and site, $F(1.45, 11.62) = 1.94$, $p > .05$, were also not significant. The second-order interaction involving the three factors was not significant, $F(1.47, 11.73) = 0.74$, $p > .05$.

ANOVA involving the midline data revealed no significant main effect for the response category factor, $F(1.58, 12.66) = 1.46$, $p > .05$. In addition, the interaction between response category and site was also not significant, $F(2.54, 20.31) = 1.21$, $p > .05$.

ERP Data: Controlling for Confidence

ERPs were formed into the three critical response categories by selecting highly confident artifact-free responses only. With respect to the correct rejection ERP, only eight participants provided a sufficient number of trials in order to form a sufficiently reliable waveform (i.e., 16 trials). The mean number of trials contributing to the grand averaged ERPs for highly confident responses was 81 (range, 32 – 132), 33 (23 – 44), and 61 (16 – 95) for the recognised/recalled, recognised/unrecalled, and new response categories, respectively. Only five participants contributed a sufficient number of artifact-free responses with respect to the new and recognised/unrecalled ERP waveforms (i.e., 16 trials). The ERPs were again quantified by computing the mean amplitude (relative to the 100 ms prestimulus baseline) of the two successive latency regions (i.e., 500 - 800 ms and 800 – 1100 ms poststimulus onset). Figure 8 displays the ERP waveforms, formed from highly confident responses, from electrode sites in Experiment 4. Table 16 presents the means and standard deviations of the amplitudes (μV) of the ERPs evoked by the critical response categories for the 500 – 800 ms latency region in Experiment 4, while Table 17 presents similar data relating to the 800 – 1100 ms latency region.

500-800 ms latency region. ANOVA of the 500-800 ms data comprising highly confident responses revealed no significant main effect for the response category factor, $F(1.03, 3.09) = 3.67$, $p > .05$. In addition, the first-order interaction effects between response category and site, and response category and hemisphere were also not significant, $F(1.23, 3.68) = 0.71$, $p > .05$; and $F(1.55, 4.64) = 2.01$, $p > .05$, respectively. The second-order interaction between response category, site, and hemisphere was not significant, $F(1.34, 4.03) = 2.94$, $p > .05$. In addition, ANOVA of the midline electrode sites revealed no significant effect of response category, $F(1.33, 3.98) = 1.13$, $p > .05$; and no interaction between response category and site, $F(1.74, 5.21) = 0.89$, $p > .05$.

800-1100 ms latency region. The main effect of the response category factor was not significant, $F(1.12, 3.37) = 0.46$, $p > .05$. The interaction between response category and site was also not statistically significant, $F(1.46, 4.37) = 0.12$, $p > .05$. Moreover, neither the first-order interaction between response category and hemisphere nor the second-order interaction between response category, site, and hemisphere achieved significance, $F(1.24, 3.71) = 0.19$, $p > .05$; and $F(1.33, 3.98) = 0.86$, $p > .05$, respectively. The global ANOVA involving the midline sites revealed no significant main effect of the response category factor, $F(1.19, 3.57) = 0.01$, $p > .05$, and no significant interaction between response category and electrode site, $F(1.86, 5.59) = 0.80$, $p > .05$.

Discussion

As in all previous experiments, the level of recognition performance indicated that participants in Experiment 4 were able to discriminate between old and new test items at above chance levels. The level of recognition performance and the rate of successful recall of the studied associate, were similar to those reported in Experiment 3. Dual-process models propose that old test items were discriminable on the basis of veridical information concerning the study episode (Atkinson & Juola, 1973; 1974; Mandler, 1980, 1991; Moscovitch, 1992, 1994). Such theories suggest that this information was derived from either a sense of conscious recollection of the study episode (operationalised via recognised/recalled trials) or from a sense of familiarity regarding the test item associated with partial retrieval of the study phase (recognised/unrecalled trials).

As expected, the ERP results of Experiment 4 replicated those observed in all previous experiments with respect to the 500-800 ms poststimulus recording interval. Specifically, the recognised/recalled waveform deviated in a positive direction relative to the new item waveform at posterior electrode sites, during this recording period. This result is consistent with Rugg et al. (1996) despite the use of a delayed recall task in the current study. Participants in the Rugg et al. study were instructed to recall the studied associate of test items identified as old, immediately following the recognition decision. As in all previous experiments in the current series, the effect was maximal at posterior electrode sites and the topographical distribution of the old/new effect corresponds with that of previously reported recognition memory parietal old/new effects (Rugg, 1995).

As in previous experiments, the ERP data relating to the recognised/unrecalled waveform revealed a similar pattern of old/new effects when compared to the recollected item waveform. This result is consistent with the results of Smith (1993) who found a similar pattern but greater magnitude of the old/new effects for recollection-based responses relative to familiarity-based responses. This outcome is also consistent with the view that familiarity reflects explicit memory processes (Moscovitch, 1992, 1994).

The present data revealed no reliable difference between the magnitude of the old/new effect at left-posterior and right-posterior electrode sites. This outcome may be due to variability in encoding strategies across participants in the current study and will be discussed further in the General Discussion. The present electrophysiological findings are consistent with the view proposed by Rugg et al. (1996) that when recollection is operationally defined as successful associative recall the magnitude of the parietal old/new effect varies according to whether successful recollection has occurred.

Consistent with all previous experiments in the current series, the ERP data in Experiment 4 revealed no evidence of the late positivity with respect to recollected items relative to new items, maximal at right frontal electrode locations which was reported by Wilding and Rugg (1996) using a source memory task. The current results are therefore consistent with those reported by Rugg et al. (1996). Rugg et al. suggested that, compared to the parietal old/new effect, the right frontal ERP component is more sensitive to task-related factors. This issue will be further addressed in the General Discussion.

Late Negative Wave

In Experiment 4, analysis of the 800 - 1100 ms data revealed no evidence of the parietal old/new effect. This result is consistent with the findings of Rugg et al. (1996). Moreover, the results of Experiment 4 revealed no indication of the late negative shift at posterior electrode sites with respect to recognised items (i.e., the recognised/recalled and recognised/unrecalled) relative to new items. This result is concordant with that obtained previously in Experiment 2. Evidence of the late negative shift *was* observed in Experiments 1 and 3 and by Rugg et al. using a similar recognition/associative recall task. The only methodological difference between these studies and Experiments 2 and 4 was that subjects in the latter studies were not required to retrieve the studied associate of recognised test items at the point of recognition. Recall of the B items was delayed until the completion of the recognition test. Rugg et al. suggested that as the effect did not vary across the two classes of recognised items (i.e., recognised/recalled and recognised/unrecalled), it can be distinguished from the parietal old/new effect. As outlined previously, both Rugg et al. (1996) and Rugg et al. (1998) suggested that the functional significance of the effect may be related to response-related factors rather than mnemonic factors. The results of the current experiments suggest that methodological differences across studies may account for the variability in findings related to the late negative wave. That is, the primary aim of Experiments 3 and 4 was to replicate the results of Experiments 1 and 2 in the context of weakly semantically related word pairs. A similar pattern of results was observed in Experiments 3 and 4 which strongly suggests that the methodological differences are more likely to account for the discrepant findings involving the late negative wave.

Response Confidence and the Old/New Effect

As in previous experiments, evidence of a confounding between response confidence and response category was revealed in Experiment 4. That is, the levels of response confidence varied significantly across the levels of the response category factor. Higher levels of reported response confidence were found for recognised/recalled trials relative to trials involving the successful identification of new items. The new item waveform therefore included many trials involving low levels of response confidence. This result was consistently observed across all four experiments in the current series. Consistent with Experiments 1 to 3, after forming ERPs for the response conditions using highly confident responses only, no evidence of the parietal old/new effect was observed with respect to either the 500-80 ms or the 800-1100 ms poststimulus recording epoch. The results relating to the influence of response confidence are not consistent with those reported previously by Rugg and Young (1992). As outlined previously, the conflicting pattern of ERP results between these studies may be due to the different operational definitions of response confidence. This issue will also be addressed in the General Discussion.

General Discussion

The level of recognition performance indicated that participants across all four experiments were able to reliably discriminate between previously studied and new items. Behavioural performance measures, such as the rate of successful recognition and the rate of successful recall of the studied associate, were similar to those reported in previous research involving the recognition/associative recall task (e.g., Donaldson & Rugg, 1999; Rugg et al., 1996). The proportion of recognised words associated with correct recall was significantly higher in Experiments 3 and 4 (relative to Experiments 1 and 2 and Rugg et al., 1996) which involved study word pairs that were weakly semantically related. These results suggest that the effectiveness of the previously studied A words to elicit the associated B words (and hence satisfy the current operational definition of *recollection*), was enhanced by the use of word pairs with a preexisting semantic relationship. This outcome is consistent with previous research involving the cued-recall paradigm (see Humphreys, 1976,1978; Thomson & Tulving, 1970). The false alarm rate observed across all four experiments was higher than the rate of 6% which was reported by Rugg et al. The relatively low rate of false positives reported by Rugg et al. may be due to the provision of a "don't know" response option to participants in this study. From the perspective of the dual-process theories of memory (Atkinson & Juola, 1973; 1974; Mandler, 1980, 1991; Moscovitch, 1992, 1994), successful recognition performance in the current experiments was based on veridical information concerning the study episode which was derived from either the successful retrieval of the study episode involving the test item (i.e., recognised/recalled trials involving *recollection*) or from partial retrieval of the study episode (i.e., recognised/unrecalled trials involving *familiarity*).

As predicted, when ERPs for the experimental conditions were formed irrespective of the level of response confidence associated with each trial, the electrophysiological data indicated that the recognised/recalled waveform deviated in a positive direction relative to the new item waveform during the 500 - 800 ms poststimulus onset period. This result was observed in all four experiments and is consistent with the findings reported by Rugg et al. (1996) using a similar recognition/associative recall task during the test phase of the experiment. The effect was most pronounced at posterior electrode sites. Although the effect was absent during the 800 -1100 ms poststimulus onset recording period, the distribution of the old/new effect observed in the current experiment corresponds with that of previously reported recognition memory parietal old/new effects in a variety of recognition memory paradigms (e.g., Curran, 1999, 2000; Friedman, 1990; Johnson et al., 1985; Paller & Kutas, 1992; Paller et al., 1995; Rugg, 1990; Rugg et al., 1995; Rugg & Doyle, 1992; Rugg & Nagy, 1989; Rugg et al., 1996; Rugg et al., 1998; Sanquist et al., 1980; Smith, 1993; Smith & Guster, 1993; Wilding et al., 1995; Wilding & Rugg, 1997). That is, ERP results similar to those observed in the current study have been reported previously in recognition memory studies which have operationalised recollection as the ability to retrieve contextual details regarding the initial encoding of the test item (e.g., Rugg et al., 1996; Wilding et al., 1995; Wilding & Rugg, 1996). Rugg et al. (1996) operationally defined recollection as the ability to both recognise a previously studied word, and to retrieve it's studied associate. These researchers found that relative to the new item waveform, these *recognised/recalled* words elicited an ERP that deviated in a positive direction at posterior electrode sites between 500-800 ms poststimulus onset. The effect was most pronounced at left temporo-parietal electrode locations. In addition, Wilding et al. (1995) operationally defined recollection as the ability to both recognise a test item as having been previously studied and assign the particular item to it's correct encoding context (i.e., modality of presentation during the study phase). The results of this study were similar to those reported by Rugg et al. and to those observed in the current experiments.

The present experiments revealed no reliable difference between the magnitude of the old/new effect at left-posterior and right-posterior electrode sites. However, the pattern of descriptive statistics across all current experiments indicated that the difference between the recollected (operationalised via recognised/recalled trials) ERP waveform and the new item waveform was maximal at left posterior electrode locations. The consistent failure to observe significant interactions between the factors of hemisphere and response category in the current experiments may represent Type II errors. A more likely explanation however involves the variability in encoding strategies employed by the participants. Many participants in the current studies reported using a visual imagery strategy to form associations between the word pairs. Previous ERP studies involving the recognition/associative recall task have involved encoding tasks that are more likely to result in verbal strategies. For example, participants in the Rugg et al. study were required to combine the members of each word pair into a meaningful sentence during the study phase. Previous research suggests that the posterior parietal cortex is essential for the encoding of visuospatial information (particularly in the right hemisphere) and temporal/parietal association cortices are the likely repositories of long-term memories (Fuster, 1995; Squire, 1987; 1992). In addition, the right inferotemporal cortex has been implicated in visual memory (Milner, 1958). Therefore, participants employing a strategy of visual imagery may exhibit an old/new effect which is lateralised in the *right* hemisphere. As the current results were averaged across all subjects, it seems not unreasonable that no interaction was observed between the factors of response category and hemisphere if encoding strategies varied across subjects. Future research should aim to replicate and extend the current design, for example, by directly manipulating the encoding task, in order to establish the reliability of the current results.

The present findings are consistent with the view proposed by Rugg et al. (1996) that when recollection is operationally defined as successful associative recall, within the context of a recognition memory test, the magnitude of the parietal old/new effect varies according to whether successful recollection has occurred. In all experiments in the current series the descriptive pattern of the ERP waveforms during the 500-800 ms poststimulus period is consistent with the position of Rugg et al. as the old/new effect was consistently larger with respect to the recognised/recalled waveform compared with the recognised/unrecalled waveform (although the inferential pairwise contrasts indicated that these waveforms were not consistently different). Rugg et al. concluded that when operationalising recollection via an associative recall task, the parietal old/new effect is dependent upon successful recollection in a similar manner to that observed when recollection is operationalised as the ability to retrieve contextual details regarding the original study experience (Wilding & Rugg, 1996; Wilding et al., 1995). When ERP waveforms were formed by averaging across response confidence, the current data was consistent with this conclusion.

No evidence of the late sustained positivity, maximal at right frontal electrode locations, which was reported by Wilding and Rugg (1996) using a source memory task, was found in the current experiments. In this regard, the current results are consistent with those reported by Rugg et al. (1996). Rugg et al. adopted a similar methodology to that employed in the current studies and found no right frontal ERP component. Rugg et al. further suggested that, relative to the parietal old/new effect, the right frontal ERP component is more sensitive to task-related factors. These authors suggested that the right frontal effect reflects post-retrieval functions which are selectively involved during contextual discrimination tasks. This view is supported by research indicating that prefrontal cortical lesions selectively impair memory for contextual information (e.g., source memory) as opposed to associative information (e.g., performance on the paired associate subtest of the Weschler Memory Scale) (Janowsky et al., 1989; Stuss et al., 1994). The current results also support this conclusion. Donaldson and Rugg (1999, Experiment 2) *did* however find a late positive shift at right frontal electrode sites. This effect was not evident until 1400 ms poststimulus onset. These researchers also operationalised recollection via the recognition/associative recall task. A limitation of the current experiments however was that the recording epoch was restricted to 1100 ms. Future research should aim to replicate this finding by extending the recording epoch beyond the 1400 ms poststimulus interval.

An additional aim of the current experiments was to examine the implicit versus explicit nature of familiarity-based recognition decisions via an examination of the scalp distribution of activity associated with the two classes of recognition response (i.e., recognised/recalled and recognised/unrecalled). Smith (1993) found quantitative as opposed to qualitative differences in activity between familiarity- and recollection-based responses, which was consistent with the view that familiarity-based recognition responses reflect explicit processes (Moscovitch, 1992, 1994). The data from all four experiments provide further support for this proposal as the distribution of the old/new effects associated with the recognised/unrecalled ERP waveform relative to the new item ERP was similar to that observed with respect to the recollected versus new item ERPs. Consistent with Smith (1993), quantitative as opposed to qualitative differences were observed with respect to these comparisons in all experiments.

Late Negative Wave

Analysis of the 800 - 1100 ms data revealed no evidence of the parietal old/new effect which is consistent with the findings of Rugg et al. (1996). In Experiments 1 and 3, a negative shift was observed at posterior electrode sites with respect to both classes of recognised items (i.e., the recognised/recalled and recognised/unrecalled) relative to the new item waveform, during this recording epoch. (This negative shift was also evident following the experimental control of the confounding factor of response confidence.) The negative shift was maximal at midline central and parietal electrode sites (i.e., Cz and Pz), which is consistent in terms of spatial distribution to the negative wave identified by Rugg et al. using a similar recognition/associative recall task. Moreover, using a source memory task, both Rugg et al. (1998) and Wilding and Rugg (1997) reported a similar late negative shift with respect to recollected items relative to new items. Wilding and Rugg reported that the amplitude of the negative-going wave covaried with mean reaction time rather than the study status of the eliciting item. In addition, Rugg et al. suggested that as the effect did not differ between the recognised/recalled and recognised/unrecalled waveforms, it can be distinguished from the temporally overlapping parietal old/new effect. Both Rugg et al. and Rugg et al. (1998) suggested that the functional significance of the effect may be due to response-related factors such as variability in reaction time across the different classes of test item as opposed to mnemonic factors. As was the case with the Rugg et al. (1996) study, one of the limitations of the current experiments is that reaction time data is unavailable. Future research should therefore aim to further examine the relationship between the late negative wave and reaction time in the context of the recognition/associative recall task. Alternatively, the results of the current experiments indicate that methodological factors may also provide insight into the correlates of the late negative wave. The only methodological difference between Experiments 2 and 4 and relevant previous studies (e.g., Rugg et al., 1996; Rugg et al., 1998; Experiments 1 and 3) was that during the recognition test in the former experiments, the participants were not required to retrieve the studied associate of recognised test items. Therefore, the results of the current experiments suggest that the requirement to retrieve the studied associate is associated with the emergence of the late negative wave. As previously mentioned, a limitation of the current experiments is that reaction time data is unavailable, therefore it is not possible to determine whether the late negative wave is associated with postretrieval processes as suggested previously (e.g., Rugg et al., 1998; Wilding & Rugg, 1997). Future replication of the current design involving the recording of reaction time data is therefore required in order to assess the cognitive processes associated with the late negative shift.

Response Confidence and the Old/New Effect

The analysis of waveforms in the previous section involved ERPs formed without regard for the level of response confidence associated with each trial. As outlined in the introduction, very few previous studies have explicitly incorporated a measure of response confidence. Therefore, this strategy is consistent with previous research involving the old/new ERP effect in recognition memory. However, analysis of the behavioural data involving the levels of confidence for the response conditions across all four experiments indicated that confidence levels varied reliably across the conditions. Trials involving both correct recognition of the test item and successful retrieval of the item's studied associate were associated with substantially higher levels of response confidence than trials involving the successful identification of new items. (The confidence level associated with the recognised/unrecalled waveform was midway between the new item and recognised/recalled waveform across all experiments, as can be seen in Table 1.) This result indicates that the new item waveform included many trials involving low levels of response confidence. The mean confidence rating for the recognised/recalled category was extremely high across all four experiments with all means exceeding 2.90 on the 3-point confidence rating scale. This suggests that almost every trial contributing to the recognised/recalled waveform attracted the highest possible confidence rating. Reliable differences in response confidence found between the experimental conditions in the current experiments indicate that the factor of condition is *confounded* with response confidence. After experimentally controlling for the effect of response confidence by forming ERPs for the various conditions from highly confident responses only, the pattern of ERP results substantially alters. No evidence of the parietal old/new effect was observed with respect to either the 500-80 ms or the 800-1100 ms poststimulus recording epoch across all experiments. In all four experiments, only the new item ERP waveform was influenced by the selection of highly confident trials. That is, the new item waveform exhibited a positive shift in the EEG amplitude following the control of response confidence. As mentioned previously, the recollected waveform was composed of trials which were almost exclusively associated with maximal levels of response confidence. Therefore, the control technique had minimal influence on the amplitude of this ERP waveform. The influence of response confidence (given the confounding identified in the current experiments) is consistent with previous research which suggests a positive association between response confidence and a positive shift in the EEG record. For example, decision confidence has been found to be positively associated with the magnitude of the P300 ERP component in a variety of cognitive tasks (see Hillyard et al., 1971; Rohrbaugh et al., 1974; Rushkin & Sutton, 1978). In addition, Paller et al., (unpublished) obtained confidence measures during a recognition memory test of words and subsequently obtained ERPs by averaging separately as a function of response confidence. Paller et al. found that words recognised with a greater degree of confidence elicited ERPs that were more positive than those based on ERPs formed from low confidence trials only. The current results are therefore consistent with these findings.

The pattern of ERP results observed in the current experiments differed from those reported by Rugg and Young (1992). In one of the few studies involving the influence of response confidence, Rugg and Young found that, in a recognition memory test for low-frequency words, the magnitude of the ERP old/new effect was not affected when the waveforms for the recollected and new items were formed using confident responses only. The contrasting pattern of ERP results observed in the current experiments may be due to the different methods used to operationalise response confidence between these studies. The current design involved the use of 3-option measurement of the subject's response confidence. Conversely, participants in the study by Rugg and Young were simply required to categorise each response as either *confident* or *nonconfident*. It is possible that many responses in the *confident* category included both trials involving the conscious recollection of the study episode (which the ERP in this category purports to measure) *and* trials involving a sense of familiarity without conscious recollection. The resulting ERP formed from these trials may therefore not provide a pure measure of recollection. The current results indicate that when participants are able to more precisely define their degree of confidence at the point of recognition (by providing a wider variety of response options) and ERPs can be formed which control for differential confidence levels across experimental conditions, then the old/new effect is not evident.

Rubin, Van Petten, Glisky, and Newberg (1999) also examined the influence of response confidence in the context of a recognition memory paradigm. Rubin et al. employed a six-alternative confidence scale with responses including *Definite*, *Probable*, and *Maybe*, following each recognition decision. These researchers found that the magnitude of the old/new effect was only partially mediated by the effect of response confidence. That is, although the temporal duration of the effect was reduced following the control of confidence, evidence of the old/new effect was observed during the 600-900 ms poststimulus recording epoch. There are many methodological differences between the current research and that reported by Rubin et al. (1999) which may account for the differential effect of response confidence observed between these studies. That is, differences involving materials, procedural details, and in the operationalisation of response confidence may account for the discrepant findings. As will be discussed in a later section, the robustness of the present results will be established via future replication and extension of the current research.

The current results cannot be generalised beyond the recognition/associative recall task and future research involving alternative recognition memory paradigms is required in order to establish the external validity of the influence of response confidence on the magnitude of the parietal old/new ERP effect. However, as outlined previously, there is reason to suspect that such a confounding of response confidence and experimental condition may have been present in earlier research involving the ERP old/new effect, given the various operational definitions of *recollection* employed. For example, Rugg et al. (1996) employed a similar methodology to the current study. These researchers operationalised recollection as the ability to both recognise a previously studied word and to correctly retrieve the item’s study associate. Trials (and the associated ERP waveform) associated with these performance characteristics are likely to involve a high level of response confidence during the initial recognition decision. The new item waveform is based on the average of *all* successfully rejected new items. The average level of response confidence for this waveform may be lower than that for the recollected ERP waveform, which is based on a restricted category of successful recognition trials. Specifically, the recollected waveform is formed from trials involving both successful recognition of the test item *and* retrieval of the studied associate. These trials are likely to involve a high degree of confidence in terms of the recognition decision. Conversely, the new item waveform may be based on a greater number of trials associated with low response confidence regarding the status of previously unstudied test items. The reliable difference in confidence between the recollected and new item waveforms observed in the current study, supports this view. This argument is similarly applicable to the alternative paradigms employed by researchers to measure the construct of recollection (e.g., process dissociation and the Remember/Know task). For example, the operational definition of recollection according to the process dissociation procedure involves successful recognition of the test item *and* correct allocation of the item to its original encoding context. For example, for test items identified as *old*, Rugg et al. (1998) required participants to indicate in which of two voices items had been presented during the study phase. It is likely that such trials would involve a high level of confidence regarding the recognition decision at test.

A further aim of current experiments was to examine the effect on the old/new effect following the manipulation of the preexperimental semantic relationship between the study pairs. Varying the degree of cue-target semantic association is expected to increase the extent to which the task relies on retrieval from long-term semantic memory. Following Tulving (1989) it is possible that the degree of semantic relatedness of the items will be positively related to the magnitude of the parietal old/new effect. Conversely, unrelated word pairs may require a greater episodic retrieval contribution at test which may be reflected in greater frontal activity (see Van Petten et al., 2002). Variations in the pattern of old/new effects across these conditions will provide neurophysiological support for Tulving’s view regarding the functional distinction between episodic and semantic memory. However, in the current experiments, no alteration in the pattern of old/new effects was observed following the manipulation of the semantic relatedness of the study pairs. Although the bahavioural data revealed that the level of recall of the studied associate was higher in Experiments 3 and 4, which involved weak associates as the study pairs, this difference was not reflected in the electrophysiological results.

One potential limitation of the current studies is the low number of participants in each experiment, although this is offset by the increased number of trials in each condition relative to previous research. The low number of participants may have the effect of reducing power and making Type II errors more prevalent. To evaluate this possibility it is possible to combine the data from Experiments 1 and 3 and Experiments 2 and 4 into larger analyses where sematic relationship between the words is the added dimension. In both instances the analyses revealed an identical pattern of inferential results to that reported in the individual analyses. That is, the effects of response confidence and the emergence of the late negative wave again emerged as the only main effects. There were no interactions involving the materials factor. In short, the power of the experiment has been increased substantially via doubling the number of participants, but no change has occurred in the output. That is, with increased power there is no evidence to support the contention that a type II errors have contaminated the results.

It is possible to speculate regarding the nature of the cognitive processes responsible for the pattern of ERP results observed in the current series of experiments. As stated previously, the emergence of the late negative wave was associated with the requirement to retrieve the studied associate of recognised test items. This result suggests an association between retrieval or search processes and a negative shift in the EEG record. Similarly, with respect to the influence of response confidence, it is arguable that during trials involving high levels of confidence, retrieval/search processes were minimal during the recording intervals under examination in the current experiments. For example, in posttest debriefing, participants consistently indicated that during recognised/recalled trials (which almost exclusively attracted the maximum confidence rating), the recognition/recall requirements were accomplished "almost instantaneously". This suggests that during the critical recording epochs, minimal retrieval/search processes occurred. Conversely, trials involving new items were associated with lower levels of confidence. It is possible that during trials involving low confidence levels, search processes were likely to be engaged during the recording epochs. Therefore, after controlling for confidence by selecting highly confident trials only, the differences in the likelihood of retrieval/search processes occurring across the critical conditions (i.e., recollected versus new) were similarly controlled, resulting in the elimination of the old/new effect. As stated previously, the effect on the new item waveform after the exclusive selection of highly confident trials when forming ERPs, was to positively shift the ERP, particularly at posterior electrode sites. In the current experiments, this positive shift served to eliminate evidence of the parietal old/new effect. Although the sites of activational differences observed in the current experiments are consistent with neuropsychological models of memory and the likely cortical repositories of long-term explicit memories (e.g., Fuster, 1995; Moscovitch, 1992, 1994; Squire, 1987, 1992), the current results suggest that the old/new effect is related to differential retrieval/search processes across response conditions as opposed to the study status of the test item. As discussed previously, it is not possible to unequivocally ascribe currently observed differences in ERP results as a function of delayed recall to differential retrieval/search processes, due to the unavailability of reaction time data. Therefore, the resolution of this question awaits future research.

Conclusion

The results of the current experiments suggest that response confidence is an important factor with respect to the magnitude of the old/new ERP effect. When ERP waveforms were formed without regard to the level of confidence associated with each recognition decision, the current experiments replicated the general pattern of ERP results observed in a variety of paradigms involving recognition memory and the parietal old/new ERP effect. However, across all four experiments, behavioural performance data indicated that the level of response confidence was significantly higher in the recognised/recalled condition relative to the new item condition. That is, the factor of condition was consistently confounded with response confidence. When this confounding was addressed by including only highly confident trials when forming the ERPs, the old/new effect was absent.

To summarise, the distribution of the old/new effects in the current experiments varied neither as a function of the immediate versus delayed recall of the studied associate nor the semantic relationship between the word pairs. (The only exception involved the emergence of the late negative deflection which was associated with the delayed recall of the studied associate.) The ease with which participants were able to form a strong association between the word pairs *was* influenced by the use of unrelated versus weakly associated word pairs (with weak associates involving higher levels of recall). However, this effect was not reflected in the pattern of electrophysiological differences between the primary response conditions under examination in the current experiments (i.e., recollected and new). The behavioural data consistently revealed that the level of response confidence was significantly higher for the recollected item waveform relative to the new item waveform. When ERPs were formed without regard to response confidence, the old/new effects replicated relevant previous research involving the recognition memory ERP parietal old/new effect (Johnson, 1995; Rugg, 1995). However, no evidence of the old/new effect was observed following the experimental control of response confidence. Future research should attempt to replicate and extend the current findings via an examination of the influence of response confidence in the context of the alternative paradigms used to examine the recollection component of recognition memory using the ERP methodology. The current results cannot be generalised beyond the recognition/associative recall task and future research should aim to establish the external validity of the influence of response confidence on the magnitude of the parietal old/new ERP effect across the variety of paradigms employed in ERP research which purport to isolate the electrophysiological activity associated with the recollection component of recognition memory.

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Table 1

Mean (SD in Brackets) Recognition/Recall Performance (% correct) and Confidence Levels as a Function of Experiment

	Experiment			
	1[a]	2[b]	3[c]	4[d]
Performance				
Hits	83 (9)	90 (9)	88 (9)	87 (6)
False alarms	19 (18)	22 (15)	16 (12)	19 (15)
Correct rejections	81 (18)	78 (15)	84 (12)	81 (15)
Recalled (Recollected)	29 (11)	33 (17)	53 (20)	53 (15)
Confidence Level				
Recognised/Recalled	2.99 (.01)	2.93 (.10)	2.98 (.03)	2.91 (.10)
Recognised/Unrecalled	2.62 (.19)	2.58 (.13)	2.43 (.30)	2.29 (.32)
New (Correct rejection)	2.26 (.57)	2.25 (.29)	2.23 (.45)	1.89 (.45)

Note. Confidence level has a possible range of 1 (low confidence) to 3 (high confidence).

[a]*n* = 9. [b]*n* = 7. [c]*n* = 9. [d]*n* = 9.

Table 2

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 500-800 ms Latency Region in Experiment 1

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.15	1.00	2.69	2.41	.83	4.59	3.20
SD	(3.16)	(3.02)	(2.59)	(3.30)	(4.50)	(3.98)	(4.73)
Recognised/Unrecalled							
M[b]	.68	.18	2.59	2.37	-.19	3.52	3.68
SD	(1.89)	(1.92)	(3.32)	(3.30)	(2.82)	(4.48)	(4.83)
Correct Rejection							
M[c]	.68	.49	.48	.84	-.31	1.72	1.88
SD	(2.16)	(2.27)	(1.49)	(1.76)	(2.37)	(2.14)	(3.86)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]*n* = 9. [b]*n* = 9. [c]*n* = 9.

Table 4

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by Highly Confident Responses in the Critical Response Categories for the 500-800 ms Latency Region in Experiment 1

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.16	1.00	2.68	2.41	.83	4.58	3.19
SD	(3.16)	(3.01)	(2.58)	(3.30)	(4.49)	(3.97)	(4.72)
Recognised/Unrecalled							
M[b]	.81	.38	2.97	2.55	.34	3.57	3.81
SD	(2.09)	(2.09)	(3.45)	(2.98)	(3.49)	(4.05)	(4.37)
Correct Rejection							
M[c]	1.43	1.74	2.87	2.05	.37	4.21	2.56
SD	(2.35)	(3.04)	(2.17)	(2.12)	(2.83)	(2.65)	(2.69)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]*n* = 9. [b]*n* = 9. [c]*n* = 8.

Table 3

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 1

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.02	1.18	-.35	-.52	-.15	-.22	-1.95
SD	(2.69)	(1.88)	(1.98)	(2.36)	(2.85)	(2.64)	(2.83)
Recognised/Unrecalled							
M[b]	1.06	.87	.47	.35	-.56	.90	-.40
SD	(2.21)	(1.15)	(2.48)	(2.34)	(2.50)	(2.77)	(3.22)
Correct Rejection							
M[c]	1.53	1.64	.75	1.01	.92	3.06	1.51
SD	(1.84)	(1.83)	(1.14)	(1.17)	(2.04)	(1.81)	(2.58)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]$n = 9$. [b]$n = 9$. [c]$n = 9$.

Table 5

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by Highly Confident Responses in the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 1

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.04	1.16	-.34	-.52	-.16	-.24	-1.94
SD	(2.71)	(1.87)	(1.96)	(2.35)	(2.84)	(2.65)	(2.82)
Recognised/Unrecalled							
M[b]	.56	.98	.45	.28	-.62	.75	-.47
SD	(2.37)	(1.14)	(2.39)	(2.09)	(2.64)	(2.91)	(3.27)
Correct Rejection							
M[c]	1.82	1.95	2.68	2.86	1.60	4.35	3.15
SD	(1.43)	(1.83)	(1.59)	(2.05)	(1.34)	(1.05)	(2.28)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]$n = 9$. [b]$n = 9$. [c]$n = 8$.

Table 6

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 500-800 ms Latency Region in Experiment 2

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	.84	1.53	4.43	4.19	2.72	5.42	5.47
SD	(1.58)	(1.71)	(2.37)	(1.89)	(2.53)	(2.34)	(2.72)
Recognised/Unrecalled							
M[b]	-.39	-.10	3.17	2.79	.06	3.22	3.93
SD	(1.35)	(1.56)	(1.61)	(1.54)	(1.72)	(2.06)	(1.97)
Correct Rejection							
M[c]	.03	.84	1.84	1.72	.33	2.43	2.86
SD	(1.37)	(1.30)	(2.71)	(2.34)	(2.41)	(2.85)	(2.39)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]*n* = 7. [b]*n* = 7. [c]*n* = 7.

Table 8

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by Highly Confident Responses in the Critical Response Categories for the 500-800 ms Latency Region in Experiment 2

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.13	1.83	4.46	4.24	2.61	5.40	5.52
SD	(2.03)	(1.83)	(2.35)	(1.87)	(2.60)	(2.42)	(2.71)
Recognised/Unrecalled							
M[b]	1.08	.90	4.06	3.55	1.73	4.36	4.74
SD	(1.09)	(1.30)	(1.43)	(1.53)	(1.55)	(1.88)	(1.89)
Correct Rejection							
M[c]	.68	1.82	3.91	3.90	1.97	4.70	4.95
SD	(1.36)	(1.75)	(2.30)	(2.52)	(2.10)	(2.88)	(2.60)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]$n = 7$. [b]$n = 7$. [c]$n = 7$.

Table 7

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 2

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	.10	1.48	1.96	2.19	1.15	2.70	1.92
SD	(1.56)	(1.48)	(1.47)	(1.21)	(1.84)	(1.81)	(1.69)
Recognised/Unrecalled							
M[b]	-.40	.37	1.48	1.50	-.20	1.60	1.38
SD	(0.71)	(1.01)	(1.32)	(2.28)	(1.37)	(2.31)	(1.92)
Correct Rejection							
M[c]	.03	.83	1.47	1.83	.87	1.97	1.82
SD	(1.04)	(1.33)	(2.24)	(3.05)	(2.19)	(3.85)	(2.88)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]*n* = 7. [b]*n* = 7. [c]*n* = 7.

Table 9

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by Highly Confident Responses in the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 2

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	-.17	1.26	1.86	2.15	.93	2.60	1.87
SD	(1.87)	(1.67)	(1.60)	(1.29)	(2.33)	(2.04)	(1.73)
Recognised/Unrecalled							
M[b]	-.25	.20	1.92	1.79	.09	2.22	1.81
SD	(1.01)	(0.76)	(1.22)	(1.93)	(1.22)	(2.22)	(2.06)
Correct Rejection							
M[c]	.04	.89	2.30	2.83	.68	3.01	2.05
SD	(1.65)	(1.99)	(1.60)	(1.95)	(2.57)	(3.10)	(1.64)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior sites (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]*n* = 7. [b]*n* = 7. [c]*n* = 7.

Table 10

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 500-800 ms Latency Region in Experiment 3

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	-.02	.43	2.98	2.32	-.16	2.44	4.50
SD	(2.75)	(2.45)	(2.26)	(2.59)	(3.21)	(3.51)	(2.26)
Recognised/Unrecalled							
M[b]	-.07	.43	1.44	1.12	.15	1.09	1.84
SD	(2.49)	(2.45)	(2.56)	(3.12)	(2.07)	(3.11)	(4.35)
Correct Rejection							
M[c]	-.70	-.27	-.32	-.11	-.86	-.08	.78
SD	(2.68)	(2.76)	(1.56)	(1.71)	(2.84)	(1.15)	(1.85)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]*n* = 10. [b]*n* = 8. [c]*n* = 10.

Table 12

Means and Standard Deviations of the ERP Amplitudes (μV) evoked by Highly Confident Responses in the Critical Response Categories for the 500-800 ms Latency Region in Experiment 3

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	-.10	.36	2.90	2.00	-.07	2.44	4.31
SD	(2.51)	(2.48)	(2.33)	(2.40)	(3.17)	(3.45)	(2.38)
Recognised/Unrecalled							
M[b]	.17	.79	2.22	1.92	1.01	1.62	2.90
SD	(2.03)	(2.03)	(2.27)	(2.90)	(2.24)	(2.93)	(3.79)
Correct Rejection							
M[c]	-.57	.20	2.48	1.89	-.06	2.79	3.48
SD	(3.19)	(3.39)	(1.70)	(1.81)	(3.31)	(3.06)	(2.39)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]*n* = 10. [b]*n* = 8. [c]*n* = 9.

Table 11

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 3

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	.09	.55	.94	.10	-1.11	.11	-.79
SD	(1.90)	(2.38)	(2.75)	(2.29)	(2.49)	(2.58)	(2.78)
Recognised/Unrecalled							
M[b]	.83	1.34	.21	.50	-1.24	-.38	-1.20
SD	(2.21)	(2.51)	(1.79)	(1.91)	(1.79)	(2.13)	(2.31)
Correct Rejection							
M[c]	.97	1.47	1.27	1.73	-.21	1.63	1.00
SD	(2.17)	(2.14)	(1.57)	(2.09)	(2.37)	(1.82)	(1.96)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal sites (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]*n* = 10. [b]*n* = 8. [c]*n* = 10.

Table 13

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by Highly Confident Responses in the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 3

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	.49	.95	1.01	.16	-1.09	.15	-.71
SD	(2.27)	(2.75)	(2.62)	(2.20)	(2.49)	(2.48)	(2.66)
Recognised/Unrecalled							
M[b]	.94	1.60	.67	.99	-.39	.39	-.63
SD	(1.12)	(2.12)	(1.14)	(1.94)	(2.00)	(1.63)	(1.59)
Correct Rejection							
M[c]	1.05	1.58	2.62	3.31	1.41	3.70	3.12
SD	(1.49)	(2.36)	(1.50)	(1.91)	(4.06)	(2.74)	(1.77)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]*n* = 10. [b]*n* = 8. [c]*n* = 9.

Table 14

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 500-800 ms Latency Region in Experiment 4

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	.82	1.08	2.54	2.00	-.27	2.57	3.50
SD	(2.24)	(2.81)	(2.16)	(2.13)	(3.04)	(2.99)	(3.85)
Recognised/Unrecalled							
M[b]	.51	.86	1.26	.83	-.82	.84	2.21
SD	(2.26)	(3.77)	(1.90)	(2.13)	(3.03)	(4.38)	(3.22)
Correct Rejection							
M[c]	.03	.33	-.12	-.08	-1.11	-.27	.56
SD	(2.06)	(3.23)	(1.93)	(2.00)	(2.02)	(3.76)	(2.57)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]*n* = 9. [b]*n* = 9. [c]*n* = 9.

Table 16

Means and Standard Deviations of the ERP Amplitudes (μV) evoked by Highly Confident Responses in the Critical Response Categories for the 500-800 ms Latency Region in Experiment 4

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	.98	1.29	2.79	2.22	.01	2.63	3.78
SD	(2.04)	(2.54)	(2.05)	(2.02)	(2.72)	(3.13)	(3.73)
Recognised/Unrecalled							
M[b]	.93	1.38	1.59	1.47	-.27	2.70	3.50
SD	(1.79)	(2.01)	(1.65)	(1.88)	(2.31)	(2.99)	(1.86)
Correct Rejection							
M[c]	.46	.91	2.82	1.46	.90	3.55	3.30
SD	(1.99)	(2.49)	(2.38)	(2.43)	(2.77)	(1.17)	(4.29)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior (C4, P4, T6, O2). [a]n = 9. [b]n = 5. [c]n = 5.

Table 15

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 4

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.29	2.02	2.30	2.50	.23	1.96	1.88
SD	(2.07)	(2.71)	(1.43)	(1.85)	(2.72)	(4.32)	(3.32)
Recognised/Unrecalled							
M[b]	1.93	2.36	1.63	1.87	.30	1.45	1.14
SD	(2.78)	(3.27)	(2.09)	(2.11)	(3.23)	(4.59)	(4.10)
Correct Rejection							
M[c]	1.52	2.13	2.11	2.65	.51	2.47	2.63
SD	(1.88)	(2.64)	(1.46)	(1.73)	(2.50)	(3.68)	(2.81)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]n = 9. [b]n = 9. [c]n = 9.

Table 17

Means and Standard Deviations of the Amplitudes (μV) of the ERPs evoked by Highly Confident Responses in the Critical Response Categories for the 800-1100 ms Latency Region in Experiment 4

	Site						
Response Category	LF	RF	LP	RP	Fz	Cz	Pz
Recognised/Recalled							
M[a]	1.31	2.18	2.59	2.83	.43	2.31	2.26
SD	(2.10)	(2.81)	(1.40)	(1.93)	(2.83)	(4.39)	(3.36)
Recognised/Unrecalled							
M[b]	1.94	2.65	1.57	2.19	.79	3.06	1.65
SD	(0.73)	(3.68)	(1.12)	(3.04)	(3.19)	(3.03)	(2.68)
Correct Rejection							
M[c]	2.06	2.70	1.52	2.31	1.25	2.08	2.04
SD	(1.42)	(1.97)	(1.79)	(1.83)	(3.05)	(3.74)	(2.71)

Note. Fz, Cz, and Pz signify midline frontal, central, and parietal sites, respectively. LF = left frontal (Fp1, F7, F3). RF = right frontal (Fp2, F4, F8). LP = left posterior (C3, T5, P3, O1). RP = right posterior sites (C4, P4, T6, O2). [a]n = 9. [b]n = 5. [c]n = 5.

Appendix

Stimulus Materials

Critical Word Pairs (Experiments 1 and 2)

Friar Arrow	Oyster Bull	Inform Tree	Peak Artist
Knot Affair	Acre Avoid	Raisin Pixie	Medal Thick
Pardon Coins	Canoe Profit	Adverb Spring	Moist Fence
Linen Health	Jewel Obtain	Hinge Fake	Perch Hoover
Puddle Sting	Eagle Pipe	Itch Gloves	Guitar Heavy
Faucet Bullet	Option Black	Brawl Filly	Helium Death
Maple Phrase	Trophy Greet	Adorn Eject	Towel Mascot
Plaid Number	Ache Waves	Blaze Novel	Alias Cast
Scalp Tasty	Pebble Sweep	Ankle Caress	Mouse Taste
Paste Cove	Groom Malice	Harp Almond	Sleeve Shiny
Robot Thirst	Donor Effort	Monk Cards	Sentry Puzzle
Domain Radio	Mink Pond	Ditch Flying	Frown Skate
Prank Scoop	Socket Flare	Kettle Stroll	Scent Knot
Loaf Crypt	Grape Rescue	Cotton Search	Lash Frost
Nail Sand	Alley Garden	Calf Ascent	Thaw Orbit
Mildew Barge	Bandit Sizzle	Oven Wharf	Link Dizzy
Reap Scale	Paddle Query	Obey Rights	Mist Young
Meteor Strike	Siren Panic	Frail Lake	Deceit Soft
Squint Relief	Mammal Lodger	Mill Stem	Acid Leader

Vanity Skimp	Monkey Bitter	Raft Mint	Quench Twang
Mall Image	Fawn Virtue	Spine Helmet	Nerve Exotic
Marrow Menace	Pest Lichen	Aisle Potion	Admire Wind
Deer Porch	Snail Damsel	Trance Gorge	Bead Bridge
Dice Eggs	Fabric Indian	Rattle Shrine	Cavity Statue
Choir Irish	Alibi Thin	Peach Mutiny	Pliers Doomed
Launch Clothe	Bacon Steal	Inmate Ocean	Canal Humid
Ivory Stocks	Pouch Error	Sail Tooth	Rubric Print
Salute Plaque	Opium Glide	Squad Melon	Blank Shower
Possum Lever	Quill Slime	Essay Flame	Rake Pond
Psalm Cedar	Lover Lace	Leaf Clause	Roost Letter
Reef School	Rage Shrimp	Misery Lines	Ponder Tennis
Peanut Lyre	Hunt Omen	Keeper Browse	Chaos Danger
Nurse Thread	Maze Feud	Hazard Field	Lily Sable
Kiss Pain	Abuse Galaxy	Greed Float	Liver Crazy
Poise Shock	Thrift False	Famine Cyborg	Candy Clean
Hustle Rock	Fairy Cookie	Shovel Fool	Reward Plasma
Scarf Bump	Pail Tack	Gossip Suit	Remedy Narrow
Riot Fresh	Outlaw Sour	Knight Pace	Sketch Graph
Fungus Tick	Fever Piece	Stripe Motive	Purse Fiddle
Pepper Tube	Flea Cells	Ballot Bogus	Hike Copper
Oval Snow	Perish Screw	Retain Tracks	Flute Rolled

Slab Ribbon	Bison Tweed	Jeep Hero	Rotten Oxygen
Flour Lose	Mellow Sinful	Noose Pretty	Insect Fibre
Petals Oats	Lion Pool	Ghost Crowd	Ledge Braid
Onion Friend	Chisel Molar	Ethics Beige	Cradle Eyes
Pier Toast	Shield Ache	Meadow Timid	Mosque Clang
Picket Strict	Jungle Vein	Canyon Awake	Ladder Veal
Sabre Sponge	Blade Scorn	Saloon Hood	Tavern Angel
Vacuum Bass	Banjo Spill	Logic Armed	Chill Scold
Carpet Gutter			

Critical Word Pairs (Experiments 3 and 4)

Reward Effort	Canal Barge	Lily Pond	Kiss Caress
Inmate Lodger	Hustle Obtain	Famine Thirst	Hunt Arrow
Bacon Sizzle	Fairy Pixie	Rubric Number	Ponder Query
Mare Filly	Possum Fake	Shovel Scoop	Alarm Radio
Scarf Gloves	Essay Novel	Nurse Health	Lover Affair
Hazard Avoid	Rake Sweep	Abuse Strike	Thrift Skimp
Psalm Phrase	Salute Greet	Reef Cove	Gossip Malice
Poise Flare	Pouch Coins	Liver Bitter	Sail Waves
Roost Tree	Rage Bull	Squad Rescue	Ivory Black
Pail Sand	Candy Tasty	Quill Sting	Leaf Spring
Blank Bullet	Ounce Scale	Misery Relief	Greed Profit
Opium Pipe	Chaos Panic	Maze Garden	Keeper Crypt

Launch Eject	Peanut Almond	Rotten Death	Sabre Fence
Pier Wharf	Tavern Irish	Onion Taste	Petals Stem
Purse Heavy	Saloon Cards	Hike Stroll	Insect Search
Canyon Gorge	Logic Puzzle	Oval Orbit	Picket Rights
Ballot Cast	Ghost Image	Riot Mutiny	Remedy Potion
Ladder Ascent	Knight Damsel	Meadow Lake	Retain Porch
Cradle Young	Jungle Exotic	Ledge Bridge	Shield Helmut
Slab Thick	Vacuum Hoover	Stripe Thin	Sketch Artist
Pepper Mint	Noose Knot	Chisel Statue	Perish Doomed
Flea Menace	Chill Frost	Mellow Soft	Flour Eggs
Banjo Twang	Flute Shiny	Fever Dizzy	Bison Indian
Blade Skate	Outlaw Leader	Mosque Shrine	Ethics Virtue
Carpet Flying	Fungus Lichen	Lion Mascot	Jeep Wind
Socket Shock	Plaid Print	Ankle Pain	Grape Melon
Ache Tooth	Canoe Float	Bandit Steal	Blaze Flame
Paste School	Alley Fight	Acre Field	Oyster Shrimp
Trophy Plaque	Friar Omen	Hinge Lever	Nail Tack
Squint Lines	Mildew Humid	Harp Lyre	Groom Suit
Monkey Crazy	Adverb Clause	Pardon Error	Maple Cedar
Donor Plasma	Knot Lace	Pebble Pond	Loaf Browse
Puddle Slime	Eagle Glide	Adorn Clothe	Jewel Rock
Paddle Tennis	Raisin Cookie	Siren Danger	Mammal Ocean

Robot Cyborg	Inform Letter	Domain Realm	Itch Bump
Mink Sable	Scalp Clean	Prank Fool	Option Stocks
Reap Wealth	Faucet Shower	Brawl Feud	Vanity False
Meteor Galaxy	Linen Thread	Choir Angel	Fabric Tweed
Lash Scold	Dice Lose	Thaw Snow	Perch Bass
Deceit Sinful	Pliers Screw	Deer Tracks	Calf Veal
Pest Tick	Obey Strict	Bead Braid	Cotton Fibre
Mall Crowd	Spine Ache	Fawn Beige	Sentry Armed
Towel Pool	Acid Sour	Kettle Copper	Sleeve Rolled
Monk Hood	Cavity Molar	Helium Oxygen	Alias Bogus
Raft Tube	Medal Ribbon	Guitar Fiddle	Rattle Clang
Snail Pace	Oven Toast	Admire Hero	Moist Sponge
Marrow Cells	Frail Timid	Scent Pretty	Trance Awake
Peach Fresh	Alibi Motive	Nerve Vein	Mist Eyes
Peak Graph	Mill Oats	Mouse Friend	Ditch Gutter
Aisle Narrow	Link Piece	Frown Scorn	Quench Spill

Buffer Word Pairs (Experiments 1 and 2)

Milk Morgue	Couch Thump	Flat Church	Police Visit
Casket Cereal	Heart Relax	Loft Rough	Office Safety

Buffer Word Pairs (Experiments 3 and 4)

Flat Rough	Police Safety	Milk Cereal	Couch Relax
Loft Church	Office Visit	Casket Morgue	Heart Thump

New Items (All Experiments)

Secure Bagel Movie Junk Expel Suffer Fable Serum Hymn

Evaded Cube Parent Dour Surf Statue Tissue Stumpy Mess

Thorns Staple Edit Primal Palm Canary Munch Hoist Palace

Neon Foray Infirm Rice Rustle Nugget Trauma Sulfur Rival

Pigeon Starch Ornate Podium Stale Pliers Admit Robe Verse

Acorn Poke Stupor Sleek Pout Ignite Panel Amulet Anvil Blonde

Devour Tangy Ascend Astral Reap Turret Atone Awash Parrot

Scope Subtle Mirage Shame Apple Pause Regret Bleach Baffle

Legend Lemon Gaze Wilt Tonic Smirk Magic Luxury Turtle

Chute Cruise Fish Barrow Basil Bond Legacy Pencil Marble

Cactus Shiver Silky Beckon Scythe Benign Carrot Champ

Script Sickle Chives Stain Claw Whirl Myth Castor Grim

Horror Hobo Scribe Diva Canopy Spouse Scant Stoop Drapes

Drip Elapse Pledge Brink Drowsy Waver Enrage Ether Shell

Absurd Crow Fright Blush Fallow Slam Adult Fiance Fickle

Patch Agile Fable Trace Valve Tablet Blunt Germs Graze

Toner Peel Trout Haggle Silky Graft Tempt Hangar Infirm

Wager Irate Joust Laces Shawl Ticket Blush Leash Livid

Dagger Malt Sprig Slouch Schism Sector Saute Words Coal

Wrist Joiner Serene Renown Slime Weed Optics Pallet

Muffin Clergy Salon Molten Moth Lather Crumb Vendor

Sauce Foyer Soap Vigil Toxin Umpire Strain

UNIVERSITY OF SOUTHERN QUEENSLAND

The Recollection Component of Recognition Memory as a Function of Response Confidence: An Event-Related Brain Potential Study

A dissertation submitted by

David M. Lalor

BAppSc (with distinction), BSc (Hons), BBus(Econ)

For the award of

Doctor of Philosophy

2003

Certification of Thesis

I certify that the ideas, experimental work, results, analyses, and conclusions reported in this thesis are entirely my own work, except where otherwise acknowledged. I also certify that the work is original and has not previously been submitted for any other award.

_________________ _________________

David M. Lalor Date

Endorsement

_________________ _________________

Associate Professor Gerald Tehan (Supervisor) Date

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