Electrophysiological Correlates of Individual Differences in Strategic Retrieval Processing

Emma Bridger

A thesis submitted to Cardiff University for the degree of Doctor of Philosophy in Psychology.

February 2010

Abstract

Processes engaged when information is encoded into memory are an important determinant of whether that information will be recovered subsequently. Also influential, however, are processes engaged at the time of retrieval, and these were investigated in four experiments using event-related potentials (ERPs). Contrasts were made between ERPs elicited by new (unstudied) test items in distinct tasks, the assumption being that these contrasts index operations that are engaged in service of retrieval and which vary according to the demands of different retrieval tasks. Functional accounts of these retrieval processing operations, termed throughout as *strategic retrieval processes*, assume that they influence the accuracy of memory judgments. The experiments reported here comprise the first direct tests of this assumption. In Experiment 1, the magnitude of the differences between new item ERPs from retrieval tasks with distinct retrieval requirements were correlated positively with response accuracy. This pattern was interpreted as indicating that participants who made relatively more accurate responses did so by prioritising the recovery of different types of information in each of the two retrieval tasks. Encouraging participants to adopt this approach in Experiment 2, however, did not lead to changes in response accuracy, or to ERP modulations comparable to those obtained in Experiment 1. In Experiments 3 and 4, ERP evidence for the degree of strategic retrieval processing was again related to response accuracy. These two experiments had different retrieval requirements, and the scalp distributions of the differences between the new item ERPs differed across the experiments. These findings therefore provide further support for a relationship between strategic retrieval processes (as indexed by differences between new item ERPs) and response accuracy, whilst also emphasizing that the specific retrieval processes engaged vary according to task demands. These findings provide new insights into how and when strategic retrieval processes are engaged in service of accurate memory judgments.

Declaration

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

Signed...Emma Bridge................... Date.31.12.10...........

Statement 1

This thesis is being submitted in partial fulfillment of the requirements for the degree of PhD.

Signed...Emma Bridge................... Date..31.12.10...........

Statement 2

This thesis is the result of my own independent work/investigation, except where otherwise stated. Other sources are acknowledged by explicit references.

Signed..Emma Bridge..................... Date..31.12.10...........

Statement 3

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed....Emma Bridge................... Date..31.12.10...........

Statement 4

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loans after expiry of a bar on access previously approved by the Graduate Development Committee.

Signed... Date........................

Acknowledgments

Patience and well-timed encouragement have been the mainstay of my supervision, thanks to both my supervisors, Dr Ed Wilding and Dr Jane Herron. I am especially grateful to Ed for his invaluable guidance and instruction throughout this process.

It is vital that thanks go to members of the support network that has been Cardiff Memory Electrophysiology Lab (CaMEL), which includes Dr Lisa Evans, Rachael Elward, Belle Yick and Damian Cruse as well as honorary members Hilary Watson and Jonathan Shine. Rhys Davies, Kevin Hotson and Rebecca Cottam have also ensured that coming to work has remained more of a pleasure than a chore.

My parents have provided all the support I could ever want and I am indebted to and grateful for their love and friendship. Carrie has remained my person above all others and her continuing kindness and love have helped me more than she can know.

I would like to express my greatest thanks to all those family and friends who have unwittingly eased this thesis along by providing me with plentiful and beautiful distraction.

This work was funded jointly by the Biotechnology and Biological Sciences Research Council and the School of Psychology, Cardiff University.

Table of Contents

Chapter 6: Experiment 2 – Further Investigation of Strategic Retrieval Processing in an Exclusion Task

Chapter 7: Experiment 3 – Individual Differences in Strategic Retrieval Processing in an Item Recognition Task

List of Figures

List of Tables

Chapter 1

Electrogenesis of Event-Related Potentials (ERPs)

Electroencephalography

The human electroencephalogram (EEG) provides a direct index of real-time changes in electrical brain activity. These can be acquired intra- or extra-cranially. Within its fluctuating output, electrical activity associated with the presentation of a specific stimulus can be extracted to provide an event-related potential (ERP; Coles & Rugg, 1995). ERPs employed in sophisticated designs have contributed to the understanding of higher-level cognitive processes beyond providing a mere enumeration of the neural correlates of behaviour (Donchin, 1981). In particular, contrasts between ERPs from conditions which are designed to invoke psychological processes to various degrees have been used to illustrate the time course of cognitive processes. The fundamentals of the event-related potential technique are introduced in this chapter because ERP indices of episodic retrieval operations are used throughout this thesis to determine the extent to which these processes relate to recognition memory accuracy. To gain a complete understanding of how ERP data can reflect the engagement of particular cognitive operations in this way, it is necessary to address the manner in which brain physiology generates the signals which the EEG comprises.

Neuronal Electrogenesis

Neuronal activation occurs because of the engagement of an action potential, the brief disturbance of cellular resting potential via ionic current flow across the cellular membrane (Wood, 1987). Net ionic outward flow from the neuron (source) is matched at passive regions along the membrane in which there is a net inward flow (sink). If there is sufficient separation of source and sink, achieved by neuronal structure and the specific location of activation, a dipole field will be generated in the extracellular space (Picton, Lins, & Scherg, 1994). Figure 1.1 shows an example of a dipole in which the source is towards the surface (top of the diagram), along with the shape of the electric field that would be produced if a microelectrode was passed through it (along planes *a*, *b* and *c*), demonstrating the relationship between the polarity of an ERP and the orientation of the dipole. Electroencephalography, at least under the circumstances described below, involves the detection of the summation of both distant and close dipoles, most commonly by using electrodes located on or near the scalp. The associated magnetic fields generated by dipoles can be recorded by the magnetoencephalographic (MEG) technique.

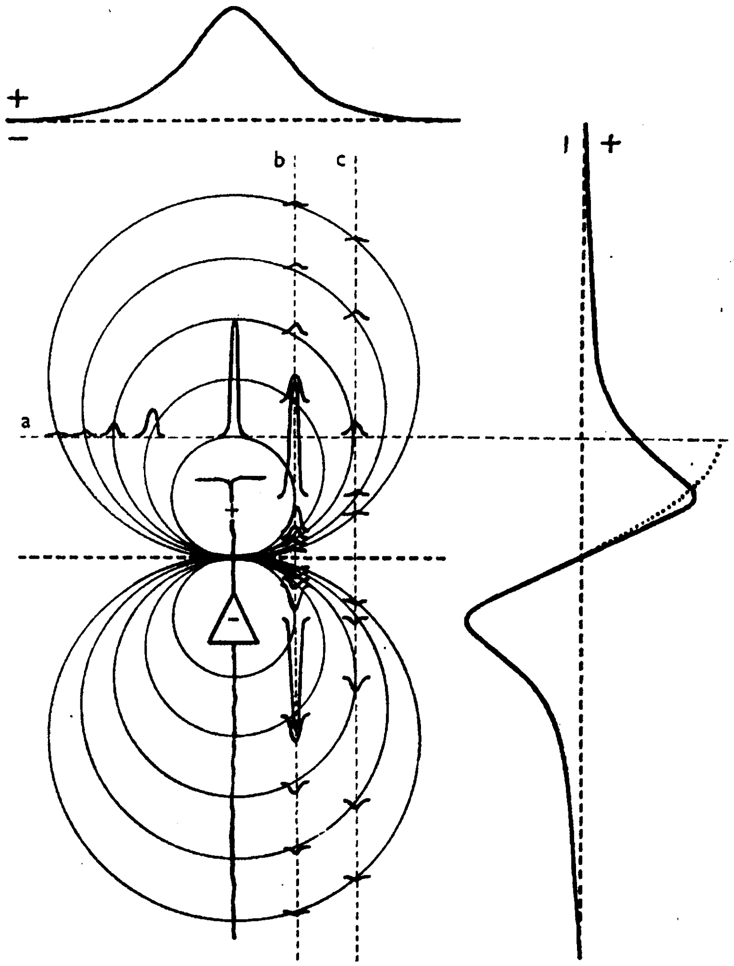

Figure 1.1: Taken from Bureš (1967). The field arising around an electric dipole along with characteristic equipotential lines. The dashed lines represent sections through the field perpendicular to the axis of the dipole (a) or parallel to it (b, c). The amplitudes and polarities of deflections at the corresponding points of the field are illustrated. Towards the top of the figure, the spatial distribution of the dipole potential along plane *a* is shown. To the right of the figures is the spatial distribution of the dipole potentials in plane *b*.

Postsynaptic potentials occur when the propagation of an action potential leads to the cell's own release of neurotransmitter (across the synapse to downstream neighbouring cells) initiating either an inhibitory or excitatory effect on the secondary cell. All potentials are subject to similar relationships between transmembrane current flow and extracellular potentials, but the potentials recorded at the scalp are thought to be purely excitatory (EPSP) or inhibitory postsynaptic potentials (IPSP). This is supported by the link in time course between EEG and IPSPs and EPSPs (Cooper, Osselton & Shaw, 1980). Action potentials are thought to be too short-lived to sum to a degree that is detectable at the scalp.

As a conducting medium, the brain allows electromagnetic activity to travel throughout it. Helmholtz's principle of superposition (Wilson & Bayley, 1950; Wood, 1987) in turn allows potential fields generated by various individual neurons to summate linearly at all locations in the extracellular space (e.g. local field and scalp potential). Specifically, if cells are synchronously active and produce resultant potentials of comparable latency, these fields will summate to create large-amplitude potentials which can be recorded even at reasonable distances from the generator site. Additionally, superposition also holds that potentials of opposing polarities summate and effectively negate each other. It follows, therefore, that EEG technology is limited to the detection of cells arranged in a manner that does not cause potentials to negate each other.

Wood (1987) describes the most appropriate cellular configuration for electrical detection by referring to the earliest experiments in this area performed by Lorente de Nó (1947). One model potential field is that found in cells with long apical dendrites arranged in parallel such as those in the neocortex, hippocampus and cerebellum. The structure of such an arrangement allows for electrical flow to predominate down the long neuronal axis, producing an appropriate dipolar field. As outlined above, superposition posits that the locus and temporal pattern of cell activation is also integral to the detection of potentials, and so if (and only if) all cells in such a hypothetical arrangement fire synchronously, generating similarly oriented dipoles, they will summate. This orientation is known as an 'open field' and is that which is most conducive to detection at the scalp (see Figure 1.2).

Alternative fields, wherein neurons are not congruently aligned, cause the cancellation of potential fields, as a positive portion of one cell's field may cancel another cell's negative aspect, extinguishing any recordable dipole. Summation of this process would lead to the absence of an observable extracellular potential at the scalp, despite each cell generating comparable action potentials and successful information transmission (see Figure 1.2). Importantly, 70% of pyramidal cells in the neocortex meet the requirements for a detectable cellular arrangement. Inherent in this principle and applicable therefore to all studies utilising electrical or magnetic fields is the following restriction: a large proportion of cellular activity such as that from anatomical regions in which cells are not arranged appropriately or where activity is asynchronous, will never be evident at the scalp. Although this selectivity does allow for measures of activity to be deciphered more easily (Coles & Rugg, 1995), it limits the interpretations that data showing an absence of differential ERP effects can allow. This is a severe qualification embedded within the use of ERPs as neuroimaging tools, which means that null findings cannot be taken to mean that experimental conditions do not produce divergent effects on brain activity.

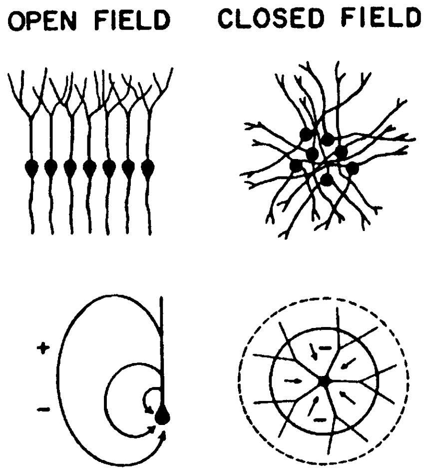

Figure 1.2: Taken from Wood (1987). The upper portion of the figure represents the orientation of cell bodies of a row of neurons with parallel orientation (open field) and a group with cell bodies clustered in the centre and dendrites spreading radially (closed field). The lower portion of the figure depicts the predicted current flow produced by synchronous depolarization of the cell bodies in each of these cell configurations. Only an open field arrangement allows the generation of a potential field that is detectable at far locations (commonly electrodes located on the scalp).

Models of ERP Generation

Currently there are two models for the generation of ERPs from ongoing electrophysiological activity. The classical or additive evoked model assumes that an evoked response, which is fixed in its polarity and latency across trials, is superimposed upon the ongoing 'background EEG'. Averaging across these trials then yields the event-related potential and any ongoing neural activity is simply treated as noise. A competing view is that ERPs are generated following the reorganisation of ongoing oscillations in the EEG (Hanslmayr, Klimesch, Sauseng, Gruber, Doppelmayr, Freunberger et al., 2007). The EEG is known to hold a degree of rhythmicity and to be comprised of ongoing oscillations within a number of frequency ranges (Sauseng & Klimesch, 2008). These oscillations include, amongst others, those in the delta (0-4 Hz), theta (4-10 Hz) and alpha (8-13 Hz) bands, and can be described in terms of their frequency, amplitude and phase. The interdependent relationship between the amplitude and phase of oscillations allows increases in amplitude to follow from the reorganisation of phase. If stimulus presentation causes the resetting of activity from particular frequencies to become phase-locked, averaging these phase-coherent rhythms may lead to the detection of an ERP (Hanslmayr et al., 2007; Min, Busch, Debener, Kranczioch, Hanslmayr, Engel et al., 2007).

The issue concerning which model explains event-related potentials remains open (Sauseng, Klimesch, Gruber, Hanslmayr, Freunberger, & Doppelmayr, 2007), and is hampered because the phase-reset model cannot generate unambiguous predictions (Hanslmayr et al., 2007). Recent studies pitting these models against each other claim to provide data indicating that both models contribute to ERPs (Min et al., 2007; Hanslmayr et al., 2007), and it is likely that the most appropriate model varies for specific ERP components (Mecklinger et al., 2007). Few studies have examined the spectral (oscillatory) components of ERPs associated with recognition memory, although one analysis on event-related fields (ERFs), which correspond to the same electric generators, reported that although it is likely that a combination of large-scale neuronal responses correspond to the generation of scalp-recorded ERFs, there is clear evidence that evoked responses contribute to activity elicited during a recognition task (Düzel, Neufang & Heinze, 2005; see also Klimesch, Doppelmayr, Schwaiger, Winkler & Gruber, 2000). Despite this support for the evoked model in the generation of recognition old/new effects, it is important to be aware of alternative theories for ERP genesis. Complementary models and their associated analysis techniques such as those based in the frequency domain are necessary to reach a detailed description of the complement of neural processes that contribute to recognition memory.

Regardless of which neurophysiological model is correct, ERPs can make a substantial contribution to the constraint of cognitive theories because inferences are based solely upon the pattern of potentials at the scalp. Although these inferences are agnostic with regards to the underlying physiological model, they are dependent upon a number of functional assumptions. The following section discusses interpretations of ERP components and the assumptions upon which these are predicated.

Interpreting ERP Data

Describing ERPs

The standard nomenclature in the ERP literature brands waveforms by combinations of their polarity at the scalp (P meaning scalp positive; N meaning scalp negative), their characteristic scalp topography, their latency and in terms of maximal 'peaks' and 'troughs' (Allison, 1984; Kutas & Dale, 1997). The latency of a waveform's peak can be thought to correspond to the point at which a cognitive process is engaged to the greatest degree, whereas the amplitude indexes the magnitude of that activity. Referring to an ERP 'component' begins with identifying one particular feature (such as a 'peak') and observing the sensitivity of this feature to manipulations. The following section reviews some of the problems that surround using only the physiological attributes of ERPs to identify cognitive components, before addressing the ways in which the sensitivity of ERPs to experiment manipulations can be used to understand the functional significance of components.

Approaches to Defining Components

The physiological approach presupposes that a component's definition is dependent upon the specific locale of its neural generators. The difficulties of a purely physiological approach come about primarily because of the 'inverse' problem (Coles & Rugg, 1995). EEG data can provide little indication of the exact location of the neural generators that contribute to the signal recorded at the scalp because for any given scalp distribution of an effect there remains an infinite number of possible distributions and locations of dipoles within the brain that could correspond with a detected field (Kutas & Dale, 1997). For example, the volume conducting property of the brain means that activity in one region may be disseminated towards manifold detection locations and as such creates a confound of component overlap, wherein observed waveforms may be generated from dipoles from various regions. It is not appropriate to assume that activity detected at one electrode is generated at the most proximal brain region.

New methods of localisation techniques take advantage of the fact that not all possible neural generators or solutions to the inverse problem are equally likely. For example, brain electrical source analysis (e.g. BESA; Scherg, 1990) provides sufficient spatial accuracy to be used in conjunction with PET and fMRI in an effort to constrain estimated dipole location (Miltner, Braun, Johnson, Simpson & Ruchkin, 1994). New research has consequently resulted in which the spatial resolution of fMRI and the temporal acuity of EEG are combined by conjoint measurement (Ritter & Villringer, 2006). Independent Components Analysis (ICA) also enables further insight into the source dynamics of EEG data (Makeig, Debener, Onton & Delorme, 2004). All current localization techniques must be replicated and verified many times however before they are accepted as appropriate.

A full discussion of source localization techniques is not included here because these methods are not utilised in this thesis. Similarly, claims about the functional significance of effects in this thesis are not made on the basis of the scalp distribution of effects, although possible generators are discussed where relevant.

Functional Components

An assessment of the areas in which ERPs have been most influential in scientific research supports the view that ERP data are best suited to questions concerning the constraint of cognitive theory. According to this 'functional' approach, components can be isolated by separating consistent differences in waveforms across experiment manipulations (Kutas & Dale, 1997).

The simplest approach to identifying a component that is representative of a process is to subtract waveforms generated across conditions that are designed to vary the degree to which they employ the process of interest. This 'subtractive' approach rests upon the assumption of 'pure insertion'; that it is possible to create conditions which differ purely with respect to their engagement of only one process (Coles & Rugg, 1995). This critical assumption has not gone unchallenged (Friston, Price, Fletcher, Moore, Frackowiack & Dolan, 1996), because it cannot be ruled out that a number of psychological processes may occur in parallel and interact to produce a scalp-recorded ERP.

There exist a variety of functional inferences that can be taken from statistically verified variability in waveforms compared across experimental conditions. The primary inference that a divergence across experimental conditions permits is that a difference exists and thus that cognitive processing varies between experimental conditions (Rugg & Coles, 1995). The temporal acuity of EEG measurements also means that the time-point at which waveforms begin to differ can provide an upper bound for the time at which processing differs. In episodic recognition memory paradigms, for example, contrasts are typically made between ERPs associated with items that have been encountered in a previous experimental context (old items) and unstudied (new) items. Divergences between ERPs associated with these items, ERP old/new effects, are taken to reflect processing associated with successful retrieval, because this can be present only for previously seen items.

Secondary inferences can be made when observing previously verified components. These are those components for which, on the basis of previous demonstrations of their sensitivity to experimental manipulations, we are generally satisfied with the processes that are most likely to be associated with them. Firstly, changes in the amplitude of a component across conditions can be used to infer a difference in the degree to which a process is invoked. Changes in the latency of a component peak across experiment manipulations can also allow inferences about changes in the timing of a psychological process. Chapter 3 provides examples of the ways in which several different experimental manipulations have been used to functionally dissociate old/new effects. The clearest example of this is an old/new effect that peaks between 500-800ms post-stimulus and which has been shown to provide a reliable marker of recollection-based recognition. The time course of this effect can then be used to determine the time by which recollection has occurred (e.g. Yick & Wilding, 2008). It is also the case that changes in the relative amplitude of this effect have been taken to infer the degree to which recollection is associated with a particular class of item (Vilberg & Rugg, 2006).

A final set of functional inferences come about when there is an interaction between ERP effects and electrode sites. All ERP effects (subtraction waveforms between two experiment conditions) will vary with scalp region, but if effects associated with different contrasts demonstrate reliably distinct scalp distributions this can be taken to infer that not entirely the same neural generators are employed in each case and hence that functionally distinct processes are engaged across conditions (Wilding, 2006). For example, the topographies of old/new effects associated with distinct study histories have been shown to dissociate in this way, and this pattern has been taken to indicate the engagement of retrieval processes that are sensitive to content that is specific to each class of old items (Johnson, Minton & Rugg, 2008).

Assumptions underlying ERP Interpretations

The inferences described above are based upon a number of fundamental assumptions as well as the assumption of 'pure insertion'. Firstly, one of the most frequently adopted theoretical frameworks for combining functional and physical features of neural activity is the standard materialist standpoint and its associated invariance assumption (Coles & Rugg, 1995). This assumes that each given biological state can lead to only one functional state. Equally, it assumes that a cognitive process is caused exclusively by one active physical feature in the brain. This is a common, parsimonious and defensible assumption (Rugg & Coles, 1995) but the possibility that multiple biological states might give rise to the same functional process cannot be ruled out. Mesulam (1990), for example, provides a model of cognitive networks that are distributed in such a way that there can exist 'one-to-one', 'one-to-many' and 'many-to-one' representations across both the anatomical, neural computational and behavioural levels. Behaviour, from this viewpoint, is an emergent feature which is generated by multiple interacting networks. Such an account is highly problematic for imaging techniques because it suggests that knowledge about neural processes is unable to inform functional understanding. Similarly, Mehler, Morton & Jusczyk (1984) argue that there is no empirical justification for assuming a 'one-to-one' mapping between cognition and neural activity. The goal of cognitive neuroscience should therefore be one of determining the way in which neural and cognitive processes can inform one another.

The invariance assumption is especially significant here because ERP data and their interpretation so heavily rest upon it. It is perhaps best illustrated by an example of possible interpretations of ERP data. For instance, the topographical distribution of ERP data may differ significantly across experimental conditions. Consequentially, it is often reasoned that a qualitative difference across conditions reflects the adoption of functionally distinct cognitive processes, but this can only be the case if one is satisfied with the assumption that the same process cannot be produced by multiple neural generators. Although these arguments highlight important issues, there is as yet no empirical evidence against the assumption. The work in this thesis is founded generally upon the assumption that there is a systematic relationship between neural and cognitive levels of analysis which enables them to be examined and to subsequently inform understanding of cognitive processes.

An additional problem that ERPs pose surrounds their correlational nature. No matter how tight the fit between variations in the degree of involvement of a cognitive process and changes in the indices of neural processes, it can never be concluded that a neural component is responsible for the adoption of a given process (Rugg & Coles, 1995). Although demonstrating that variation in the amplitude of a component closely mirrors experimental manipulations associated with a particular cognitive operation does lend credence to a causal hypothesis, this is still an untested assumption that all EEG data rests upon. These causal issues are not unique to ERP studies and extend equally to all haemodynamic modalities and single-cell intracranial recording studies (Rugg & Coles, 1995). Likewise the problems posed by the invariance assumption reviewed above are common to all cognitive neuroimaging methods, although this section has addressed specific ways in which inferences are affected by the nature of EEG data.

Strengths and Weaknesses of the Event-Related Potential Technique

As discussed above, an important shortcoming of EEG data is that they can provide no indication of the exact location of the neural generators that contribute to the signal recorded at the scalp. Source localisation is severely handicapped by the 'inverse problem' (Kutas & Dale, 1997). An additional important problem is the sensitivity of EEG data to only a proportion of the ongoing electrophysiological activity at any time. This limitation continues to limit the inferences that can be on the basis of null findings.

The most valuable aspect of EEG is the ability to produce a direct index of neural activity associated with cognitive processes in real-time (Wilding, 2001). EEG research provides a sensitive investigation of the temporal aspects of cognitive functions, which has been well-exploited across a wide range of psychological areas. It is useful to briefly compare EEG (and MEG) methods with haemodynamic neuroimaging techniques, specifically positron emission topography (PET) and functional magnetic resonance imaging (fMRI). PET and fMRI provide indirect measures of neural activity by tracking changes in regional cerebral blood flow (rCBF) assumed to correlate with increases in neuronal activity. The manner with which the two techniques track rCBF is very different, but it is sufficient to note here that the main limitation of rCBF measures is that they are smeared temporally, typically lagging around 2-5 seconds behind events and returning to baseline some 10 seconds later. This severe temporal limitation is offset by the fact that fMRI and PET can indicate areas in which there is likely to have been a relative increase in neural activity at a spatial scale of millimetres.

Another notable advantage that electrophysiological methodology permits is that data can be analysed specific to a particular stimulus-type in such a way that experimental manipulations (e.g. stimuli) can be mixed together within blocks. This event-related approach is advantageous compared to its blocked counterpart which dominated early fMRI studies, because it does not possess inherent confounds such as the inability to exclude variability related to item-processing within a block (Wilding, 2001). The importance of this kind of data separation is supported by the increasing adoption of event-related approaches in fMRI since it has become technologically available. Nonetheless, the real-time index of activity that ERPs provide allows for more sophisticated designs than fMRI due to the temporal smearing that impedes the haemodynamic modality.

Recording ERPs

Placement of Electrodes

Electrode locations typically correspond to the international 10-20 system (Jasper, 1958) which relates electrode positions to the proximal cortex area (e.g. frontal, parietal, temporal, occipital), and locations within the lateral plane of each area (with odd numbers to the left of midline, Z at midline, and even numbers to the right). Standardised placement programmes are implemented to compensate for variations in head size (Picton, Lins, & Scherg, 1994). For non-invasive scalp recordings, electrodes are commonly attached to their pre-specified locations marked upon an elastic cap. The cap should be appropriately sized to the individual's head and the exact positioning of electrodes to standardized positions should be determined (Picton et al., 2000). A conducting medium is required, usually an electrolyte solution, that separates electrode and skin to optimise detection, yet also allows the potential to reach the electrode (Picton, Lins, & Scherg, 1994).

An ERP measurement is essentially the difference in electrical potential between two scalp/electrode points. In the oft-adopted 'common reference' procedure (Binnie, 1987), all exploratory electrode points are contrasted with a standardised reference channel. This common reference may be a single electrode or a linked pair of electrodes, such as the mastoid points behind each ear, chosen to be relatively close yet relatively unaffected by electrical activity generated by neurons in the brain itself. In order to determine whether electrical activity at each individual mastoid is sufficiently symmetric not to add noise to the EEG, a midline electrode may be adopted as a reference for online processing, the mastoid output monitored for asymmetric activity and the entire data set re-referenced to the linked-mastoid reference (Picton, Lins & Scherg, 1995). The employment of differential amplifiers with this set-up also allows for the detection and cancellation of activity that is equivalent at the ground electrode and exploratory electrodes (common-mode rejection).

A/D Conversion and Filtering

An analogue-to-digital (A/D) converter samples data from the ongoing EEG at regular points, generating an ERP waveform which represents the difference in electrical potential between a specific electrode and the reference electrode at each data point. The rate of A/D conversion or number of microseconds analysed between each discrete point is known as the 'sampling rate'. Recording also requires the employment of amplifiers that enable microvolt signals to be magnified to a level at which they can be detected and digitised (Picton et al., 2000). Amplifiers allow for the specification of high and low cut-off frequencies, such that frequencies detected outside of this bandpass are rejected by the amplifier (Picton et al., 2000). This allows for the detection of activity that falls within frequencies of interest.

Signal Extraction and Averaging

The average amplitude range of an EEG varies between -100 and +100 microvolts with a frequency range of up to 80Hz (Coles & Rugg, 1995). The main concern of cognitive theorists is the voltage variation that is time-locked to a specific stimulus and which tends to be only 5-10 microvolts (Kutas & Dale, 1997). This 'signal' needs to be extracted from the 'noise' of the background EEG, be it unrelated brain activity or from external generators. Referencing as implemented above is one way to remove any electrical activity common to all electrodes, and is a primary stage in removing unwanted or irrelevant activity.

These steps are still insufficient to render the smaller signal detectable from the background on each trial. The most widely used approach to extract the signal is to average multiple EEG epochs time-locked to the same event-type. For each epoch, a short duration prior to the onset of the stimulus (signalled by a *trigger*) is also recorded. This acts as a baseline in order to control the influence of pre-stimulus activity on post-stimulus activity. The averaged data from the baseline epoch (usually at least 100ms) is subtracted from all post-stimulus data points, and this data is averaged subsequently. The single-vector value that averaging yields represents the averaged activity in the specified epoch and any activity not related to specific stimulus processing in the EEG is assumed to vary randomly across trials and consequently average to zero. It is the individual's averaged ERP waveform for each experiment condition on which statistical analyses are later performed. The reliability of averaged waveforms is dependent upon the signal: noise ratio. An averaged waveform will necessarily differ from any individually produced waveform. If a signal of interest is identical across individual trials the representation of this signal in the averaged ERP will be an accurate representation. If the latency of a signal varies from trial to trial, averaging will obscure and reduce information concerning amplitude and time, a phenomenon known as latency jitter.

Artefact Rejection

Non-cerebral signals within the EEG are problematic because they often occur at the same frequencies as important ERP waveforms (Coles & Rugg, 1995) and contribute to overall EEG noise. Major sources of artefacts are eye movements, eye blinks, muscle effects, and background electrical activity. The methods of removal or reduction of background artefacts begin with the use of low-pass amplifier filtering at acquisition. Electro-oculographic (EOG) effects however vary across ERP epochs and so cannot be removed via filtering (Picton, 1987). The eyeball functions as an electrical dipole with a positive cornea (source) opposed to the negative retina (sink).

Eye blinks and saccades differ in their manner of disturbance; whereas saccades cause the rotation of the dipole, the eyelid movement during blinks propagates the current backwards over the head.

Standard EEG procedure therefore requires the measurement of EOG, in order to (i) detect artefacts so that trials on which eye movements occur can be rejected and (ii) to estimate and remove the contribution that eye blinks may have made to the electrical record via regression analysis. This has been shown to be both reliable and valid and allows a suitable proportion of trials to be retained for analysis (Semlitsch, Anderer, Schuster, & Presslich, 1986). Ideally, this should be supplemented by instructing participants to reduce eye and head movements during testing, although this may provide an additional and problematic cognitive load to a task.

Concluding Comments

This chapter has introduced the reader to the fundamentals of electrophysiological recordings, the cognitive inferences they allow, as well as the assorted caveats that are entailed. Despite the assumptions upon which ERP inferences lie, they produce valuable indices of differences in the electrical record which can fundamentally impact cognitive psychology, while complementing behavioural measures and other imaging methods. The role of ERP data is most constructive when properly placed in the context of its associated practical considerations and theoretical assumptions, and when used appropriately, ERPs are a useful tool in the constraint of theories of high-level cognition. This is demonstrated clearly in the subsequent chapter, which reviews a number of models of control in episodic retrieval and the ways in which ERPs have contributed to the understanding of these processes.

Chapter 2
Introduction to Controlling Episodic Retrieval

An efficient mnemonic system must be able to not only retain large amounts of information but also rapidly select appropriate information when required. That the human memory system is capable of this is obvious from everyday experience. Of principal interest in the work presented here is the role of processes that occur prior to retrieval. These are thought to operate by affecting which memories are recovered and/or how recovered content is processed later. Although a degree of understanding into these kinds of retrieval processes has been offered by behavioural experiments and neuropsychological studies (e.g. Moscovitch, 1989; Jacoby, Shimizu, Daniels & Rhodes, 2005), considerable insight has come from neuroimaging methods that can provide a direct index of processes of this type. These measures provide indicators of the retrieval processes engaged by healthy participants that are not accessible via behavioural measures alone. Event-related potentials (ERPs) provide one approach to indexing these processes and possess a degree of temporal sensitivity that is not available for some other neuroimaging modalities. ERPs can provide indices not only of processes engaged in service of retrieval but also those that come about during successful retrieval. The work in this thesis capitalises on this sensitivity in an effort to further understand the factors that are associated with accurate responding in tasks requiring the recovery of information from episodic memory.

Episodic Memory

The currently accepted definition of episodic memory comes from the work of Tulving (1983b), whose ideas have been influential for a number of reasons. Firstly, they flesh out the terminology distinguishing the episodic and semantic memory systems by laying out the differences and similarities between them, including the general characteristics and the kind of information processed by each. Broadly speaking, whereas the semantic system concerns the acquisition of knowledge about the world independent of one's personal experience the episodic system deals with the storage and retrieval of personal episodes that have been directly experienced. Neuropsychological evidence has since provided support for the claim that the two forms of memory are dissociable from one another (e.g. Vargha-Khadem, Gadian, Watkins, Connelly, Van Paesschen, & Mishkin, 1997; Squire & Zola, 1998; Temple & Richardson, 2004). It is episodic memory that is the concern of this thesis.

The second important feature of Tulving's work was to introduce the taxonomy developed by Semon (1921) to the vocabulary of modern day memory theorists (Schacter, Eich, & Tulving, 1978). Amongst the most important of these terms is the *engram,* which refers to the permanent changes that come about in a biological system following the presentation of a stimulus. This term is currently used interchangeably with the phrase *memory trace.* The process of inscribing an engram is *engraphy*, although this is often replaced with the more general term, *encoding.*

Tulving also re-introduced Semon's use of the term *ecphory* as a critical process for retrieval. According to Tulving's framework, this process enables a latent engram to be converted into ecphoric information wherein stored details become activated and re-experienced. Ecphory is dependent upon the successful interaction between a retrieval cue and an associated engram. A retrieval cue comprises any stimulus, externally or internally generated, which influences the retrieval process. Crucially however, for a stimulus to operate as a retrieval cue in this framework an individual must be in *retrieval mode*. This cognitive state or task set is an important precondition for retrieval, because without it, almost any encounter or stimulus might elicit the recovery of all associated experiences. Once retrieval mode has enabled a retrieval cue and an engram to successfully interact, ecphoric information is activated and can then be converted to enable an appropriate response to be made (see Figure 2.1; Tulving, 1983a). If the current goals do not require an overt response, the conversion stage may not be engaged. The significance of this final stage of retrieval is easiest to observe in the experimental laboratory. For example, conversion can transform behaviour into a simple yes/no response or the recovery of explicit details. Whereas ecphory remains a relatively automatic process, conversion can be adopted when necessary and tailors responses to the task demands. Thus, it is made clear in this framework that processes engaged both pre and post-retrieval have an influence on behaviour in episodic memory tasks.

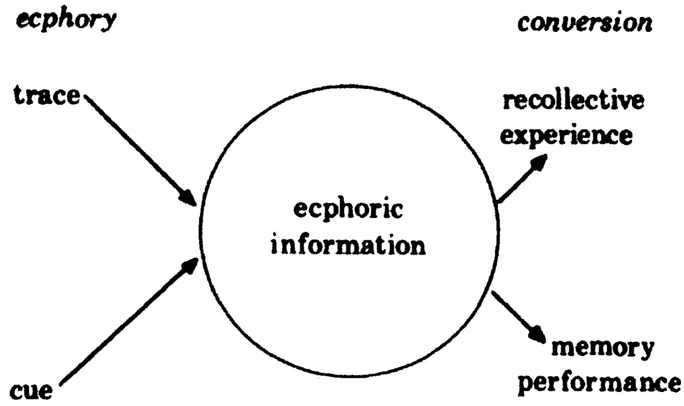

Figure 2.1: Taken from Tulving, 1983a. A schematic representation of Tulving's two stages of retrieval.

Processing Approaches to Episodic Memory

Proceduralist or "activity-based" approaches to cognition focus upon mental procedures in order to explain psychological phenomena. Arguably, one of the most influential models of this kind in the field of episodic memory is Craik & Lockhart's (1972) levels-of-processing framework, which states that the 'level' at which information is processed affects the later retrieval of that item. Information that is dealt with at a relatively 'deep' level, often by engaging semantically with it, is more likely to be recalled later than information that is processed relatively 'shallowly' perhaps by attending primarily to its perceptual characteristics. Although Craik & Lockhart's framework is far from immune to criticism (for a review see Roediger & Gallo, 2002) it has provided fertile ground for insight into the way in which encoding processes can affect performance in episodic memory tasks (e.g. Gardiner, 1988; Gardiner, Java & Richardson-Klavehn, 1996; Rugg et al., 1998; Rugg et al., 2000).

Later theories challenged the sufficiency of the levels of processing approach for explaining memory phenomena by stressing the role of processes that are engaged during retrieval as well. Tulving and Thomson's (1973) encoding specificity principle for example, stipulates that the effectiveness of a retrieval cue depends upon the particular operations that are employed when an item was initially studied. The principle of transfer appropriate processing (Morris, Bransford & Franks, 1977) takes this further by stating that test goals can impact upon memory performance by determining the degree to which the operations engaged at encoding are also re-implemented at retrieval. Empirically, Morris and colleagues demonstrated this by showing that memory performance can be superior for shallow rather than deeply encoded items when the retrieval task requires participants to attend to the same features that were processed in the shallow acquisition task. The finding that the degree to which encoding and retrieval operations overlap with one another affects memory performance has been reproduced with various stimuli and in numerous paradigms (for reviews see Roediger, Gallo & Geraci, 2002 and Kent & Lamberts, 2008). The importance of the principle of transfer appropriate processing, particularly in the context of the work presented in this thesis, is the emphasis it places upon the processes that are engaged when a retrieval cue is processed.

Models of Control in Episodic Memory Retrieval: Insight from Confabulation

Controlled memory retrieval refers to the ability to guide retrieval to ensure task appropriate behaviour (Mecklinger, 2010) and is dependent upon control mechanisms that operate both before and after retrieval. If operations at these stages fail, then information may still be retrieved but is more likely to be false or inappropriate for the current task context. Individuals who pathologically retrieve false information and act upon this are said to *confabulate.* A number of models have been developed to account for confabulation, including those that stress the role of deficits in temporal awareness and the ability to suppress memories that do not relate to the present (Schnider, 2003; Metcalf, Langdon & Coltheart, 2007). Most importantly for present purposes, however, are those models that describe the phenomenon as a consequence of impairments at retrieval and in the mechanisms that control it (e.g. Johnson, Hashtroudi & Koutstaal, 1993; Moscovitch & Melo, 1997). Confabulation is most often observed in individuals with lesions to the frontal system, particularly following damage to the anterior communicating artery, and as a consequence many models hypothesise that the seat of the control processes that facilitate controlled memory retrieval lies within the frontal lobes (e.g. Burgess & Shallice, 1996; Metcalf et al., 2007).

One set of operations that the frontal lobes have been linked with and in which a deficit might lead to confabulation is source monitoring processes. Posited as part of the *source monitoring framework* (SMF; Johnson, Hashtroudi & Koutstaal, 1993), *source* refers to characteristics which specify the conditions in which an episode was committed to memory and includes features related to an item's perceptual content, contextual information, semantic detail as well as affective experiences and cognitive operations. According to the SMF, decisions about a source depend upon average differences in the characteristics of memories from different sources. For example, deciding whether something was heard on the radio as opposed to seen in a newspaper might depend upon the extent to which the source information associated with a memory included visual as opposed to auditory details. Various criteria and decision processes are subsequently employed to make an appropriate response, and these criteria, including the weightings given to certain features depend upon the situational demands, although the underlying processes that are available remain the same across all classes of episodic task. An impairment or a failure to engage in source-monitoring processes may lead to confusion between imagined and real events or events with different temporal contexts, as is often reported in cases of confabulation (Metcalf et al., 2007).

Other models place an additional emphasis upon the role of searching processes that operate before retrieval. Moscovitch (1989; 1992; Moscovitch & Melo, 1997) makes a distinction between lower-level binding automatic processes that enable ecphory and higher-level strategic processes which organise, reason about and select from memory outputs. Whereas automatic processes are supported by the hippocampus, strategic processes are mediated by the frontal lobes. When a patient confabulates, these strategic processes are impaired and the patient combines information from various sources, muddles event sequences and accepts the version of events that they have generated. Consequently, these patients are able to perform normally on recognition tasks that require them to determine whether they have previously encountered retrieval cues but are markedly poorer at free recall tasks. In later developments of this model, Moscovitch & Winocur (2002) made specific claims about the separate strategic processes in which a deficit might cause confabulation, including those that formulate a strategy, specify the necessary cue processes, and guide the search as well as those that monitor and evaluate outcomes. Moscovitch & Winocur also proposed possible neuroanatomical sites for these processes based upon the relevant animal and neuroimaging literatures. Figure 2.2 provides a representation of the hypothesised relationship between the different stages of strategic retrieval in this framework.

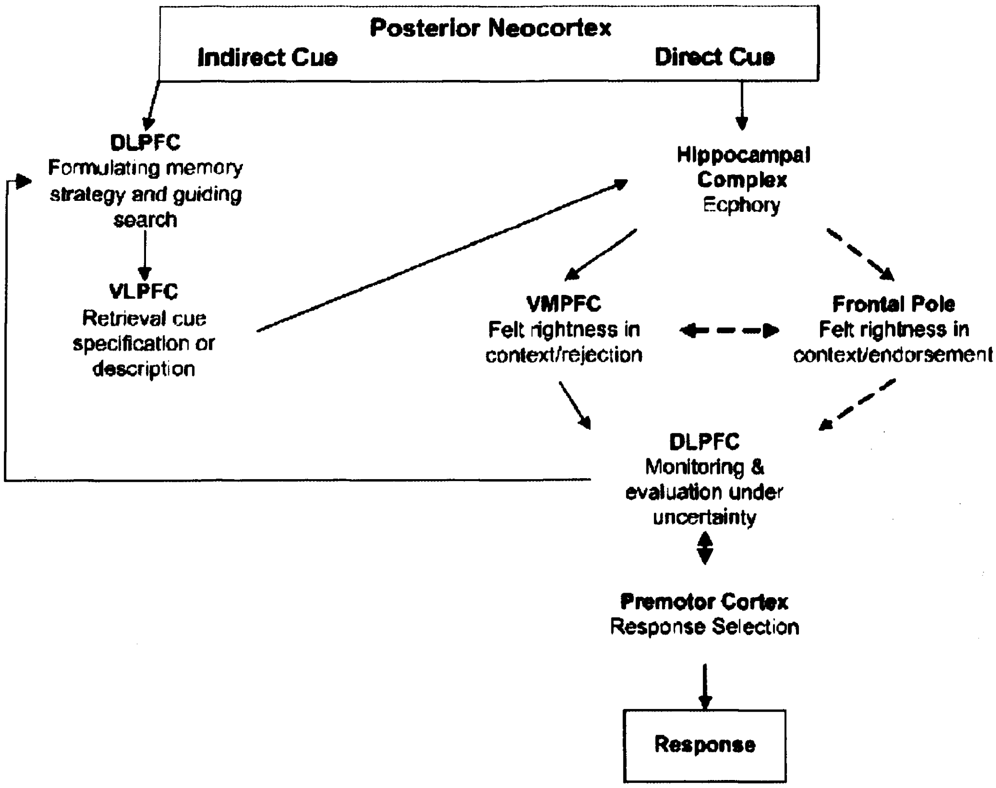

Figure 2.2: Moscovitch & Winocur, 2002. Proposed neuropsychological model of strategic retrieval. DLPFC = dorsolateral prefrontal cortex, VLPFC = ventrolateral prefrontal cortex, VMPFC = ventromedial prefrontal cortex.

In a related framework, Burgess & Shallice (1996) also identified control processes that operate at distinct retrieval stages, some of which map onto those specified by Moscovitch & Winocur (2002). *Descriptor* processes specify the class of memory information that will meet the retrieval demands and *editor* processes constantly monitor the outputs of memory to determine whether they meet current demands as well as whether they agree with previously generated mnemonic outputs. A third set of control processes, those that take the role of *mediators,* reason about the plausibility of memory outputs.

Evidence for impaired editor processes follows reports that confabulators provide less evidence of the engagement of self-corrective processes compared to non-confabulators, often failing to pause before responding or to engage in 'verbal checking' (Mercer, Wapner, Gardner, & Benson, 1977, as cited in Burgess & Shallice, 1996). A breakdown in problem-solving processes would lead to an inability to reason about the credibility of the outputs from memory. In line with this, patients with frontal lesions have been shown to perform poorly on tests that tap into the capacity to make reasonable estimates on the basis of prior knowledge such as the Cognitive Estimates test (Shallice and Evans, 1978). Deficits in these processes alone, however, cannot explain the high frequency of erroneous memories that confabulators generate, but fault at the level of descriptor processes would, if the system does not make sufficiently clear specifications about the targeted memory representations.

An emphasis on specification processes was also included in the *constructive memory framework* put forward by Schacter, Norman & Koutstaal (1998). This perspective focuses upon the inherently constructive nature of memory as indicated by numerous instances in which memory is prone to errors and distortions in normal as well as impaired memory (e.g., Loftus, 1993; Schacter, Koutstaal & Norman, 1996). The framework begins with the assumption that the constituent features of memory traces are located in different regions of the neocortex. These features must be bound together to provide a coherent memory representation, yet each particular pattern must remain distinct enough to allow isolated episodes to be retrieved separately (O'Reilly & McClelland, 1994). At the point of retrieval the rememberer must describe the characteristics to be retrieved at an appropriate level, a process known as *focusing*. If focusing is not engaged appropriately, the likelihood of recovering irrelevant information or poor memory for source-specifying details becomes greater. Retrieval occurs when the features that had been bound together to make a particular representation are activated together again via pattern completion (O'Reilly & McClelland, 1994). Once a successful match has been made, the various details (e.g. perceptual or semantic content) must be compared using a criterion setting process to monitor and verify the exact origin of an episode.

Common to the above models is the potential for the engagement of strategic control operations at multiple stages. Critical, for present purposes is the importance of processes that stipulate and specify the targeted class of memories prior to retrieval, which were encountered in the concepts of focusing (Schacter et al., 1998), cue specification processes (Moscovitch & Winocur, 2002) and descriptor processes (Burgess & Shallice, 1996). The role of description processes of this kind in episodic retrieval was first outlined by Norman & Bobrow (1979) who stipulated that the effectiveness of a *description* is a function of both its *constructability* and its *discriminability*. Constructability is the likelihood that a particular description can be constructed, whereas discriminability refers to the capacity for that description to distinguish between all possible memory traces. According to Norman & Bobrow, descriptions guide memory search and help ensure retrieved records meet retrieval needs, not as a step in a sequence of events, but in an ongoing cycle that employs these operations iteratively. The influential role of descriptor processes is highlighted by the possibility that a deficit at this level alone might be sufficient to cause confabulation. Dab, Claes, Morais, & Shallice (1999) made such a claim following the performance of patient P.A.D. who performed normally on recognition memory and cued recall tasks but confabulated consistently on free recall tasks. Dab and colleagues interpreted this pattern as evidence of an individual who was unable to generate descriptions with sufficient discriminability.

These models and the data used to support them highlight the role of descriptor processes in retrieval. Across these models, however, the influence of these processes is restricted to instances in which an individual must recall information on the basis of indirect questions (i.e. free recall tasks). Descriptor processes, moreover, are assumed to have only limited or no influence over retrieval processing in recognition memory tasks in which individuals must determine whether they have previously encountered an event. As Figure 2.2 shows, for example, Moscovitch & Winocur's (2002) model assumes that direct cues, such as those employed in recognition memory tasks, should lead directly to hippocampally-mediated ecphory, effectively bypassing the need for search processes. Similarly, the claims made by Dab et al. (1999) concerning the locus of P.A.D.'s retrieval deficit are made under the assumption that descriptor processes are somewhat redundant in recognition memory tasks.

There is, however, a growing literature of neuroimaging data that indicates that processes of this kind are employed prior to retrieval as part of a retrieval attempt in recognition paradigms. In so far as these processes have been shown to engage before retrieval they correspond with the descriptor processes outlined in the models discussed above and implicate a functional role for such processes in normal recognition memory. The following sections include a comprehensive review of the way in which these neuroimaging studies - in particular those that use event-related potentials (ERPs) - have contributed to discussion of the processes that enable strategic retrieval in various recognition memory paradigms.

Retrieval Mode and Retrieval Orientation

Retrieval mode is a cognitive set, entry into which ensures that stimuli are to be processed as episodic retrieval cues (Tulving, 1983b; Rugg & Wilding, 2000). According to Tulving, engaging retrieval mode is necessary to ensure that stimuli do not continuously elicit all previous associations made with an item. Once retrieval mode is adopted, the relevant cognitive operations that enable this processing are held in abeyance until external cues are encountered (or generated, in the case of internal cues). It is also the case that certain operations will dictate the way in which cues are processed according to the specific episodic retrieval demands. In order to begin a structured examination of the neural correlates of these more precise retrieval processes, Rugg & Wilding (2000) defined the term *retrieval orientation*. Retrieval orientations operate in all episodic tasks but are likely to vary with stimuli, response requirements and task structure.

One way of characterising retrieval processes is to distinguish between state- and item-related processes; those that are maintained throughout a task and those associated with individual trial events or episodes (Rugg & Wilding, 2000). Both retrieval mode and orientation represent state-related processes that can be maintained for as long as a retrieval task must be performed. Some early imaging studies used this assumption to distinguish retrieval mode, a state-related process engaged throughout a retrieval phase, from transient item-related processes associated with successful retrieval (LePage, Ghaffar, Nyberg & Tulving, 2000; Donaldson, Petersen, Ollinger, & Buckner, 2001). It is also possible, however, to observe the consequences of adopting retrieval sets on a trial-by-trial basis by analysing item-related effects (Rugg & Wilding, 2000). In order to comprehensively describe retrieval set processes, therefore, it is useful to distinguish between neural correlates of retrieval sets that are unique to each retrieval trial (item-related indices) as well as activity that is maintained throughout tasks that require retrieval (state-related indices) and the advent of mixed block/event-related fMRI designs has provided a degree of understanding for both state and item-unique activity of retrieval sets. Nonetheless, as will be demonstrated below, the contribution of event-related potential (ERP) data to an understanding of these retrieval sets has been by far the most lucrative method for investigating these processes.

Neural Correlates of Retrieval Mode

By definition, the neural indices of retrieval mode should be maintained from the initial engagement of an episodic task until its completion and should not vary in any way across different types of episodic tasks. This task invariance allows neural correlates to be revealed when contrasting any episodic retrieval task with any non-episodic retrieval task.

Assuming that retrieval mode and retrieval success are neurally and functionally dissociable, an additional feature of brain regions that support retrieval mode is that they should demonstrate activity that is invariant across changes in retrieval success (Rugg and Wilding, 2000). A number of early imaging studies of retrieval processing by one research group used blocked designs in positron emission tomography (PET) to uncover the location of brain regions that are associated with episodic retrieval while remaining invariant to retrieval success (Kapur, Craik, Jones, Brown, Houle & Tulving, 1995; Nyberg, Cabeza & Tulving, 1996; Düzel, Cabeza, Picton, Yonelinas, Scheich, Heinze et al., 1999). In these experiments, participants completed two episodic recognition tasks with either a high or low percentage of old items, as well as a baseline semantic task. Activity in right prefrontal sites near the frontal pole was invariant across the proportions of old:new items but greater in the episodic than semantic task, a key motivation for linking activity in these areas to the adoption of retrieval mode (LePage et al., 2000; although see Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996; Rugg, Fletcher, Allan, Frith, Frackowiak, & Dolan, 1998).

Düzel and colleagues (1999) also recorded direct-coupled (DC) event-related potentials from the same participants who took part in one of the recognition tasks in which PET was used. The combination of both imaging techniques allowed the authors to begin to dissociate state- and item-related activity in a single retrieval paradigm. ERPs were recorded during retrieval blocks in which old and new items were presented in short lists of four items. Before each block, participants were cued to perform either a semantic (living/non-living) or an episodic (old/new) judgment. The DC event-related potential data demonstrated a sustained positive-going shift over right frontopolar electrodes when episodic rather than semantic retrieval was required (see Figure 2.3). This DC component continued throughout an episodic retrieval block, thereby meeting one of the critical predictions for a correlate of 'retrieval mode'; that the adoption of such a cognitive set should be maintained while retrieval from episodic memory is required. If the assumption that the DC effect was generated in right PFC is valid, the correspondence between this and the PET data provides strong support for the role of the right PFC in retrieval mode. In sum, the data presented by Düzel and colleagues indicate the role of the right anterior cortex in the adoption and maintenance of retrieval mode (Düzel et al., 2001).

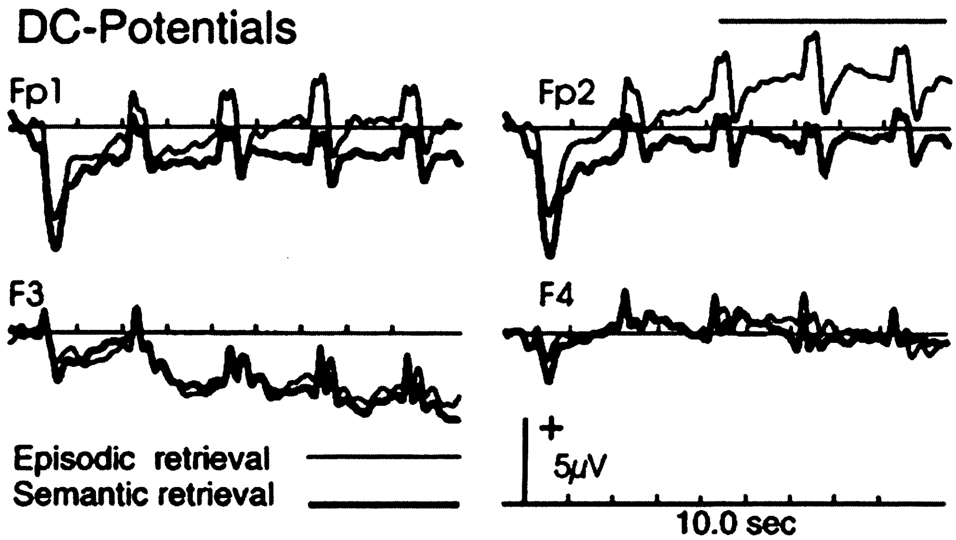

Figure 2.3: Taken from Düzel et al., 1999. ERP waveforms elicited by lists each comprising 4 items presented during the episodic (thin lines) and semantic (bold lines) retrieval tasks. The displayed epoch of 10 sec encompasses the entire list, starting at 500ms before the onset of each task instruction and ending 1500ms after the presentation of the fourth (last) item. Data are shown for electrodes at left and right frontopolar and frontal locations (see Figure 4. 1 in Chapter 4 for a schematic that includes these locations).

Data on the issue of the time course of the engagement of retrieval mode comes from item-related indices of cue processing indexed by ERPs. Morcom and Rugg (2002) focused upon activity elicited by preparatory task-cues that preceded each retrieval cue and signalled which task was to be performed on that trial (often referred to as task cue-elicited effects). These preparatory cues determined whether a retrieval cue should be subjected to an old/new recognition or a semantic memory judgment. Differences between ERPs elicited by task-cues signalling recognition or semantic judgments appeared from 500 milliseconds (ms) until the onset of the retrieval cue for those trials on which the task was the same as that on the preceding trial (*stay* trials). Effects were not reliable when analyses were limited to those trials in which the cue differed from that on the preceding trial (*switch* trials). Where effects were present they were greatest at right hemisphere sites, consistent with previous reports of the right-lateralisation of other ERP and haemodynamic indices of retrieval mode. The sensitivity of this effect to whether trials were switch or stay led Morcom & Rugg to propose that at least a single retrieval trial is required before retrieval mode is engaged.

Although the effects Morcom and Rugg reported were right-lateralised they failed to show the frontal maximum of Düzel and colleague's findings, implying that the two studies may have reflected the engagement of distinct neural processes. Regardless of differences in design and participant, the scalp location of indices retrieval mode should not vary across designs. These differences are consistent with the possibility that whereas the effect reported by Düzel and colleagues indexed processing responsible for maintaining a retrieval mode (or a direct index of mode itself), the effect uncovered by Morcom & Rugg provides a signature of processing related to the initial adoption of a retrieval mode.

In sum, both state-related and item-related contrasts between episodic and non-episodic tasks provide strong support for the concept of retrieval mode. The following sections review reports in which contrasts are made between different episodic tasks, which consistently indicate that retrieval processes are also sensitive to the particular episodic task requirements. These changes in episodic retrieval processing provide indices of the engagement of distinct retrieval orientations.

Neural Correlates of Retrieval Orientations

In their review, Rugg & Wilding (2000) distinguish between retrieval mode and retrieval orientations. The processing bestowed by a retrieval orientation is inherently more discriminating than that assumed to be encountered when an individual enters into retrieval mode. An important assumption is that specific processes are engaged because they depend upon the current task conditions. The neural correlates of retrieval orientations should vary with particular task requirements and are evident when contrasting physically identical retrieval cues from tests in which the retrieval demands vary. In this manner, it is possible to index item-related processes related to the adoption of a retrieval orientation.

Throughout this thesis, retrieval orientation indices of this kind are referred to as correlates of *strategic retrieval processing* because the specificity of retrieval cue operations is thought to come about because they are associated with the recovery of information that is maximally diagnostic for the current task. Prioritizing only those features that are most diagnostic should be relatively efficient if one considers the multitude of potential contexts with which information could be associated (Marsh & Hicks, 1998). An example of when such strategic processes might be employed is in the case of reality monitoring judgments in which it must be decided whether an episode was actually experienced or only imagined (reality monitoring; Johnson & Raye, 1981). When making decisions of this kind participants report that they monitor the extent to which perceptual characteristics are associated with an episode, under the assumption that these will be somewhat greater for those episodes that they directly experienced (Johnson, Foley, Suengas & Raye, 1988). Engaging processes that encourage the retrieval of this kind of information might then be beneficial to the task of distinguishing between real and imagined events.

Processes of this kind are inherently more specific than those associated with the engagement of retrieval mode. In an effort to dissociate the processes associated with retrieval orientation and retrieval mode, Herron and Wilding (2004) cued participants, trial-by-trial, to perform one of three retrieval tasks upon subsequent test items. These cues specified either a semantic judgment or one of two episodic retrieval judgments, allowing contrasts to be made between electrical activity elicited by these cues. Processes related to retrieval mode should be evident when contrasting the episodic and semantic cue whereas processes related to retrieval orientation can be revealed by contrasting the two episodic cues. It was also possible to examine whether ERP correlates of retrieval set differed for the two types of cue depending upon whether trials were switch (task-cue differs from the preceding trial) or stay (task-cue is the same as in the preceding trial), to describe the timescale over which the different retrieval sets are engaged.

There were reliable differences between task cue-elicited ERPs at frontal sites on stay trials only. Activity that was common to both sets of episodic cues was more positive than that specifying the semantic condition at right-frontal sites from 800-1900ms post-cue. The distribution of this effect is again consistent with claims that the right prefrontal cortex supports the adoption and/or maintenance of retrieval mode (Düzel et al., 1999; Kapur et al., 1995; LePage et al., 2000). In the same time window, divergences between ERPs elicited by the two episodic cues showed a more left-lateralised and fronto-central distribution. Rescaled analysis of the data suggested that at least partially non-overlapping brain regions supported these different distributions. Thus, the data indicate that functionally distinct processes were engaged in the two contrasts, demonstrating that retrieval mode and orientations are neurally dissociable retrieval processes. The behavioural data recorded in this paradigm also provided further insight into the implications of switching between retrieval mode and orientation. Participants responded reliably faster on stay than on switch trials (a similar pattern was reported by Morcom & Rugg, 2002). Combined with electrophysiological evidence that the different task sets are not engaged until at least one trial has been performed, this indicates that retrieval mode and orientation can affect the efficiency with which information is recovered and/or processed.

In a later study, Herron & Wilding (2006a) showed that even when the interval between task and retrieval cues was extended to 4000ms, differences between cue-elicited ERPs still occurred only on stay trials. This suggests that a retrieval set (in this case, retrieval mode) cannot be adopted fully until at least one full trial has been completed. Under some circumstances however, cue-elicited processing can vary on switch trials. This pattern has been observed in experiments in which only two episodic task cues were used (Herron & Wilding, 2006b; Johnson & Rugg, 2006). The removal of the requirement to switch in and out of retrieval mode (as was the case in the experiment reported by Herron & Wilding, 2004) may have facilitated participants' capacity to switch between retrieval orientations. The combined data therefore stress the interactive relationship between retrieval mode and orientation and indicate specifically that the efficiency with which a retrieval orientation can be adopted is dependent upon the adoption of retrieval mode. This suggests that switching into and out of retrieval mode is more cognitively demanding than changing processing within the episodic system (Herron & Wilding, 2006b).

Retrieval Cue-Elicited Effects

It is also possible to index processes engaged as a consequence of retrieval orientations by contrasting neural activity elicited by *retrieval cues* from tasks with different retrieval requirements. This approach is based upon the assumption that adopting a retrieval set has consequences for the processes engaged when a retrieval cue is encountered. It is contrasts of this kind that are employed in the experiment designs reported in this thesis. An important stipulation for contrasts between ERPs elicited by retrieval cues is that they should be made separately for correctly identified old and new items. This is necessary in order to distinguish between the way in which processing of cues differs across tasks (which may be revealed in contrasts of neural activity for both new and old items) and the way processing may differ following variation in the retrieval of different memory contents (evident primarily when contrasting old items). This logic means that in order to ensure that neural correlates index only pre-retrieval processing following the adoption of a retrieval orientation, contrasts across tasks must be limited to activity elicited by new items (Rugg & Wilding, 2000). The majority of studies using these contrasts have used ERP data and here these are termed *ERP new item effects.*

In the first ERP investigation of this type, Johnson, Kounios & Nolde (1997) contrasted ERPs from two groups of participants who completed either a simple recognition task in which they had to determine whether they had previously encountered each item or a source retrieval task in which they were required to retrieve the format in which items had been presented at test. ERPs associated with the simple old/new task were significantly more positive–going at frontal sites from 1300-2000ms post-cue. This differentiation was in line with the authors' hypothesis that the two tasks engaged source monitoring requirements to a different degree (Johnson et al., 1993), and that the neural generators of source monitoring operations lie within the frontal lobes. The same study also allowed for a contrast between ERPs elicited by groups of participants for whom the tasks at encoding differed. The authors reported that retrieval ERPs elicited by these two groups showed sustained divergences for the majority of the recording epoch at both anterior and posterior sites. Although the authors noted that both new and old items elicited similar effects they failed to conduct separate contrasts for old and new making it impossible to separate the way processing of retrieval cues differs across tasks with the way retrieved information is processed across test items (Rugg & Wilding, 2000).

Further evidence that electrophysiological effects related to strategic retrieval are frontally distributed has been shown in two studies by Ranganath and Paller (1999; 2000) that do meet this criterion however. In these studies, participants performed a series of study-test blocks, in which black and white pictures were presented at study. Intermixed with new items, previously studied pictures were either presented at test in a manner that was identical to their studied presentation (also known as *copy cues*) or smaller/bigger than their original presentation. Within each experiment, participants completed two types of test instruction; 'general' instructions demanded simple old/new judgments to all items regardless of the format of test pictures, whereas 'specific' instructions comprised the requirement to respond old on the basis of the relationship between a studied item and it's originally presented counterpart. In the first of these experiments, the 'specific' task required only determination of whether the item differed from its original presentation (Ranganath & Paller, 1999). ERPs elicited in the specific task demonstrated a greater relative positivity, primarily at left frontal scalp sites. Although this effect onset earlier for ERPs associated with new items across the two task types, the topography of the effects did not differ significantly across all classes of old and new item. What may be a corresponding effect in the left anterior prefrontal cortex was observed in an analogous fMRI experiment reported by Ranganath, Johnson, & D'Esposito (2000).

The second ERP experiment required participants to explicitly retrieve whether a studied item was a smaller or larger reproduction of its original (Ranganath & Paller, 2000). This requirement ensured that participants could only perform the specific test by recollecting an item's original presentation, because differences in familiarity following study/test match or mismatch may have been sufficient to make judgments in the previous experiment. ERPs associated with the general and specific task again diverged at frontal sites, albeit in a manner that was greater in magnitude and more protracted in time for old than new item contrasts. This anterior effect dissociated topographically from a parietal component that was observed for old items only, leading the authors to propose that whereas the posterior effect was related to the greater likelihood of recollection of previous episodes in the specific than the general test (by virtue of the explicit retrieval judgment), the anterior 'test' effects were associated with memory-monitoring activities.

Wilding (1999) contrasted correctly rejected new items from test blocks that required retrieval of either the gender of the voice in which auditory words were presented or one of two types of semantic information associated with each studied item. ERPs elicited by *correct rejections* (correct responses to new items) diverged from one another at anterior sites from 300ms until the end of the recording epoch. Contrasts between ERPs elicited by correctly identified old items across the two types of retrieval task also revealed reliable divergences, albeit across different time windows than for the new item contrasts. As a result, Wilding (1999) suggested that at least under some circumstances, there exist strategic mnemonic processes that operate only on new items, and that such processing is likely to terminate once an item is successfully recognised.

Performance in the two retrieval tasks reported by Wilding (1999) differed markedly, allowing the possibility that differences between ERPs from the two tasks may correspond to variation in task difficulty (Rugg & Wilding, 2000; see section below on the issue of retrieval effort). A similar problem was encountered by Rugg, Allan & Birch (2000) who reported a fronto-central distribution of differences between ERPs elicited by new items from test phases in which old items had either been encoded in a deep or shallow encoding task (Craik & Lockhart, 1972). Reaction times were longer and Pr values (index of old/new discrimination; Snodgrass & Corwin, 1988) lower in the shallow recognition test. Rugg et al. reported that there was no correlation between the differences in reaction times across retrieval phases and the amplitude difference in microvolts between ERPs elicited by new items at the site where the effect was largest. This shows that the difference in ERP amplitude was not related to differences in reaction time but does not help determine the extent to which these differences relate to changes in accuracy for the two tasks.

Although the possibility of confounding changes in task difficulty is important (a thorough discussion of this issue is provided in the following section), the pattern across studies consistently shows the anterior distribution of effects associated with contrasts between tasks with different retrieval requirements. Neuropsychological studies consistently imply the role of the prefrontal cortex in memory control tasks (e.g. Janowsky, Shimamura & Shire, 1989; Moscovitch, 1989; Wheeler, Stuss & Tulving, 1997) making it reasonable to assume that this region contributes to the controlled processing bestowed by retrieval orientations. The data used to make these claims also show that the correspondence between test effects for old and new items is not always consistent (Wilding, 1999; Ranganath & Paller, 2000), although similarities do exist (Ranganath & Paller, 1999). This pattern highlights the importance of limiting contrasts to new items from different retrieval phases in order to make the unreserved claim that such effects index processes related to retrieval orientations.

Retrieval Effort

Wilding (1999) and Rugg et al. (2000) reported consistent behavioural differences between the two tasks from which ERPs were compared, introducing the possibility that any processing differences may index *retrieval effort.* The relationship between retrieval effort and retrieval orientation has been addressed directly in two studies. In the first of these, Robb & Rugg (2002) employed a factorial design that orthogonally manipulated study context (by presenting items as either words or pictures) and difficulty (by extending the length of study lists). In four recognition memory tests participants' electrical activity at test was recorded, while they judged the study history of old words, new words and words representing previously-seen pictures. Retrieval effort was assumed to be greater in the more difficult task whereas retrieval orientation was operationalised by contrasting new item ERPs elicited from test phases in which the associated study material differed. This enabled retrieval orientation and retrieval effort to be crossed while keeping test items physically identical in all four tests.

Participants' memory performance benefited both for the easy recognition test over the difficult test and when words rather than pictures were the study material. The improvements related to study material were as great as those afforded by difficulty manipulations. Differences between ERPs evoked by new items, however, were observed predominantly in the study material contrasts. Earlier short-lived differences appeared for the difficulty contrasts, whereas differences related to study-material were more prolonged and considerably larger. The non-overlapping time courses of these differences and their sensitivity to the two manipulations demonstrate that retrieval orientation and effort processes can, in some circumstances, be dissociated from one another. This study provides evidence of a difficulty-invariant ERP index of retrieval orientation.

Dzulkifli, Sharpe and Wilding (2004) adopted a different approach to investigate this issue, in which they adapted a version of Jacoby's (1991) exclusion task. A full description of this task is necessary at this point because the structure of the task is important not only for understanding the empirical work presented in this thesis but also for many of the data points on which the rationale for that work is predicated. Typically, items are processed in two separate contexts at study, perhaps different colours, formats or semantic operations. During the test phase of the exclusion task, new items are presented interleaved with all old items but, crucially, participants are required to only endorse one class of old items as old depending upon their study history (*targets*). The remainder of old items must be excluded (*nontargets*) by responding to them as if they were new items. The exclusion task is an important component of the process dissociation procedure (PDP) which was developed by Jacoby (1991) to determine the relative contributions of recollection and familiarity to recognition memory. According to dual-process models of recognition memory these qualitatively dissociable processes can contribute to recognition; familiarity provides an indicator of the strength of the relative familiarity of an item whereas recollection comprises the recovery of contextual details associated with an item (Yonelinas, 2002; see Chapter 2). The critical assumption for the PDP is that, unlike item recognition tests in which judgments can be made on the basis of either recollection or familiarity, recollection is essential for appropriate responding in an exclusion task.

In the exclusion task employed by Dzulkifli and colleagues (2004) to investigate retrieval effort, participants were required to distinguish between words for which they had previously generated either a semantic or phonological associate. Task demands were manipulated by changing whether items from the semantic or phonological task were designated as targets. Participants were split into one of two groups depending upon the relative difference in their memory accuracy across the two target designations. The behavioural performance of participants in the high relative difficulty group indicated that they experienced the greatest variation in difficulty across the two tasks. A frontally distributed divergence between classes of new items observed from 300ms onwards occurred only in the high relative difficulty group.

These findings indicate that ERP new item indices of strategic retrieval processes can relate to differences in relative difficulty. Although additional support for this interpretation in the form of qualitatively similar but smaller effects in the low relative difficulty group was not found, the pattern nonetheless highlights the relationship between retrieval effort and orientation by indicating that changes in effort may manifest simply as changes in the levels of activity in regions typically engaged in certain tasks. The data from the Robb & Rugg (2002) and Dzulkifli et al. (2004) studies indicate that changes in effort may therefore correspond to increases or decreases in the engagement of retrieval orientation processes, or the engagement of additional compensatory processes.

Task Switching and Retrieval Orientations

Reliable differences between ERPs elicited by classes of new items appear only in recognition memory tests in which task demands are continuous or consistent (Wilding & Nobre, 2001; Werkle-Berger, Mecklinger, Kray & Düzel, 2005; Johnson & Rugg, 2006; Herron & Wilding, 2006b; Benoit, Werkle-Berger, Mecklinger & Kray, 2009). In blocks in which tasks were mixed, differences between new item ERPs are either smaller in magnitude or less protracted in time (Johnson & Rugg, 2006) or are not apparent at all (Wilding & Nobre, 2001; Werkle-Berger et al., 2005; Benoit et al., 2009). These findings are in line with the assertion that multiple switches between different retrieval tasks are not conducive to the maintenance of a consistent retrieval orientation (Johnson & Rugg, 2006).

Analysis of the behavioural switch costs associated with frequent changes between retrieval tasks corroborates the ERP pattern. Accuracy is consistently higher and reaction times reliably faster in blocks in which retrieval demands remain constant (Werkle-Berger et al., 2005; Benoit et al., 2009), paralleling generic task-switching findings (Rogers & Monsell, 1995). It is difficult to determine the extent to which these differences in accuracy are a consequence of task composition as opposed to response confusion, however the observation that accuracy deteriorates to a greater degree in blocks where tasks switch randomly as opposed to predictably indicates that differences are due to the imposed unpredictability rather than difficulties arising from performing multiple tasks.

There exist behavioural benefits associated with engaging a retrieval set. In line with evidence that retrieval sets can be adopted only on stay trials, reaction times are reliably shorter on stay than switch trials (Werkle-Berger et al., 2005; Herron & Wilding, 2006b; Benoit et al., 2009). Herron & Wilding (2006b) have also reported that when participants are required to retrieve contextual information rather than just make simple old/new judgments (Morcom & Rugg, 2002) the accuracy of judgments is also greater in stay than switch trials. This particular finding was observed in a paradigm designed to elicit correlates of retrieval mode and so does not provide any indication of the behavioural advantages that arise from the engagement of distinct retrieval orientations.

Aging and Retrieval Orientations

The effect of age on ERP new item effects has been investigated following the proposal that older subjects may struggle with episodic memory tasks because they are limited in their ability to utilise strategies at retrieval regardless of the strength of external cues presented to them. To examine this, Morcom and Rugg (2004) recorded new item ERPs from younger (18-30 years) and older (63-75) participants who performed a version of the recognition memory task reported by Robb & Rugg (2002). For the younger participants, correct rejection ERPs differed from each other across the scalp with a right fronto-central maximum from 300ms onwards. This effect was smaller in amplitude and onset later in the older group, for whom the effect showed a left fronto-central maximum. Moreover, these effects were independent of differences in accuracy, and were unlikely to be the result of greater latency jitter (see Chapter 4) associated with more variable responses in the older group: jitter would cause the effects to become more extended in time, not less so.

The data show that older subjects process retrieval cues in a manner that is less differentiated than for younger participants. Morcom & Rugg (2004) outlined three possible explanations for why this might be. First, it is possible that older participants may not encode stimuli as distinctively as younger participants, reducing the capacity for distinctive retrieval processes to usefully distinguish between memory representations. A second, and not necessarily mutually exclusive, possibility is that cognitive flexibility deteriorates with age so that various retrieval orientations cannot be adopted to retrieve distinct memory representations. Thirdly, it may be that the ability to spontaneously adopt such retrieval orientations diminishes with age. If this third account is accurate then older participants may show comparable evidence of the adoption of retrieval orientations in conditions in which the task more explicitly requires the retrieval of contextual information.

In order to investigate this third possibility, Duverne, Motamedinia & Rugg (2008) asked a group of older (63-77) and younger (18-20) participants to perform four study-test blocks. Items were words in two study phases and pictures in the remainder, either presented to the left on a green background or to the right on a red background. At test, items were studied or unstudied words, or words corresponding to studied pictures, all presented centrally. In two blocks, participants made simple old/new judgments and in the remainder they made a second judgment concerning what study context the item was studied in. As reported elsewhere (Robb & Rugg, 2002; Herron & Rugg, 2003a; Hornberger et al., 2004) younger participants showed reliable material-dependent differences in ERPs associated with new items both in the recognition and source memory task. Older participants showed no reliable differences between classes of new item in the simple recognition task (Morcom & Rugg, 2004), but did demonstrate differences between new item ERPs when required to retrieve source. These differences were comparable to those from the younger group and, combined with the lack of new item effects in the recognition task, indicate that older participants' ability to spontaneously adopt such strategic cue processing is compromised but is not altogether absent.

Age-related differences in the processing of retrieval cues have also been reported on the basis of behavioural data alone. These reports follow Jacoby, Shimizu, Velanova & Rhodes' (2005) investigations into source-constrained retrieval, which manipulate the processing of foils by presenting them in recognition test blocks in which all critical studied items have either been encoded at a deep or shallow level (Craik & Lockhart, 1972). In the clearest demonstration of this (Jacoby, Shimizu, Daniels & Rhodes, 2005), participants took part in an initial study phase that required them to encode items at a deep level by judging their pleasantness or at a shallow level by judging the presence of certain vowels. Two subsequent deep and shallow memory tests were then conducted in which only items from one of these two conditions were presented alongside new foils, and simple old/new judgments were required. In a final test, participants were presented with studied foils from the middle two tests alongside a third group of unstudied foils. Memory for studied foils from the deep test was superior to memory for those from the shallow test. This pattern occurred even though foils from the deep condition were rejected more speedily and accurately than those from the shallow conditions, discounting the possibility that increased processing time for deep foils led to this effect. Instead it is likely that foils from the two tasks were subjected to qualitatively different processing by virtue of the test context. For example, relatively deep processing for foils in the deep memory test in line with the principle of transfer appropriate processing (Morris et al., 1973) would lead to superior recognition for these items subsequently. A follow-up study contrasted the performance of younger (18-26) and older adults (61-87 years) on a series of similar tasks (Jacoby, Shimizu, Velanova & Rhodes, 2005). Although younger adults again repeatedly showed superior performance for items acting as foils in a previous deep memory task, older adults showed no such depth of processing effect for foils, suggesting that this group did not qualitatively differ their processing of foils across the test phases.

Although these findings cannot help determine which of the possibilities put forward by Morcom & Rugg (2004) best accounts for age-related memory decrements, they support the observation that the ability to automatically adopt qualitatively different retrieval processing strategies deteriorates with age. They also provide an interesting example of how processing of retrieval cues can be differentiated using a behavioural paradigm alone. These findings however are unable to determine how strategic retrieval cue processing can actually affect the likelihood or efficiency of retrieval when it is engaged. Experiments that make more direct contributions to claims about the functional significance of these effects (and the mechanisms by which they might operate) are reviewed below.

Functional Interpretations of ERP New Item Effects

The distributions and time courses of ERP new item effects, although often anteriorly distributed, vary with design, in line with the assumption that retrieval orientations are specific to each task (Rugg & Wilding, 2000). Implicit in discussions of retrieval orientations is the understanding that they are in some way adaptive for correct responding on recognition memory tasks. Retrieval orientations may benefit memory by increasing the likelihood that relevant information will be retrieved while reducing the probability that irrelevant information is retrieved (Woodruff, Uncapher & Rugg, 2006), perhaps by increasing the likelihood that operations engaged at retrieval overlap with those employed during encoding (Morris, Bransford & Franks, 1977; Rugg, Morcom & Herron, 2002; Mecklinger, 2010). The following section reviews experiments that allow further discussion of the functional characterisation of these effects, as well as the way in which fMRI data has been used to constrain certain hypotheses.

ERP New Item Effects in a Direct Retrieval Task

If retrieval orientation processes are adaptive and provide some benefit for performance in memory tasks, then differences between ERPs elicited by new items assumed to index these processes should only be apparent when subjects intentionally search for memories. This characterisation differentiates these effects from indices of processing that relate to automatic accommodations to changes in retrieval circumstances. Hornberger, Rugg & Henson (2006a) tested this prediction by comparing two types of memory tests, a "direct" yes/no recognition memory test in which retrieval was intentional and an "indirect" semantic judgment task in which items either had or had not been previously encountered, and for which any retrieval was assumed to be incidental. Participants saw pictures and heard words in each study phase, and were presented with corresponding visual words at test. Differences between ERPs elicited by new words from blocks in which studied items were from one of the two study contexts were observed from 400ms onwards in the direct task. Comparisons between ERPs elicited by the same items in the indirect task revealed differences that were topographically similar to their direct-test counterparts but in an earlier time window (from 100-600ms).

The observation of an earlier-onsetting, short-lived orientation effect in the indirect memory test was not predicted because participants were not explicitly required to process retrieval cues differently according to their study history in this condition, although incidental retrieval was highly likely. Participants failed to report the adoption of any strategy or intentional retrieval across blocks. One account the authors offered for this effect is that it reflects a manifestation of the engagement of cross-modality attention (Talsma & Kok, 2001), in which participants attend to different attributes of test items within each block depending upon the study material. These effects indicate that processing of new items can change relatively automatically on the basis of task demands, quite independently of the need to explicitly retrieve information. Importantly, however, only the ERP new item effect in the direct task demonstrated a time-course that corresponds with previous reports of ERP new item effects. This is in line with the implicit assumption that processes indexed by these ERP new item effects are engaged predominantly when episodic retrieval is required because they index the ways in which cues are processed in order to maximise the accuracy of retrieval judgments.

Conceptual Cue Constraint Hypothesis

In one line of investigation, Hornberger, Rugg and Henson (2004) set out to clarify the functional significance of the ERP new item effects reported by Robb & Rugg (2002; also see Herron & Rugg, 2003a). In the designs reported by these authors, items were presented at study as either words or pictures but at test, only words were employed as retrieval cues. Hornberger and colleagues noted that this study-format manipulation was confounded by the degree of similarity between study and test cues, leaving the issue open as to whether differences between these new item ERPs reflect processes related to the recovery of words or pictures or, instead, the degree to which cues were similar to the sought-after information. In order to determine whether these effects reflect changes in cue similarity, participants engaged in four study-test blocks in which either pictures or words were presented at study. Across the four test blocks, test items were presented in either the same or the alternative format (e.g. words at study - words at test or words at study - pictures at test). Regardless of which type of material was presented at study or test, new item ERPs were more negative-going when retrieval cues did not match the items format at study. The wide-spread distribution of this effect was invariant over time from 300 to 1200ms.

One hypothesis for *ERP study material effects* of this kind is that they reflect familiarity differences between matching and non-matching test cues, in line with global matching models (Gillund & Shiffrin, 1984). Traditional global matching models for example, predict that copy cues will engender greater overall familiarity to study items than non-copy cues. This explanation is less able to account for the fact that in two additional experiments in which no copy cues were employed, differences between new item ERPs remained (Hornberger et al., 2004). An additional problem is that ERP retrieval orientation effects should not be observed in experiments where study lists comprise multiple stimuli-types as opposed to blocked study lists, because the former should allow all items to have equal familiarity. One study by Herron & Rugg (2003a) reported reliable ERP new item effects in such a design.

In that study, participants completed two study-test blocks, in which they were presented with both pictures and words at study but only words in the two test phases. Task demands differed across the two test phases according to whether items presented as pictures or words at study would act as targets or nontargets in line with exclusion task instructions described earlier. At various sites across the scalp from 300-1200ms, new items differed according to which items were to be responded to as old indicating that participants were able to maintain a retrieval orientation despite both relevant and irrelevant items being encoded in the same context.

These arguments led Hornberger and colleagues (2004) to assert that the effects they reported reflect differential reliance on the conceptual information that can be derived from retrieval cues. For example, when comparing the amount of overlap that arises when study items and retrieval cues are identical, recapitulation can occur at all representational levels, conceptual or otherwise. When study and retrieval cues differ physically, overlap occurs only at a conceptual level and minimally at nonconceptual levels. These conditions require attentional and cue processing to maintain focus at the only level where overlap can occur – the conceptual level. Support for this hypothesis comes from the correspondence between the differences between new item ERPs in the Hornberger et al. experiment and the N400 ERP component, which has consistently been associated with semantic processing (Kutas & Hillyard, 1980; Osterhout & Holcomb, 1995). The differences between the two classes of new items in this task may therefore reflect the different degrees to which semantic processes were engaged in the two retrieval tasks.

This conceptual cue constraint hypothesis was tested by Stenberg, Johansson & Rosen (2006). They predicted that new item ERPs elicited during a conceptual retrieval test should be more negative-going than during a perceptual test. Participants were again presented with mixed lists of pictures and words at study, but only corresponding words and new items were presented at test. The approach in this experiment was to contrast retrieval phases in which participants had to either endorse all old items as 'old' irrespective of study context (inclusion), or only endorse copy cues as 'old' (exclusion). Stenberg and colleagues reasoned that effectively no conceptual processing is required to perform the exclusion task, because participants can simply determine whether each item's perceptual features are familiar or not. It is not possible to base responses on the experience of familiar perceptual features in the inclusion task, however, because items may have been presented in an alternative format at study. Hence, conceptual processing of cues will be engaged to a greater degree in this task. Overall, the effects of this manipulation were in line with the conceptual cue constraint hypothesis, with more negative-going ERPs for new items in the inclusion (high conceptual constraint task) than the exclusion task, from 400ms post-stimulus at widespread locations across the head. An important limitation of the conceptual cue account however is that it is limited to paradigms in which decisions must be made on the basis of conceptual information (Mecklinger, 2010) and thus cannot account for robust ERP new item effects elicited in tasks in which judgments are made on the basis of perceptual detail (e.g. Ranganath & Paller, 1999; 2000; Werkle-Bergner et al., 2005). Moreover, the sufficiency of the conceptual cue hypothesis for these effects has also been questioned on the back of related fMRI data.

fMRI Correlates of Retrieval Orientations

The existing fMRI data on retrieval orientations complements the ERP data by indicating dissociations between anatomical regions associated with certain task requirements. For example, Dobbins, Rice, Wagner, & Schacter (2003) reported that areas of the prefrontal cortex engaged during retrieval differed according to whether responses depended upon recency or source retrieval judgments. In this paradigm however it was not possible to match behavioural performance for the two types of retrieval task and the authors did not limit contrasts to trials elicited by new items, leaving these contrasts confounded by retrieval success.

Hornberger, Rugg, & Henson (2006b) avoided these concerns in a study in which they adapted the ERP design reported by Hornberger et al. (2004) for fMRI. Study items were either pictures or auditory words while only visual words were presented at test. Performance was relatively well matched across the two sets of retrieval conditions. Correctly rejected new items were contrasted depending upon whether their respective test blocks included items for which the studied counterparts were pictures or auditorally-presented words.

In line with the conceptual cue constraint hypothesis generated from the ERP outcomes of this design (Hornberger et al., 2004), the authors expected to observe relatively greater activity in regions of the brain associated with semantic processing in the picture than the auditory condition. This pattern however, was not observed, and instead regions associated with visual object processing and visual imagery (left inferior temporal regions and left fusiform; Démonet, Chollet, Ramsay, Cardebat, Nespoulous, Wise et al., 1992) were engaged in the picture condition. Moreover, greater activation occurred in regions associated with auditory/phonological processing (left middle temporal gyrus and bilateral parietal opercula) for the auditory than picture condition. The haemodynamic data suggest that participants were attempting to retrieve words depending upon the associated study format of old items.

Hornberger and colleagues qualified their initial interpretation of the ERP data on the basis of the contradictions arising out of the fMRI data, reasoning that specific regions are engaged at retrieval in order to constrain search to areas associated with certain types of encoded information. This material-specific interpretation is consistent with the principle of transfer appropriate processing (Morris et al., 1977) and the cortical reinstatement hypothesis (Johnson & Rugg, 2007), which states that retrieval of items is associated with the reinstatement of the initial encoded memory trace.

Further support for the material-specific account comes from a related fMRI study. Woodruff, Uncapher & Rugg (2006) used a variant of the exclusion task (Herron & Rugg, 2003a) to uncover regions of task-related sustained activity associated with different retrieval orientations. Participants were presented with visual words and pictures at study, but only corresponding words were re-presented at test, alongside new words. At test, participants endorsed previously studied items depending upon whether they were in the same or different format to their initial presentation (following exclusion task instructions), and the designation of which class of old item acted as targets varied across short test blocks. Much of the observed neural activity could be accommodated by a material-specific account; for example, the lateral-temporal region implicated in lexico-semantic processing was activated for new items in word blocks. Processing of these items may have been adjusted in order to enhance the likelihood of recapitulating material-specific operations in order to maximise cue-trace overlap (Morris et al., 1977). It appears therefore that processing in service of retrieval differs in line with the sought-after material type, presumably in an effort to increase the likelihood that the relevant materials are retrieved.

ERP New Item and Old/New Effects

Perhaps the most useful line of investigation into the functional interpretation of retrieval orientation effects follows examination of their relationship with ERP correlates of retrieval success (ERP old/new effects; see Chapter 2). One influential example comes from Herron & Rugg's (2003a) report of ERP old/new effects in the exclusion task, briefly reviewed above. Specifically, the authors were concerned with the putative index of recollection in the electrical record, the left parietal old/new effect. The weight of electrophysiological evidence (reviewed in Chapter 2) suggests that this effect is an index of recollection (Smith, 1993; Wilding, 2000; Tendolkar, Schoenfeld, Golz, Fernandez, Kuhl, Ferszt, & Heinze, 1999; Vilberg & Rugg, 2009).

Alongside the ERP new item effects described above, Herron and Rugg (2003a) observed that target items elicited robust left parietal old/new effects regardless of the class of study material, in concordance with the assumption that they are recollected in order to be successfully endorsed. A dissociation was observed, however, for nontarget left parietal old/new effects across the two conditions. In the picture condition, ERPs to nontargets were approximately equivalent to those for targets, whereas in the word condition they did not differ statistically from new items. Herron & Rugg reasoned that this asymmetry occurred because retrieval of items could be limited to targets in the word condition following the high level of cue-target compatibility in this condition. This may no longer be possible in the picture condition because of the reduced cue-target compatibility in this task, leading to the recovery of both target and nontarget information and associated left parietal old/new effects for both classes of old item. Accordingly, a reasonable possibility is that the differences between ERPs to new items in this task index changes in cue processing that follow the adoption of different retrieval orientations in each test phase.

Support for this hypothesis comes from reports of ERPs recorded in other exclusion tasks. Dzulkifli & Wilding (2005) asked participants to encode visually presented words by either generating a potential function for them, or rating how easy they would be to draw. Electrical activity was then recorded during two separate exclusion tasks, where words encoded via the function task served as targets in one, and those encoded via the drawing task were targets in the other. From 500-900ms post-stimulus, new items in the former test phase were significantly more positive-going than new items elicited when drawing items were targets. The distribution of this effect was maximal at midline, central and anterior sites with a slightly left-lateralised bias. Alongside these differences, Dzulkifli & Wilding (2005) also reported an electrical index of recollection for targets only.

In order to investigate the proposal that the operations indexed by differences between new items across tasks are functionally responsible for the attenuation of the nontarget left parietal old/new effect, Dzulkifli, Herron, & Wilding (2006) reduced target accuracy in a second experiment by extending the inter-study interval, reducing the number of study-test blocks and increasing the number of items per block. The rationale for this was that a reduction in the likelihood of recovering targets by making the task harder would reduce the efficacy of relying predominantly on the recovery of targets (Herron & Rugg, 2003b). ERPs associated with new items did not differ reliably across test phases. Although target and nontarget ERPs still differed significantly from each other, the critical observation was the presence of a left parietal old/new effect for nontargets, where there had been none in the previous experiment. Dzulkifli et al. argued that the lack of observed differences between ERPs elicited by new items supported the account that differences that did present previously indexed processes that were responsible for selective recollection of task-relevant information, as shown by the behaviour of the left parietal old/new effect. These data points provide the first evidence of a link between the processes indexed by new item ERPs and selective recollection.

Mechanisms for Strategic Retrieval

An important issue is how the processes indexed by differences between new item ERPs might enable some details to be recovered and not others. One taxonomy for the potential mechanisms that might enable strategic retrieval has been outlined by Anderson and Bjork (1994). Mechanisms are classified according to the particular aspect of the mnemonic representation at which they operate. These changes may occur following variations at the level of the retrieval cue, the target itself or the associations that link the two. Each of these mechanisms will be briefly reviewed in turn.

Associative and *cue bias* models both begin with the assumption that retrieval is the reactivation of a stored episodic representation that is associated with a particular retrieval cue. Cue bias models assume that selecting or processing at the level of the retrieval cues themselves can affect the likelihood of retrieval. Associative bias models, in contrast, explain that inhibition or retrieval failure occurs due to the diminished efficacy of a particular route to retrieval following the strengthening of competing items. The third class of mechanisms, known as *target bias* models, involves explicit inhibitory processes that directly reduce the level of activation of certain classes of memory. The idea here is that this helps retrieval because it makes some kinds of memory information less available than others. Although models of this kind can provide powerful explanations for selective retrieval effects, they assume the engagement of an additional inhibitory mechanism. This means that these models do not have the theoretical parsimony of non-inhibitory models that explain selective retrieval simply by assuming an increase in the activation of targets.

Broadly speaking, inhibitory models can be broken down further into two types, those of lateral inhibition and attentional suppression. Lateral inhibition models are derived from and expressed in computational cognitive models and involve a parallel inhibiting input factor that reduces the target activation level. Attentional suppression mechanisms affect activation levels by increasing attentional focus on targets while reducing it for nontargets. These latter mechanisms can be applied flexibly to any internal representation and one perspective is to interpret these two mechanisms as those that inhibit classes of items either indirectly (lateral inhibition models) or directly (attentional suppression; Levy & Anderson, 2002).

Discussion concerning which of these mechanisms most likely contribute to selective retrieval has centered on retrieval-induced forgetting (Levy & Anderson, 2002; 2008). This phenomenon is observed in the retrieval practice paradigm, in which participants learn lists of category-exemplar pairs (e.g. Drinks-Rum). Half of these items are subsequently practiced and re-learnt through a series of cued-recall tests. During a final recall test, participants have been shown both to recall practiced items more often than items from non-practiced categories and to be less likely to recall non-practiced exemplars from practiced categories. The effect of practicing some items appears, therefore, to affect the likelihood of retrieving non-practiced items from the same category. This is pertinent to the issue of selective retrieval if one considers that the processes engaged during retrieval practice (and which appear to affect the later memorability of some items) may be analogous to those employed during the recognition phase of some ERP experiments previously described here. For example, non-inhibitory mechanisms which strengthen the association between cues and targeted classes of information might well be employed in both kinds of paradigm. Not only would this lead to increases in the likelihood that certain kinds of information are retrieved at the time at which these operations are employed, but these mechanisms can also account for retrieval-induced forgetting if the strengthening of practiced items or the association between the category and the exemplar interferes with the recovery of non-practiced items.

Anderson and colleagues claim, however, that it is direct inhibitory mechanisms that reduce the overall activation of some items that causes retrieval-induced forgetting. Support for this comes from the observation that strength-based non-inhibitory mechanisms (by which, strengthening the activation of target items should interfere with the recovery of nontargets) cannot account for the fact that increases in exposure time facilitate recall of practiced items but do not impair recall of related items (Anderson, Bjork & Bjork, 2000). In addition, the finding that retrieval–induced forgetting has been shown to be independent of the cues that are used and to extend to category-related unpractised items provides little support for cue-bias or associative accounts. Findings such as these indicate that the relative activation of the item itself is directly suppressed (Levy & Anderson, 2002; 2008).

According to Levy & Anderson (2002) the ability to engage in the direct suppression of items requires the engagement of executive control processes which override prepotent responses. This capacity is considered to be analogous to the ability to override motor responses, an assertion that follows data from the Think/No-Think task, a mnemonic version of the Go/No-Go task in which motor responses must either be made or inhibited on a trial-by-trial basis (Anderson & Green, 2001). In the mnemonic version of this task, participants are provided with cues specifying whether or not to retrieve the associate for paired items that they had previously learnt. Specifically, in the No-Think condition participants are required to ensure that the associate of an item does not enter conscious awareness at all. In a final free recall stage, participants have been shown to recall fewer No-Think items than baseline items (learnt items not presented during the think/no-think phase). Anderson & Green (2001) claim that this demonstrates participants' ability to suppress items on the basis of a simple instruction (recall rates remain low even when participants were given monetary incentives for high performance in the recall task) and go on to suggest that the same frontally-mediated executive control processes that suppress behaviour in Go/No-Go tasks (e.g. Garavan, Ross & Stein, 1999) cause retrieval inhibition.

ERP New Item Effects and Mechanisms for Strategic Retrieval

The strategic retrieval processes indexed by ERP new item effects might also reflect the mechanisms outlined by Anderson & Bjork (1994). The strategic retrieval observed in Dzulkifli and colleagues' (2005) exclusion task, for example, might have come about because processing of retrieval cues was biased in a way that increases the likelihood that they will interact with target information (cue bias) or because processes indexed by differences between new items caused changes in the extent to which inhibition of nontarget or activation of target representations occurred (target bias). It is also possible that retrieval processes ensured that attention was biased towards targets (attention bias; Dywan, Segalowitz & Webster, 1998; Dzulkifli & Wilding, 2005). Although it is not yet possible to rule any particular account out, one argument is that differences between ERPs elicited by classes of new items are likely to index cue bias mechanisms. This is because, unlike target bias mechanisms that are likely to be sustained throughout tasks in which demands remain the same, cue bias mechanisms that are re-deployed on each trial are more likely to be evident in ERP new item contrasts (Dzulkifli et al., 2006). Similarly, attention bias mechanisms might be expected to operate on the products of retrieval and so be less evident in new item contrasts. The pattern of a pronounced left parietal old/new effect predominantly for targets might be able to accommodate this account if the suggestion that the effect indexes attentional orienting towards the products of recollection (Dywan, Segalowitz & Webster, 1998; Rugg & Henson, 2002; Wagner, Shannon, Kahn & Buckner, 2005) is shown to be correct (Dzulkifli & Wilding, 2005). It is possible that differences between new item ERPs might index processing that later facilitates this attentional bias.

Cue bias mechanisms are likely to differ depending upon whether copy cues are used or not. In paradigms such as those employed by Hornberger and colleagues (2004; see also Herron & Rugg, 2003a; Robb & Rugg, 2002) differences between new items arose because test items often do not match studied items at the perceptual level. Cue specification processes in such a paradigm are vital in order to encourage recovery of the sought for material-type and are likely to occur by re-engaging areas involved in the initial processing of items (Morris et al., 1977; Woodruff, Uncapher & Rugg, 2006). A related observation is that, in a number of studies, the distributions of ERP new item effects have been shown to remain constant over successive epochs (Robb & Rugg, 2002; Herron & Rugg, 2003a) leading to the proposal that the effects index the maintenance of internal representations that are used to probe memory stores for particular classes of information (Rugg, Morcom & Herron, 2002; Hornberger, Morcom & Rugg, 2004). This characterisation, by definition, implies that the effects index processes that act at the locus of the cue.

Concluding Comments

Control processes can operate at many points during retrieval. Operations engaged after retrieval has occurred have a clear impact upon whether subsequent behaviour is appropriate. A number of theories also stress that processes engaged before retrieval can play an influential role. In an effort to investigate this, numerous studies have shown that differences between new item ERPs can provide reliable indices of the way in which processing of retrieval cues differs with the particular demands of episodic tasks. These contrasts have been used to make inferences about the ways in which pre-retrieval processes might be able to impact upon retrieval. One of the principal issues addressed by the experiments in this thesis is the question of the functional significance of these effects and the roles that they play at the time of retrieval. The experiments in this thesis comprise investigations of the relationship between ERP correlates of retrieval processes – principally, ERP new item effects - and response accuracy, in order to describe the way these processes interact in different retrieval tasks and how their engagement impacts on behavioural outcomes. As has been outlined above, functional characterisations of ERP new item effects can be constrained by interpreting findings in the context of ERP indices of retrieval success. This will be done for the data presented in this thesis, and consequently the subsequent section reviews the literature concerned with the ERP correlates of these processes, which are commonly referred to as ERP old/new effects.

Chapter 3
ERP Old/New Effects and Recognition Memory

Of central importance in this thesis is the functional significance of the strategic retrieval processes that are assumed to be indexed by differences between new item ERPs. One way to constrain the interpretations of these effects is to compare these effects with ERP indices of successful retrieval: ERP old/new effects. These effects have been shown to dissociate temporally, spatially (in terms of distribution across the scalp) as well as functionally, by demonstrating differential sensitivity to experimental manipulations. Demonstrations such as these provide critical evidence that the ability to make memory judgments accurately can involve multiple processes. This chapter reviews the literature that links four ERP old/new effects to distinct retrieval processing operations. This is necessary because variations in the engagement of these effects are used to constrain the functional interpretations of some of the ERP new item effects reported in this thesis. In addition to this, some of the experiments presented in this thesis allow for straightforward comparisons of the relationship between response accuracy and the amplitude of these old/new effects, an aspect of the data that has not been widely reported.

To begin, evidence linking two old/new effects to recollection and familiarity is reviewed. The way in which ERP indices of these processes contribute to the debate on dual and single process models of recognition memory is also briefly discussed. The latter half of this chapter outlines reports of two later ERP old/new effects that have been associated with various post-retrieval mechanisms.

ERP Old/New Effects and Dual Process Models

A number of models have been developed to determine the nature of the processes that contribute to recognition memory and, broadly speaking, these differ depending upon whether they posit that recognition can be based upon one or two processes. Proponents of single process models argue that recognition phenomena can be explained sufficiently by a continuous strength-based match along a familiarity (strength) dimension (e.g. Glanzer, Kim, Hilford & Adams, 1999; Wixted & Stretch, 2004). Those who argue for dual-process models hold that recognition memory cannot be explained purely by the contribution of one continuous familiarity variable, because there is considerable evidence that a functionally dissociable process also contributes to episodic recognition (Yonelinas, 2002; Diana, Reder, Arndt & Park, 2006). This process, recollection, gives rise to a conscious awareness of a previous episode including the context in which it was encountered.

Familiarity can be used to make recognition judgments because the level of familiarity associated with recently encountered variables is on average higher than that for relatively new items. The level of familiarity associated with an item relative to an independently placed criterion determines whether an old or new judgment is given. Recollection, however, is often modelled as a threshold process that becomes available only when the process breaches the threshold (Yonelinas, 2002). Importantly, recollection provides contextual details about an experienced episode whereas familiarity provides only an indicator of previous experience. Support for dual-process theories follows from evidence that these processes dissociate from one another by way of behavioural manipulations (e.g. Gardiner, 1988; Gardiner & Java, 1990; Rajaram, 1993; Dewhurst & Hitch, 1999) and process-specific deficits in clinical populations (e.g. Verfaellie & Treadwell, 1993; Yonelinas, Kroll, Quamme, Lazzara & Knight, 2002; Aggleton, Vann, Denby, Dix, Mayes, Roberts et al., 2005).

The work in this thesis does not contribute to the debate between dual and single process models of recognition. Nonetheless, the data throughout is interpreted from a dual-process perspective on the basis of the various data points from clinical and behavioural paradigms (e.g. Yonelinas, 1994; 1997; 2002; Aggleton, Vann, Denby, Dix, Mayes, Roberts et al., 2005; Diana et al., 2006) that cannot be accounted for by a single-process model. Especially relevant is the observation that within the event-related potential literature of recognition memory there is considerable evidence for two functionally dissociable ERP effects that have been shown to behave as electrical indices of recollection and familiarity. One effect, *the left parietal old/new effect*, has been consistently associated with recollection, while there is a body of evidence linking a second earlier *mid frontal old/new effect* to familiarity.

The Left Parietal Old/New Effect

From 500-800ms post-stimulus over left parietal sites, ERPs comprise a positive deflection that is significantly greater for old than new items. The link between this *left parietal old/new effect* and recollection follows from demonstrations that the amplitude of the effect is larger for old items associated with recollective experience than those associated with recognition without recollection (e.g. Wilding & Rugg, 1996; Vilberg, Moosavi & Rugg, 2006). There are a number of ways to isolate recognition with and without recollection and these are covered in turn below.

Whereas it is possible to determine whether an item has been encountered before based upon recollection or familiarity, only recollection can support the recovery of specific contextual features and enable correct source judgments to be made subsequently (Yonelinas, 2002). Accordingly, items can be separated into those to which incorrect and correct source judgments are made, only the latter of which are associated with recollection. In line with this, the left parietal old/new effect has been shown to be reliably larger for items to which a correct source judgment was made (Wilding, Doyle & Rugg, 1995; Rugg, Cox, Doyle & Wells, 1995; Wilding & Rugg, 1996; see Figure 3.1). Moreover, across a number of studies the amplitude of the left parietal old/new effect has been shown to increase with the amount of recollected material (Wilding, 2000; Vilberg, Moosavi & Rugg, 2006; Vilberg & Rugg, 2009).

Figure 3.1: Taken from Wilding & Rugg (1996). Grand average ERPs to correctly classified new items and to correctly recognised old items to which correct source judgments were (hit-hit) or were not made (hit-miss). ERPs are shown at a representative left parietal (LP) electrode. Both the time of stimulus onset and 600ms post-stimulus are indicated by the vertical dashes along the horizontal time axis.

Associative recall paradigms can also be used to isolate recollection. Upon the presentation of single items at test, participants must recall the details or other items that were associated with each item during study (Allan, Wilding, & Rugg, 1998). For example, Rugg, Schloerscheidt, Doyle, Cox & Patching (1996) presented participants with arbitrarily paired words and asked them to generate sentences using both words. At test, old words were presented alone but randomly intermixed with new words, and participants were required to determine whether each was an old or new word and then to retrieve associates for old words. Old words for which the associate was correctly recalled elicited greater left parietal old/new effects than for those to which associates were recalled incorrectly. Similar effects have been reported in both associative recall and associative recognition paradigms (Donaldson & Rugg, 1998; 1999).

An additional approach to isolating recollection is to use participants' reports of phenomenological experience. The remember/know paradigm requires participants to indicate whether they recognise an item because they can *remember* specific details of the study episode or whether they simply *know* that they have seen it before but are not able to recollect specific details (Gardiner, 1988; Gardiner & Java, 1990; Rajaram, 1993). These two categories are thought to comprise recognition based largely upon recollection and familiarity respectively (although see Dunn, 2004; Wais, Mickes, & Wixted, 2008). Several studies have reported a reliably larger left parietal old/new effect for remember than know items (Smith, 1993; Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Duarte, Ranganath, Winward, Hayward & Knight, 2004; Vilberg, Moosavi & Rugg, 2006; Leynes & Phillips, 2008; de Chastelaine, Friedman, Cycowicz & Horton, 2009, although see Spencer, Vila Abad & Donchin, 2000).

Electrophysiological data from clinical populations for whom there is little behavioural evidence for recollection have also informed this issue. Tendolkar et al. (1999) asked patients with Alzheimer's Dementia (AD) and aged matched controls to perform an old/new recognition memory experiment with an additional source judgment. Overall recognition rates were comparable across populations, but source judgments were at chance for the AD group, indicating that they were unable to use recollection to correctly recall each item's source. In line with this, old/new differences for this group were reliable only at the front of the head, providing no evidence of a left parietal old/new effect. This observation contrasts markedly with data from the control group, who made correct source judgments and for whom ERPs associated with correct source judgments were more positive than correct rejections at left posterior sites.

Manipulations that have been shown to specifically affect behavioural indicators of recollection have also been shown to affect the amplitude of the left parietal old/new effect. In one experiment, Curran (2004) divided participants' attention at study, a manipulation that has been shown to impact recollection to a greater extent than familiarity (Gardiner & Java, 1990; Yonelinas, 2001) and which, in accordance with this, is also associated with a decrease in the amplitude of the left parietal old/new effect. Similarly, depth of processing manipulations have been shown to strongly increase behavioural indicators of recollection while eliciting only a small increase in familiarity (Gardiner, 1988; Yonelinas, 2002). The amplitude of the left parietal old/new effect has been shown to be sensitive to these manipulations (Rugg, Mark, Walla, Schloerscheidt, Birch & Allan, 1998; Rugg, Allan & Birch, 2000). Importantly, whereas these manipulations affected the amplitude of the left parietal old/new effect, this was not the case for an earlier mid frontal old/new effect thought to index familiarity-based processing.

The Mid Frontal Old/New Effect

This effect has a mid frontal maximum from 300-500ms post-stimulus and is characterized by a negative deflection that is relatively more positive-going for old than for new words (Curran, 1999; 2000). The effect is often referred to as the FN400 because of its similarity in distribution, polarity and latency to the N400 (Kutas & Hillyard, 1980), although the FN400 has a more anterior maximum (Curran, 1999). One of the first arguments for an association between the mid frontal old/new effect and familiarity is in terms of its time course. Descriptions of familiarity hold the process to be more automatic and faster than recollection (Mandler, 1980; Jacoby 1991) and as such might be expected to occur earlier in the electrical record than effects related to recollection. This characterisation maps onto the chronology of the mid frontal and left parietal old/new effects.

More compelling evidence for an association between the mid frontal effect and familiarity comes from a report by Curran (2000). Participants were presented with singular and plural words at study, and then at test were presented with words in the same or reversed polarity, along with new words. Participants were required to respond 'new' to new items as well as items presented in a reversed plurality (similar lures), while endorsing the remainder of items as 'old'. Curran hypothesized that whereas familiarity should provide sufficient information to determine between old and new items, only recollection would enable recovery of the exact contextual details to determine which plurality an item was originally presented in. In support of this hypothesis, the left parietal old/new effect differentiated between same and reversed polarity items whereas the early mid frontal old/new effect made no such differentiation and responded comparably for both old items and incorrect (old) responses to similar lures. Similar ERP patterns have been observed in a design using pictures and reversed orientation picture lures (Curran & Cleary, 2003).

A different approach to testing the functional significance of the mid frontal old/new effect was taken by Azimian-Faridani and Wilding (2006), who sought to determine the sensitivity of the effect to manipulations of response criterion. Changes in criterion affect familiarity to a greater degree than recollection (Yonelinas, 2002), and specifically should affect the level of familiarity required in order to make an old judgment. For example, a conservative criterion (to only respond 'old' when the respondent is certain it is old) requires a relatively higher level of familiarity for an old response to be made than when a liberal criterion is adopted. From 300-500ms, mid frontal ERPs to correctly recognised old words were significantly greater when a conservative than a liberal criterion was adopted, in accordance with the functional hypothesis.

Some of the clearest evidence for a functional dissociation between recollection and familiarity processes follows evidence of a double dissociation between the left parietal and mid frontal old/new effects. Woodruff, Hayama & Rugg (2006) employed a modified remember/know procedure that required participants to determine whether they recollected an item as old, and failing that, with what degree of confidence an item was or was not recognised (Yonelinas, Otten, Shaw & Rugg, 2005). Specifically, if an item was not recognised along with associated contextual information, participants were required to choose between the following responses: 'confident old', 'unconfident old', 'unconfident new', and 'confident new'. The early (300-500ms) frontal negative modulation (with a left-lateralization) varied with familiarity strength (see Figure 3.2) but did not differ for items associated with high familiarity and recollection. The old/new effect over parietal sites from 500-800ms post-stimulus did distinguish between recollected items and those recognised with high confidence, but the effect did not respond to increases in recognition confidence associated with familiarity. The data demonstrate a double dissociation of the neural effects associated with recollection and familiarity.

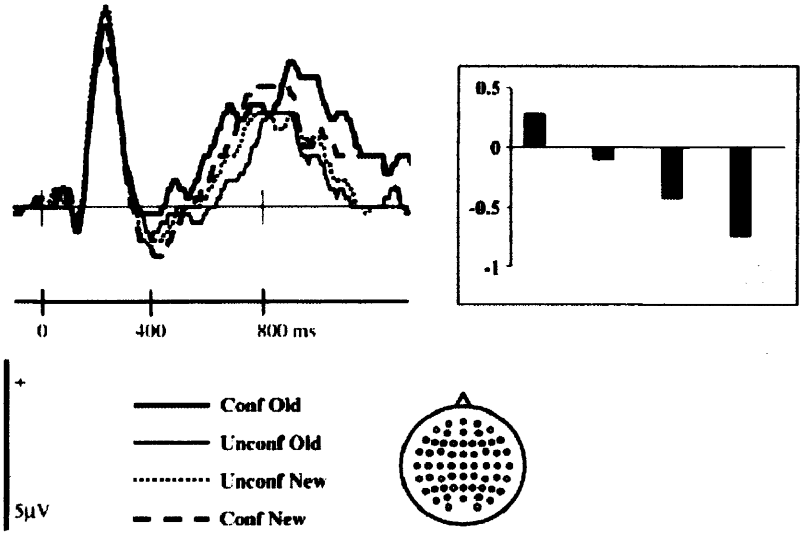

Figure 3.2: Taken from Woodruff et al (2006). On the left of the figure, grand average ERPs are shown for the F3 electrode, separated according to the nature of the associated recognition judgment. On the right of the figure, mean amplitudes of the ERPs from F3 in the 300-500ms epoch are shown for each response category. From left to right, the data represent confident old, unconfident old, unconfident new and confident new judgments, respectively.

It is possible, however, that the amplitude of the mid frontal old/new effect increased in size simply as a function of the proportion of trials associated with correctly recognising an item. This is because the proportions of old and new items varied systematically with changes in response confidence (i.e. the ratio of old: new items was greatest in the high confidence old category and the proportion of old items decreased down the response scale). This issue has been raised by authors who are concerned that the mid frontal old/new effect indexes conceptual priming rather than familiarity because the majority of data which supports the latter hypothesis can also be interpreted as evidence that the effect indexes conceptual priming (Paller, Voss & Boehm, 2007). Priming occurs when the prior presentation of a stimulus causes a later presentation of the same or associated item to be processed differently, and conceptual priming refers to changes of this kind that relate to the semantics of each item (Schacter, Chiu & Ochsner, 1993). The logic of ERP memory old/new effects allows differences between old and new waveforms to index processes with or without conscious awareness equally, processes which may well occur simultaneously. For example, as is the case with the familiarity-based hypothesis, a conceptual-priming hypothesis of the mid frontal old/new effect does not predict differential activation in terms of processing to old items and similar lures, but does predict an effect to diverge for old and new items. As a result it has been argued by some that the mid frontal old/new effect provides an index of conceptual priming and not familiarity. This extends to the interpretation of the frontal ERP data reported by Woodruff et al. (2006).

Further support for a conceptual priming account comes from studies using stimuli that are low in inherent semantic attributes – and that are thus unable to support conceptual priming – in which the mid frontal old/new effect has not been reported. These include reports using unknown human faces (Yovel & Paller, 2004; MacKenzie & Donaldson, 2007, although the effect has been reported with novel faces elsewhere, Curran & Hancock, 2007) and squiggle stimuli, hard-to-define words and kaleidoscope images (Voss & Paller, 2007; 2009; Voss, Lucas & Paller, in press).

A conceptual priming account, however, is not consistent with a number of studies which indicate that the mid frontal old/new effect varies with the degree of perceptual overlap between items at study and test while conceptual overlap is kept constant (Curran & Dien, 2003; Schloerscheidt & Rugg, 2004; Groh-Bordin, Zimmer & Ecker, 2006; Ecker, Zimmer & Groh-Bordin, 2007; Ecker & Zimmer, 2009). These data indicate that the mid frontal old/new effect cannot reduce to correlates of conceptual priming although it is likely that such processes contribute to familiarity-based judgments (Groh-Bordin et al., 2006; Rugg & Curran, 2007). Keeping in mind the correspondence between the two processes in terms of their sensitivity to experimental manipulations, in many cases it can be argued that the mid frontal old/new effect is an appropriate and useful index of familiarity-based recognition.

Post-Retrieval Processes

The ERP old/new effects associated with familiarity and recollection provide an indication of the time by which retrieval occurs. As a result, old/new effects occurring after this point are generally held to index processes downstream of retrieval. The following sections review the main data points that have been used to make inferences about the significance of two 'late' old/new effects, the *late posterior negativity* and the *right frontal old/new effect.*

The Late Posterior Negativity

Beginning around the time at which a response is made and lasting for a few hundred milliseconds, ERPs elicited by old items demonstrate a relative negativity over bilateral parietal sites. This late posterior negativity (LPN) demonstrates a maximum over the posterior midline site Pz and has been reported in a number of paradigms. The inconsistency of the experimental manipulations that determine the presence and size of the effect are indicative of an effect that reflects more than one cognitive function (Herron, 2007). In one constructive review of the LPN, Johansson & Mecklinger (2003) broadly categorized the types of task in which the LPN is most often reported. Firstly, the LPN has occurred in a number of item recognition tasks in which there exist behavioural indicators of the presence of response conflict (e.g. Nessler & Mecklinger, 2003). Secondly, the effect has been reported in source memory tasks that require the retrieval of contextual/perceptual details (e.g. Cycowicz, Friedman & Snodgrass, 2001).

Robust LPNs occur in tasks in which high false alarm rates and lengthy reaction times indicate response conflict (e.g. Donaldson & Rugg, 1998). This has led to the suggestion that the effect indexes action monitoring processes related to response conflict (Johansson & Mecklinger, 2003). Consistent with this is the similarity between the effect and the error related negativity (ERN), a modulation that onsets around the time a response is made, peaking around 80ms later, and comprising a relative negativity to erroneous responses (Holroyd & Coles, 2002). The effect is thought to reflect processes related to the detection of an error and one possibility is that the LPN may represent analogous error or action monitoring processes that occur in recognition memory tasks (Johansson & Mecklinger, 2003). In line with this is the observation that the LPN has been shown to be larger for items that are more likely to elicit response conflict, such as semantic lures (Nessler & Mecklinger, 2003) and for a group of participants who made relatively more false recognition judgments (Nessler, Mecklinger & Penney, 2001). In one explicit test of the role of the LPN in action monitoring, the amplitude of the effect was shown to increase when motor conflict was manipulated by a reversal of hand-to-response mappings (Herron, 2007).

An action monitoring explanation cannot account for all observations of the LPN, however, because the effect also occurs in tasks in which response conflict is relatively low and the number of accurate responses is high (e.g. Leynes & Bink, 2002). Instances of this kind have come mostly from source memory tasks. One possibility is that the requirement to make additional source judgments about old items also elicits a level of response conflict (Johansson & Mecklinger, 2003), but the presence of the effect even when source judgments are not immediately required (such as in two-step response judgments) or when no overt response is required at all (Donaldson & Rugg, 1999) speaks against this account. It has been proposed, therefore, that the effect may also index processes related to the reintegration of source information during retrieval. In one example used to support this account, participants made a high proportion of correct judgments about whether they had originally perceived or imagined pictures associated with retrieval cues (Johansson, Stenberg, Lindberg & Rosen, 2002). Analyses revealed an LPN that was greater for perceived than imagined items, which is congruent with an account which states that the effect relates to the re-integration of perceptual detail during retrieval.

In addition, these data were re-analysed by locking ERPs to the responses participants made, thereby enabling processing related to the response itself to be analysed. These response-locked analyses revealed a different pattern, showing equivalent posterior negativities for both class of old item (Johansson & Mecklinger, 2003). This change in the pattern of posterior negativities indicates that the negativities present in the stimulus-locked data are unlikely to be related to action monitoring processes (which were evident in the response-locked analyses and were equivalent for both classes of old item). It is reasonable to instead infer that stimulus-locked effects reflect the process of binding together or reinstating contextual features during retrieval, a process that was greater for perceived than imagined items (Johansson & Mecklinger, 2003). This, combined with reports that the LPN does not differentiate between successful and unsuccessful source retrieval, but is enhanced when specific perceptual information such as colour is to be retrieved (Cycowicz, Friedman & Snodgrass, 2001; Friedman, Cycowicz & Bersick, 2005), has lead to the claim that the effect indexes general retrieval/search or evaluation of source-specifying details.

If this account is correct, the LPN should be larger the more contextual features there are to be retrieved. Mecklinger, Johansson, Parra & Hanslmayr (2007) tested this by comparing the LPN across conditions in which participants were required to either recover the semantic operations that were employed when the item was initially encountered or to retrieve its study location. The number of contextual features associated with the recovery of encoding operations was assumed to be considerably more than the details associated with study location. The LPN was reliably greater for the condition in which participants were required to retrieve semantic operations (see Figure 3.3) in support of an account that holds that the effect is an index of the search for and re-integration of source-specifying details.

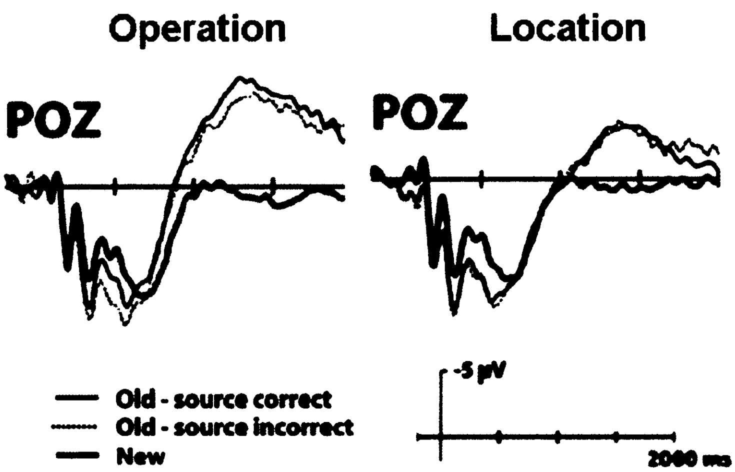

Figure 3.3: Taken from Mecklinger et al. (2007). Grand average ERPs for correct and incorrect source judgments and new items at a parieto-occipital electrode for the two retrieval conditions. Negative polarity is plotted upwards for these waveforms.

The Right Frontal Old/New Effect

First reported in detail by Wilding and Rugg (1996), this effect demonstrates a relative positivity for old items over right frontal sites from around 500ms, often remaining until the end of the recorded epoch. In light of the time course of the effect (remaining long after the ERP correlate of recollection, the left parietal old/new effect) and the effect's greater amplitude for items to which a correct source judgment was made, the effect was initially taken to index processes that operate upon the products of retrieval in order to successfully recover contextual information (Wilding & Rugg, 1996; see Figure 3.4).

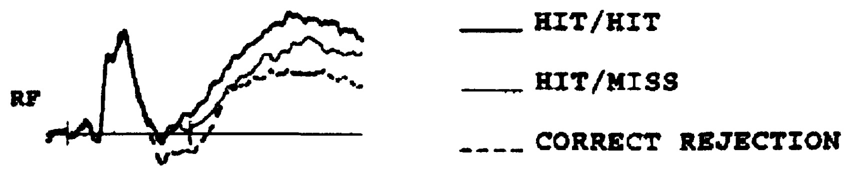

Figure 3.4: Taken from Wilding & Rugg (1996). Grand average ERPs associated with correct source judgments (hit-hit), incorrect source judgments (hit-miss) and correct rejections, at a right frontal electrode.

This pattern has not been replicated across studies however, and there are reports in which the effect has been shown to be equivalent for both accurate and inaccurate source judgments (e.g. Senkfor & Van Petten, 1998). This failure to dissociate source correct and incorrect old items has led to the conclusion that the effect reflects post-decisional aspects of mnemonic processing which are assumed to be equivalent across all old items in source judgment tasks (Trott et al., 1999; Friedman & Johnson, 2000). Further evidence that the effect cannot simply index retrieval success comes from a demonstration that the frontal effect was larger when participants were required to retrieve the semantic task they had encoded items with rather than the voice in which the item had been presented (Wilding, 1999). In that report it was concluded that the effect reflected processes that monitored retrieval for different kinds of information. Monitoring accounts are supported by the observation that the effect occurs predominantly in tasks in which specific source details about a study episode are required (Ranganath & Paller, 1999; Friedman & Johnson, 2000) rather than in tasks requiring simple old/new judgments. The assumption in these accounts is that monitoring or evaluation processes are engaged to a greater degree when making source judgments rather than simple old/new judgments.

This does not mean that there are no reports of reliable right frontal old/new effects in simple item recognition tasks. Rugg, Allan & Birch (2000) employed a depth of processing manipulation at study which ensured items were encoded by processing either the orthographic or semantic features of each word. During retrieval, participants were required to make only old/new judgments to each word and a late right frontal positivity was larger in magnitude for shallowly encoded items. One interpretation of these findings is that monitoring processes might be required to a greater degree for items associated with the recovery of relatively little detail as would typically be the case for shallowly encoded items.

Monitoring accounts are also in line with the scalp distribution of the late frontal old/new effect. Although no strong inferences about the possible neural generators of ERP effects can be made, the scalp distribution of these effects is in line with a locus in the prefrontal cortex (Wilding & Rugg, 1996; Mecklinger, 2000). This inference is supported by neuropsychological reports that frontal lobe lesions are related to selective impairments in source memory (Janowsky, Shimamura & Squire, 1989) and confabulation (Moscovitch, 1989). As reviewed in Chapter 1, a number of models of memory control posit confabulations in part to be due to deficient post-retrieval monitoring processes supported by the prefrontal cortex (Moscovitch, 1989; Burgess & Shallice, 1996).

In one recent study, Hayama, Johnson & Rugg (2008) set out to determine whether the monitoring processes thought to be indexed by the right frontal old/new effect are specific to episodic retrieval judgments. Across two experiments, right frontal old/new effects were elicited for items regardless of whether judgments were episodic or semantic. In one experiment, new items also elicited robust right frontal effects when participants were required to make semantic judgments to them. These data are consistent with an effect that indexes more general decisional/monitoring processes beyond those required in episodic retrieval tasks. These findings can also be accommodated by an alternative account. Using fMRI, Dobbins & Han (2006) have reported that activity in a candidate region for the generators of the right frontal effect, the dorsolateral prefrontal cortex (DLPFC) was sensitive to the number of internal decisions that were made.

Cruse & Wilding (2009) sought to directly test the internal-decision account of the right frontal old/new effect by asking participants to make combined source/confidence judgments for recognised old items. It was assumed that the number of internal decisions was the same across those items given high or low confidence source judgments, and as such that the right frontal old/new effect should not differentiate with confidence if the decisional account is correct. The finding that the right frontal old/new effect was larger in magnitude for items given high confidence correct source judgments, therefore, failed to provide support for the decisional account.

None of the current accounts of the right frontal old/new effect can accommodate all the existing data points. One explanation for the confusion surrounding the functional significance of this particular effect may be due to the functional and anatomical heterogeneity of the prefrontal cortex, the probable neural locus of the effect (Fletcher & Henson, 2001). It is likely therefore that a variety of frontally-supported post-retrieval monitoring/decisional and evaluation processes are engaged to different degrees in certain recognition memory tasks thereby raising the possibility that not entirely the same late frontal old/new effects have been captured across experiments. It may be that the failure to distinguish between different effects in different ERP studies is due in part to the spatial resolution available in the studies completed to date.

Concluding Comments

The previous sections provide a brief overview of the literature relating four old/new effects to processes contributing to episodic recognition memory judgments. The experiments presented in this thesis provide an opportunity to assess the way in which these old/new effects relate to the engagement of strategic retrieval processes as indexed by differences between new item ERPs, which are the main focus of this work.

Chapter 4
General Methods

Introduction

This chapter describes the experimental parameters and procedures common to all the experiments reported in this thesis. Procedures and analyses specific to each experiment are described in the necessary sections of the relevant chapters. All participants were subjected to the same exclusion criteria for participation. The ERP recording parameters and data processing methods were identical in all four experiments.

Methods

Participants

Participants were recruited via an electronic experiment management system, from the undergraduate and postgraduate populations of Cardiff University. Participants were paid £7.50/hour for their participation. All participants met the following inclusion/ exclusion criteria: native English speakers, right-handed, aged between 18 and 30 years old, without a diagnosis of dyslexia and not taking any neurotropic medication. The mean age of participants was 21 years (range: 18-29).

Experiment Materials and List Construction

Across all experiments, stimuli were concrete words between 4 and 9 letters in length. Words were selected from the MRC Psycholinguistic database (Coltheart, 1981) corpus and were of a low – medium frequency (range 1-15 per million). Words were presented in upper case white letters on a black background in Times New Roman font. Stimuli subtended maximum visual angles of 4.6° (horizontal) and 0.6° (vertical). For Experiments 1, 2 and 3, words were selected if they had at least one discernible function and were considered sufficiently concrete to be depicted visually (concreteness: 500-700; Coltheart, 1981).

List construction is specified within each experiment chapter. For each experiment lists were created so that, across participants, all words acted as both old and new task items and were encountered in each encoding condition.

Experiment Procedures

In all four experiments, participants completed a number of study-test phases. Words were presented initially during study and were then re-presented alongside new words during the test phase. Participants were instructed to respond as quickly and as accurately as possible. The hand-response mappings were counterbalanced across participants within each experiment. In Experiments 1, 2 and 4, participants were fitted with an ERP recording cap prior to the experiment. In Experiment 3, the cap was fitted between the study and test phase of the experiment.

EEG Recording

EEG recording parameters were identical for all experiments. EEG was recorded from 32 locations based on the International 10-20 system (Jasper, 1958) including midline (Fz, Cz, Pz, Oz) and left/right hemisphere sites (FP1/FP2, F7/F8, F5/F6, F3/F4, F1/F2, C7/C8, C5/C6, C3/C4, C1/C2, P7/P8, P5/P6, P3/P4, P1/P2, O1/O2). Figure 4.1 represents these electrode sites and configurations.

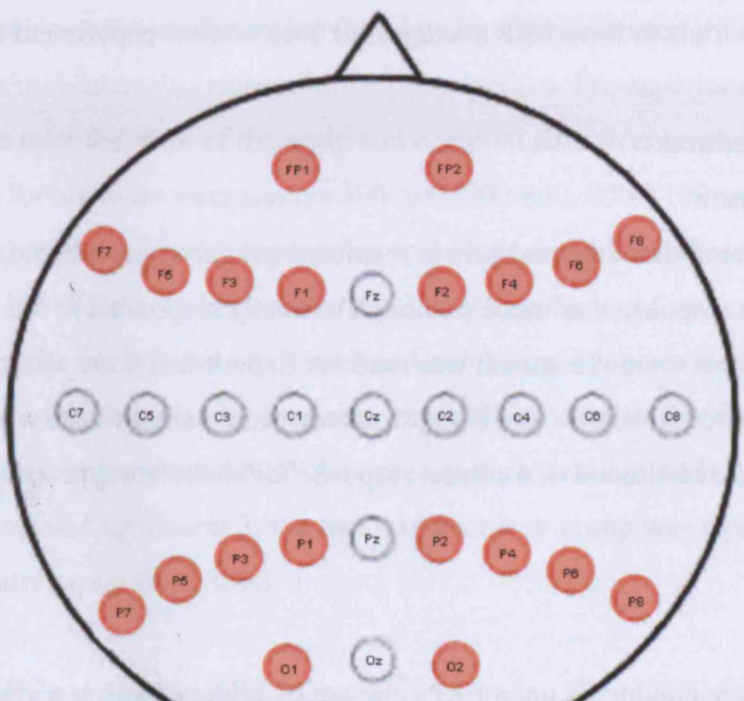

Figure 4.1: Representation of the electrode montage from which scalp data were recorded based upon the Ten-Twenty System of the International Federation (Jasper, 1958). Highlighted sites represent those electrodes employed in the standard analysis montage.

Additional electrodes were placed on the mastoid processes. Electro-ocular activity (EOG) was recorded from above and below the left eye (vertical EOG) and from the outer canthi (horizontal EOG). EEG (range DC-419 Hz; sampling rate 2048 Hz) was acquired referenced to linked electrodes located midway between midline posterior and midline occipital electrodes, and re-referenced off-line to the average signal at the mastoids. The data were band-pass filtered off-line (0.03 - 60 Hz) epoched and down-sampled to 167 Hz.

Data Processing

Recorded epochs were 1536ms in length including a 102ms baseline relative to which all mean amplitudes were computed. A 7-point (22Hz) binomially weighted smoothing filter was applied to the averaged ERPs before artefact rejection. Trials containing large EOG artefact were rejected, as were trials containing A/D saturation or baseline drift exceeding ±80μV. Other EOG blink artefacts were corrected using a linear regression estimate (Semlitsch, Anderer, Schuster, & Presslich, 1986). Across all experiments, participants were excluded if they were unable to contribute at least 16 artefact-free trials to form ERP averages for each critical experiment condition.

Analysis Procedures

Behavioural Data

All the behavioural data reported here is restricted to analysis of old and new items to which a correct response was made (although correctly responded to old items to which an incorrect source judgment was made in Experiment 4 are also reported). Repeated measures ANOVAs and Bonferroni corrected paired t-tests were used to compare both the likelihood of a correct response for each item type as well as reaction times.

ERP Data

All analyses were conducted upon ERPs elicited by items to which correct responses were made (although additional analyses were conducted on ERPs elicited by items at study to which incorrect responses were made at test in Experiment 4). Averaged ERPs were formed for all the conditions of interest, from which the mean amplitude measurements were taken from selected time windows (computed relative to the pre-stimulus baseline) and compared using repeated measures ANOVAs.

These ANOVAs included the Greenhouse–Geisser correction for non-sphericity (Greenhouse & Geisser, 1959). Non-sphericity is an important assumption of ANOVA that expects the covariance between all the different levels of factors to be equal. ERP data are especially prone to violating this assumption following the employment of multiple electrode sites as a factor and variable differences between electrodes. The Greenhouse–Geisser correction estimates the extent to which the assumption has been violated and reduces the degrees of freedom accordingly. Throughout this thesis, corrected degrees of freedom and F-values are reported where necessary.

Analyses of ERPs evoked by New Items

Analyses were conducted on data from a montage of 20 electrode sites selected equally from both hemispheres and anterior-posterior positions: FP1/FP2, F7/F8, F5/F6, F3/F4, F1/F2, P7/P8, P5/P6, P3/P4, P1/P2 and O1/O2. This montage was used in all analyses unless stated otherwise, and is highlighted in Figure 4.1. Accordingly ANOVAs were conducted with site factors including hemisphere (two levels; left/right), anterior-posterior dimension (two levels; anterior/posterior) and site (five levels; inferior/mid-lateral/superior/midline/pre-superior). Pre-superior refers to prefrontal sites over the front of the scalp and occipital sites over posterior scalp. The time windows for analyses were always 300-500, 500-800, 800-1100 and 1100-1400ms. In Experiment 3 it was appropriate to include an additional early time window from 100-300ms. In Experiments 1, 3 and 4 the factor of accuracy group (high/low) was also included in analyses (see Correlation Analyses section below). In time windows in which there was a reliable interaction including this factor and response category, subsequent ANOVAs were conducted within each accuracy group. In some analyses in Experiment 3, the factor of accuracy group was replaced with relative difficulty group (high/low).

Analyses of ERPs evoked by Old Items

The paradigm employed in Experiments 1 and 2 allowed for contrasts between ERPs elicited by classes of old item which provide additional insight into the engagement of particular retrieval strategies. Analyses on these data were identical to those specified for the ERP new item contrasts.

Correlation Analyses

One of the critical aspects of the data reported in Experiments 1, 3 and 4, was to determine whether the size of particular ERP effects (in particular, differences between ERPs elicited by new items from different retrieval tasks) vary with the proportion of correct responses that participants made. An important first step in these analyses was to split the data according to the median of the behavioural index of response accuracy (specific to each experiment) in order to create two groups that differed only in the overall proportion of correct responses that their constituent participants made. The establishment of these two groups provided a simple means by which to compare variations of specific ERP memory effects with response accuracy. Global ANOVAs in which interactions including the factors of ERP category and accuracy group (high/low) occurred indicated changes in the effect across the two groups. Interactions of this kind licensed follow-up analyses within each group in order to determine how the effect changed across groups. The maxima of the effects derived from these follow-up ANOVAs were then used to select the sites from which individual ERP data were extracted for subsequent correlational analyses. In all cases correlations were implemented by taking the difference in microvolts between the ERPs of interest for each individual and plotting this against the relevant behavioural index.

Although median splits provide a suitable initial approach to determining the relevant scalp sites and time points at which to extract data for correlational analyses, there are instances in which median splits may reveal false negatives (MacCallum, Zhang, Preacher & Rucker, 2002) making it necessary to employ sensitive correlational approaches whenever possible. Where the *a priori* hypotheses predicted a significant relationship between the size of an ERP effect and response accuracy, but the outcomes of median split analyses did not necessarily indicate this, correlations were performed at all electrodes and time windows where the effect was reliable. For each experiment, details of the sites and time windows used for each correlation are given only when the outcome was reliable. Details for the remainder can be found in appendices.

Analyses of ERP Old/New Effects

These were performed in the same time windows and at the same scalp sites as the analyses of new items. ANOVAs were conducted with factors of response category (e.g. correct old vs. correct new), hemisphere (two levels), anterior-posterior dimension (two levels) and site (five levels). In Experiments 1, 3, and 4, the between-group factor of accuracy group (two levels) was also included. A global ANOVA was performed in each time window. Where interaction terms with the factor of response category were reliable, and there were more than two levels to this factor (see Experiments 1 and 2) paired contrasts for each level of this factor were performed (e.g. target vs. new items). If this revealed further significant interaction terms including the factors of response category and group, follow-up contrasts were conducted within each group, in order to determine the way in which old/new effects differed for the two groups.

The majority of the analyses on ERP old/new effects were conducted collapsed across retrieval tasks because there were no *a priori* hypotheses that ERP old/new effects would vary with retrieval tasks and response accuracy. It was the case, however, in some of the experiments (Experiments 1 and 3) that analyses of ERPs separated for the different retrieval phases in the 500-800ms time window indicated important between-group differences. These outcomes are therefore included within the results section of each chapter, whereas the complete outcomes for the separated old/new analyses are presented in the appendices.

Rescaling and Analyses of Scalp Distributions

Comparisons of the scalp distribution of ERP effects determine whether interactions between ERP effects and electrode locations come about because reliably different scalp distributions were recorded in the two instances. This is important because effects of this type indicate that not entirely the same neural generators are employed across conditions.

The multiplicative voltage data used in ERP analysis causes problems for the additive ANOVA model when making comparisons of this kind, because in some instances the analysis may return an interaction between factors of condition and location purely on the basis of greater activity in one condition alone. In order to mitigate against this and ensure that condition/location interactions reflect real changes in the size of effects over the scalp it is necessary to perform these analyses on rescaled (or normalised) subtraction data in order to determine whether interactions remain after amplitude differences have been removed (McCarthy & Wood, 1985; Wilding, 2006). All analyses of scalp distributions in this thesis were conducted upon subtraction data that has been rescaled using the max-min method. This method normalises the size of the ERP effect at each site relative to the maximum and minimum effect across all electrode sites, effectively retaining the pattern of the effect over the head while removing amplitude differences.

There exist other techniques to rescaling ERP amplitudes, most notably the vector length method (McCarthy & Wood, 1985; Urbach & Kutas, 2002). This operates by calculating the 'vector length' from all the electrodes and using this value to divide the amplitude of the effect at each electrode. This is done separately for each condition. Whereas the max-min method has been criticised for sometimes obscuring real topographical differences (Haig, Gordon & Hooks, 1997; Picton et al., 2000) the vector-length method has been shown to produce false positives under some circumstances (Urbach & Kutas, 2002; Wilding, 2006). The more conservative (max-min) of the two methods is reported throughout this thesis.

In the experiments reported here, comparisons of the scalp distribution of ERP effects were conducted to address two sets of questions. First, these were employed when the same ERP effect was present in two or more consecutive epochs, in order to determine whether the distribution of the effect remained stable over time. The second instance in which these analyses were employed was in the case of ERP effects that interacted with group at the level of the global ANOVA. Topographic analyses help to determine whether interactions between groups, response category and factors of site come about because of changes in the scalp distribution of effects. Analyses on rescaled data included the same factors of site (anterior-posterior, hemisphere and site) that were used in all other analyses.

Presentation of Data

Tables presenting behavioural data are presented within each results section, unless specified. Tables presenting the outcomes of analyses on ERP data, ERP waveforms and scalp maps are provided at the end of each experimental chapter. Figures that provide an overview of the critical effects and between-group differences at selected sites are presented within the text where necessary. The remainder of figures can be found at the end of the appropriate experiment chapter. Significance levels greater than 0.05 are considered non-significant and all p-values less than this are reported and whether they are less than 0.05, 0.01 or 0.001 is specified. The corrected degrees of freedom (following Greenhouse-Geisser correction), F-values and significance levels are reported for all significant ANOVA outcomes in which there was an interaction with retrieval task (paired item contrasts) or response category (old/new contrasts).

Chapter 5
Experiment 1: Individual Differences in Strategic Retrieval Processing in an Exclusion Task

Introduction

ERPs associated with new items from retrieval tasks with dissimilar response requirements have, in various contrasts, been shown to differ reliably from one another (e.g. Rugg, Allan & Birch, 2000; Robb & Rugg, 2002). These differences are assumed (broadly) to index strategic retrieval processes (see Chapter 1: Introduction), and the engagement of strategic retrieval processing is assumed to be contingent upon goal-directed retrieval requirements. Data consistent with this assumption includes the demonstration that ERP indices of strategic retrieval processing are evident primarily in tasks where retrieval is required explicitly (Hornberger et al., 2006b). In keeping with this assumption, functional accounts of differences between neural activities across classes of new items have been cast in terms of the benefits that accrue from employing strategic processing operations (Hornberger et al., 2006). For example, it has been proposed that the processes indexed by ERPs reflect operations that maximise the overlap between processes engaged at encoding and retrieval (Rugg, Herron, & Morcom, 2002), or that they index processes which increase the likelihood that representations of cues will interact with some memory traces rather than others (Herron & Rugg, 2003a; Dzulkifli, Herron, & Wilding, 2006).

These accounts predict that response accuracy in memory tasks will benefit when strategic retrieval processing of the kind described above is engaged. Experiment 1 was designed to provide for the first time a direct test of this proposal. ERPs were recorded from the retrieval phases of two verbal memory tasks with different demands. The relationship between ERP indices of strategic retrieval processing and response accuracy on the tasks was then assessed. For both tasks, the encoding requirements were for participants to generate either a function for or judge how easy it would be to draw the objects denoted by study words. Response requirements at test were those used in exclusion tasks (Jacoby, 1991); a binary response was required in both retrieval tasks, where unstudied words were presented inter-mixed with words that had been encoded under either function or drawing instructions. In one task, participants were asked to respond on one key to words encoded in the function task, and on a second key to new words, as well as to words encoded in the drawing task. In the other retrieval task, the designation for which encoding task shared the same response key as new test words was reversed. Old items that were responded to on the same key as new items are termed *nontargets*, whereas the remainder of old items are termed *targets*.

ERPs were recorded for all items at test, but the critical ERPs were those elicited by new items in each task. The key prediction was that ERP evidence for the degree to which strategic retrieval processing was engaged would be correlated positively with response accuracy, in support of the view that these processes benefit the accuracy of memory judgments. Evidence for the degree to which strategic retrieval processing was engaged was operationalised as the magnitude of the voltage differences between the ERPs elicited by new items in the two retrieval tasks for each participant. The magnitude of these voltage differences is thus assumed to index to what extent strategic retrieval processing operations differed across the two tasks.

In addition to these hypothesis-driven analyses, two additional sets of contrasts were conducted in order to further explore the relationship between retrieval processes as indexed by ERPs and overall response accuracy. Firstly, separate contrasts between targets and nontargets from the two target designations are reported. Similar contrasts have been conducted previously (Ranganath & Paller, 1999; 2000), but this is the first time in which separate comparisons have been made for old and new items from tasks with specific retrieval requirements with a view to determining the relationship between them and behavioural performance. Moreover, divergences between ERPs to old items can be used to constrain inferences about the functional significance of differences between new items.

The second and final set of additional analyses is upon ERP old/new effects and specifically on the left parietal old/new effect. These analyses are conducted because of previous claims that the behaviour of this effect provides evidence for the selective recollection of targets in exclusion tasks. Specifically, across a number of studies it has been shown that when target accuracy is high the amplitude of the left parietal old/new effect for nontargets is reduced relative to that for targets (see Chapter 1; Dzulkifli & Wilding, 2005; Dzulkifli, Herron & Wilding, 2006). This has led to the suggestion that when the likelihood of retrieving targets is high participants use a strategy in which they rely predominantly on the recollection of target items. The design of Experiment 1 allows for a direct contrast of the left parietal old/new effect for targets and nontargets from two participant groups that differ only in their response accuracy, thereby permitting a test of whether there is a direct relationship between accuracy and the amplitude of the left parietal old/new effect for nontargets. Critically, the collective contribution of these additional contrasts is to constrain the possible interpretations of the functional significance of strategic retrieval processes that are indexed by differences between new item ERPs.

Method

Participants

These were 47 (7 male) students. Data from 11 participants (1 male) were discarded due to experimenter error (1), failure to follow instructions (3), and excessive EOG artefacts resulting in insufficient trials per condition (7). Mean age of the remaining participants was 21 years (range: 18-27).

Design

Three hundred and sixty words were presented on a computer monitor placed approximately 1 metre from participants. Six groups of 60 words were selected at random for a full experiment list. Each experiment list comprised two study-test cycles. Each study phase comprised two word groups (120 words). These were repeated at test together with a third word group to give 180 test words per cycle. No words were repeated across cycles. Word groups were rotated fully across experiment lists, resulting in the formation of 6 complete lists.

Procedure

Participants were first fitted with an electrode cap (see Chapter 4). They completed two study-test cycles after a short practice phase where they were familiarised with task response requirements. The requirements in the test phase of the practice session corresponded to the first set of retrieval instructions each participant was given. The researcher read aloud the task instructions and participants were also given written descriptions.

In each study phase, participants completed two tasks. Cues preceding each item signalled which task to complete; 'FUNCTION?' for the function task, 'DRAW?' for the drawing task. In the function task, they were asked to say aloud a function for the object denoted by the word. In the drawing task, they were asked to rate verbally how difficult it would be to draw the object denoted by the word on a 4-point scale: 'very easy', 'fairly easy', 'fairly difficult', 'very difficult'. Cues remained on the screen for 1000ms, followed by a blank screen for 500ms. Order of encoding task cues was pseudo-randomised so that no more than three consecutive words were preceded by the same cue. Each study word was presented for 300ms before the screen was blanked. Participants initiated the next trial by pressing a key on a response pad, and the trial started 2000ms after this response.

Each test trial began with a fixation asterisk that remained on the screen for 500ms, followed by a 500ms blanked screen and then the test word for 300ms. The screen was then blanked until the participant responded. The next trial began 1500ms later. Participants were instructed to respond using one thumb to words from one of the two encoding tasks (targets), and with the other thumb to new test words as well as those from the other task (nontargets). Target designation (function/drawing) changed across study-test cycles. Participants were informed of target designation immediately prior to each test phase, and were not informed during the practice session that a change would occur. The thumbs used for responses were balanced across participants, and 50% of participants completed the function task designation first. There was a break of two minutes between each study-test cycle and between study and test phases.

EEG was recorded with the parameters outlined in the General Methods section (Chapter 4).

Results

Behaviour

Table 5.1 shows the proportions of correct judgments and associated reaction times (RTs) to old and new items separated according to whether items encoded under function or drawing instructions were designated as targets. For both of these *target* *designations*, target responses to targets were significantly more likely than target responses to nontargets and new items (for all comparisons: $t(35) > 25.00$, $p<0.001$).

Table 5.1: Mean proportions of correct responses to targets, nontargets and new items separated according to target designation. Corresponding reaction times are also shown. Standard deviations in parentheses.

Target Designation		Response Category		
		Target	Nontarget	New
Function	*p(correct)*	0.85 (0.11)	0.88 (0.09)	0.97 (0.04)
	RT	1222 (262)	1262 (277)	1051 (242)
Drawing	*p(correct)*	0.78 (0.12)	0.90 (0.07)	0.97 (0.04)
	RT	1278 (326)	1335 (336)	1042 (249)

Further analyses were guided by the intention to compare ERP indices of strategic retrieval processing according to how well people completed the tasks (see Introduction). In a first step, participants were separated according to an averaged measure of target/nontarget discrimination (*p*(target hit) – *p*(nontarget false alarm)) collapsed across whether words from the function or drawing encoding condition were designated as targets. This step created a high accuracy and a low accuracy group. Table 5.2 shows (for both groups) mean proportions of correct responses and their corresponding RTs. Mean target/nontarget discrimination scores for the high accuracy group were 0.83 (function) and 0.79 (drawing). The corresponding mean values for the low accuracy group were 0.63 and 0.58. These discrimination scores were assessed via a two-way ANOVA with factors of group (high/low) and target designation (function/drawing). The Geisser-Greenhouse correction for non-sphericity was employed where appropriate here and in the subsequent ERP analyses (Greenhouse & Geisser, 1959).

Table 5.2: Mean proportions of correct responses to targets, nontargets and new items separated according to group (high/low) and collapsed across target designation. Corresponding reaction times are also shown. Standard deviations in parentheses.

Accuracy Group		Response Category		
		Target	Nontarget	New
High	*p(correct)*	0.88 (0.07)	0.92 (0.04)	0.98 (0.03)
	RT	1288 (218)	1328 (230)	1079 (201)
Low	*p(correct)*	0.74 (0.11)	0.86 (0.10)	0.96 (0.05)
	RT	1211 (294)	1269 (344)	1014 (233)

There was superior target/nontarget discrimination in the high group ($F(1,34) = 35.33$, $p<0.001$), and the decision to use discrimination score collapsed across target designation was supported by the absence of a reliable effect for this factor, although it did approach significance ($F(1,34) = 8.00$, $p=0.06$), reflecting a trend for superior discrimination in the function target designation. An independent t-test showed that the likelihood of a correct response to a new test item did not vary with task. This is important, because it suggests that any differences between the ERPs elicited by new tests items and separated according to target designation are unlikely to reflect task difficulty differences (cf. Robb & Rugg, 2002).

Analyses of the RT data were conducted for correct responses only via ANOVA with factors of accuracy group (high/low), response category (target/nontarget/new) and target designation (function/drawing). The analysis revealed a main effect of category only ($F(2,68) = 66.71$, $p<0.001$), reflecting the faster RTs for responses to new items. A planned comparison of the RTs for new items separated according to designation did not reveal a reliable difference ($t<1$).

ERP Analyses

The critical analyses for the experiment predictions were those for the ERPs elicited by unstudied test words, and these are described first below. These are followed by descriptions of the outcomes of comparable analyses for the ERPs elicited by targets and nontargets, again separated according to target designation. The final section of the ERP analysis presents the old/new effects collapsed across target designations.

The outcomes of the analyses for targets, nontargets and old/new effects offer the opportunity to constrain possible interpretations of the findings for the ERPs elicited by new items. ERP old/new effects are included to determine the sensitivity of the left parietal old/new effect (and to a lesser extent, other ERP old/new effects) to different classes of old item and whether this sensitivity is modulated by accuracy group. The mean numbers of trials contributing to the averaged ERPs for each participant and response category can be seen in Table 5.3 (end of chapter).

Analyses of Paired Contrasts across Target Designations

The initial analysis strategy was the same for all of the paired contrasts (new items, nontargets and targets). All analyses were conducted on ERPs to which correct responses were made. For each epoch and paired contrast, a global analysis was conducted with factors of accuracy group (high/low), target designation (function/drawing), hemisphere (left/right), anterior-posterior dimension (anterior/posterior) and site (inferior/mid-lateral/superior/midline/pre-superior). When interactions involving group and target designation were obtained in these analyses, subsequent analyses within group were conducted to determine the reasons for the interaction terms. The outcomes of these analyses were also employed to guide the selection of scalp sites that were used when calculating correlations between response accuracy and differences between ERPs separated according to target designation. The key analysis outcomes for the test of the experiment prediction are indications that the magnitude of the differences between new item ERPs is larger for individuals with relatively superior target/nontarget discrimination.

ERPs elicited by New Items

Figure 5.1 (below; see also Figures 5.2 and 5.3; end of the chapter) depicts the grand average waveforms elicited by correctly responded to new items in the two tasks for the high and low accuracy group. The upper panel (and Figure 5.2) shows that, at midline-posterior sites from 700ms onwards, ERPs associated with new items in the function target designation are relatively more positive-going than those associated with the drawing target designation. The lower panel (and Figure 5.3) depicts the ERPs for the same response categories for the low accuracy group, in which there are not comparable differences between the ERPs, although there is some differentiation between these classes of ERPs, primarily at electrodes P3 and O1.

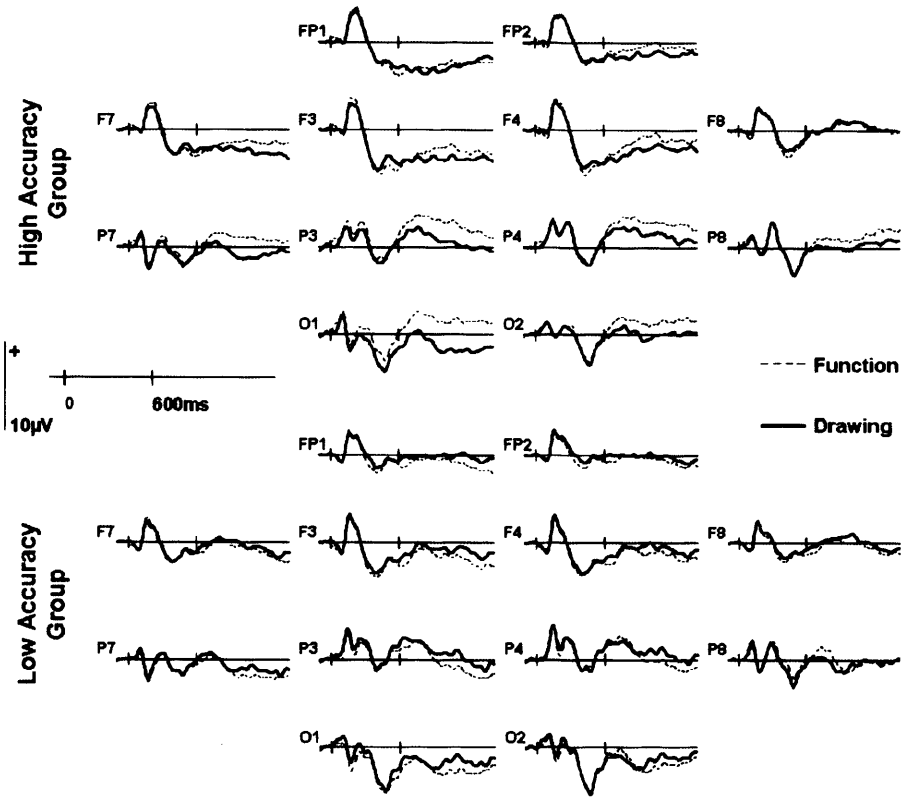

Figure 5.1: Grand average ERPs elicited by new items in the two target designation conditions for the high and low accuracy groups. Data are shown for 12 electrode locations at left and right hemisphere sites at prefrontal (FP1, FP2), anterior (F7, F3, F4, F8), posterior (P7, P3, P4, P8), and occipital (O1, O2) scalp sites.

The initial analyses of these ERPs revealed reliable interactions involving accuracy group and target designation in each epoch (see Table 5.4; end of the chapter). Follow-up analyses for each group revealed reliable effects of target designation only in the high group: a three-way interaction between designation, anterior-posterior and hemisphere was reliable from 500-1100ms (500-800: $F(1,17) = 5.35$, $p<0.05$; 800-1100: $F(1,17) = 4.86$, $p<0.05$), and the designation by anterior-posterior term was reliable for the 1100-1400ms epoch ($F(1,17) = 5.89$, $p<0.05$). The reasons for these reliable effects can be seen most clearly in the upper panel of Figure 5.9 (end of chapter), which depicts the posterior and generally left-sided maxima of the differences between the ERPs that were elicited by new items in the high accuracy group.

ERPs elicited by New Items (Correlation)

The presence of reliable differences between the ERPs elicited by new items in the high accuracy group only is consistent with the view that strategic retrieval processing influences positively the accuracy of memory judgments. The next analysis stage was implemented to establish whether evidence consistent with this account could be obtained at the level of individual participants. Towards this end, the outcomes of the preceding analyses guided the selection of left posterior/occipital sites (O1, P1, P3, P5, and P7) as those from which an ERP measure of the degree to which strategic retrieval processing differed across tasks was plotted against target/nontarget discrimination for each participant. This ERP measure for each site and epoch was a difference score obtained by subtracting mean amplitudes associated with new items in the drawing designation from those associated with the function designation. Critically, significant positive correlations between these measures were obtained at several electrodes in all three time windows (minimum significant R-value = 0.33). The R-values for each electrode site are shown in the upper section of Table 5.5 (located at end of chapter). The lower section of Table 5.5 shows that the correlations remain significant from 800-1400ms when two participants with poor discrimination scores are removed, and these findings converge with those that were obtained in the group-level analyses already described. The scatterplots depicted in Figure 5.10 (end of chapter) demonstrate this relationship clearly.

ERPs elicited by Old Items

Figures 5.4 and 5.5 (end of chapter) depict the grand average waveforms elicited by correct responses to nontargets in the two tasks for both groups. While there was little evidence for marked differences between these classes of ERPs for the high accuracy group (see Figure 5.4), Figure 5.5 demonstrates some differentiation between these classes of ERPs at posterior (and primarily right hemisphere) sites for the low accuracy group. These ERPs were subjected to the same analysis strategy as for the ERPs elicited by new items, and Table 5.4 shows that a reliable four-way interaction was revealed in the 300-500ms epoch. However, separate follow-up analyses within each group revealed no reliable effects.

Figures 5.7 and 5.8 (at end of the chapter) show the grand average waveforms for the two groups for the ERPs elicited by correct responses to targets (see also Figure 5.6 below). The ERPs associated with targets differ little according to target designation for the low accuracy group, but do vary with designation for the high group. From approximately 400ms onwards, there is a sustained relative positivity for targets associated with the drawing rather than the function condition, primarily at right-frontal sites. In keeping with this description of differences according to group, Table 5.4 shows that interactions including the factors of group and target designation occurred from 500ms onwards, and subsequent within-group analyses revealed interactions with target designation only in the high accuracy group.

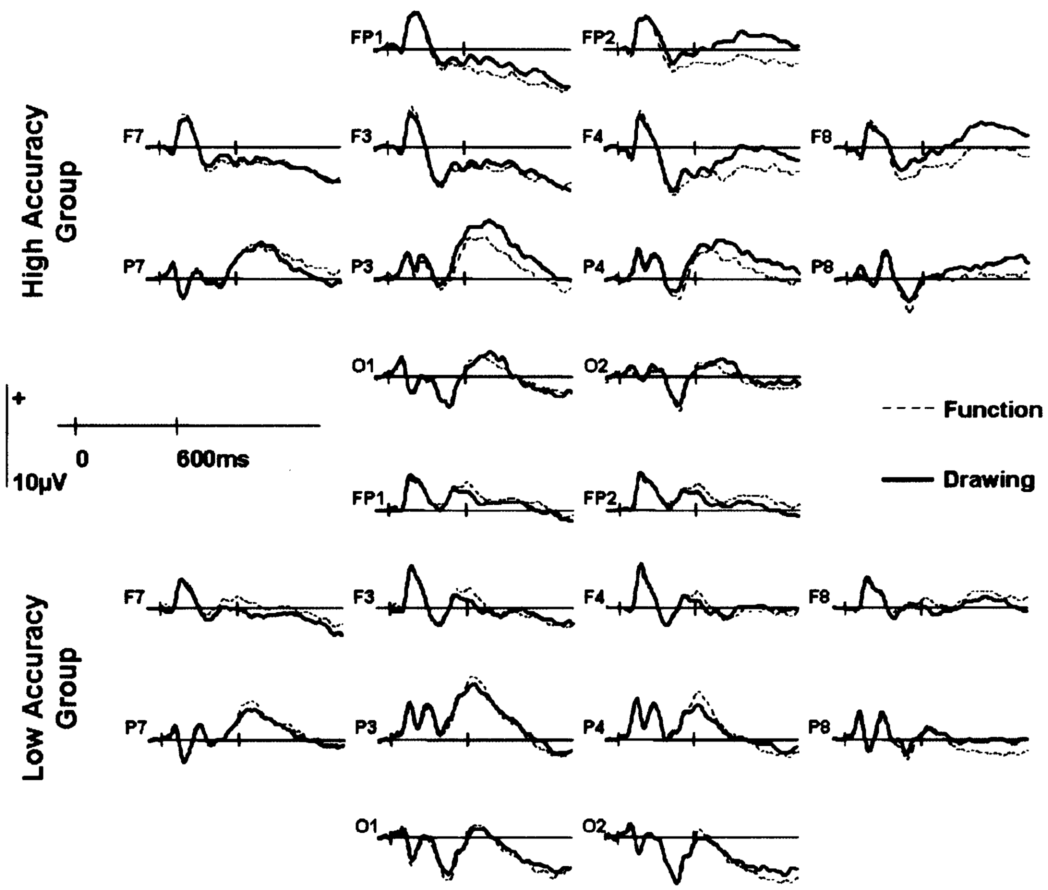

Figure 5.6: Grand average ERPs elicited by targets in the two target designation conditions for the high and low-accuracy groups. Data are shown for 12 electrode locations.

For this group, the interaction term including target designation, anterior-posterior and site was significant in all epochs after 500ms (500-800, $F(3.3,56.5) = 5.81$, $p<0.01$; 800-1100, $F(3.4,57.3) = 3.08$, $p<0.05$; 1100-1400, $F(3.3,55.4) = 3.46$, $p<0.05$). In addition, the factors of designation and hemisphere interacted from 800-1400ms (800-1100, $F(1,17) = 6.05$, $p<0.05$; 1100-1400, $F(1,17) = 15.49$, $p<0.01$), moderating a main effect of target designation in the 800-1100ms window ($F(1,17) = 7.38$, $p<0.05$). These interactions confirm that targets were more positive-going in the drawing designation over the right hemisphere, in particular at frontal scalp sites, extending to some degree to posterior midline sites, as depicted in the lower panel of Figure 5.9.

ERPs elicited by Old Items (Correlation)

As for the new item analysis, the sites where target differences were greatest in the high accuracy group were taken as those from which amplitude differences were extracted and correlated with target/nontarget discrimination. At right prefrontal and parietal sites (FP2, F2, F4, F6, F8, P1, P3), mean amplitudes associated with target hits in the drawing designation were subtracted from those associated with the function designation, mirroring the subtraction completed for the new item ERPs. Moderate correlations between these measures and discrimination were observed at a number of sites in all three time windows (all significant R-values < -0.33; see Table 5.6 at end of chapter). Although these outcomes are somewhat sensitive to the inclusion of two outliers, some effects remain after they have been removed. In addition, note that, because the ERPs associated with the drawing target designation are more positive-going than those from the alternate condition, the subtraction used here (function minus drawing, as was employed for new items) results generally in negative values for the magnitude of the differences between conditions for each participant, but the correlation that was obtained indicates that the size of the differences between conditions increases as accuracy increases, as was the case for the new item ERP contrasts.

Analyses of ERP Old/New Effects

Examination of ERP old/new effects is initially presented collapsed across target designation because, for the most part, the preceding paired item contrasts provide considerable insight into the behaviour of ERPs associated with the different item types from the two test phases. Appendix A contains a report of the complete outcomes of the analyses of old/new effects separated for the two target designations, which correspond directly to the outcomes of the paired contrasts reported above. Of specific interest was the behaviour of the left parietal old/new effect elicited by nontargets, following claims that the amplitude of the effect for this class of items relative to the size of the effect for targets is sensitive to memory accuracy (Dzulkifli, Herron & Wilding, 2006). This design also provides the first opportunity to determine how ERP old/new effects differ with response accuracy in an exclusion task.

Figure 5.11 (below) shows waveforms at selected sites for ERPs evoked by targets, nontargets and new items in the high and low accuracy groups. Figures 5.12 and 5.13

at the end of the chapter show these same waveforms at a larger selection of electrode sites. Across both groups, ERPs evoked by targets and nontargets are more positive than those evoked by new items from approximately 300ms post-stimulus. These differences are maximal at left parietal sites around 500-800ms post-stimulus. In the low accuracy group, ERPs associated with targets have larger old/new effects than nontargets from approximately 300-800ms, most prominently at frontal midline sites (Fz). Target ERPs are relatively more positive-going than nontarget ERPs across both groups at left parietal sites from 500-800ms post-stimulus. From approximately 800-900ms onwards, nontargets and targets are relatively more negative-going than new items at central and posterior midline locations, continuing until the end of the epoch. This trend occurs earlier (around 700ms post-stimulus) and to a greater extent for nontargets in the low accuracy group.

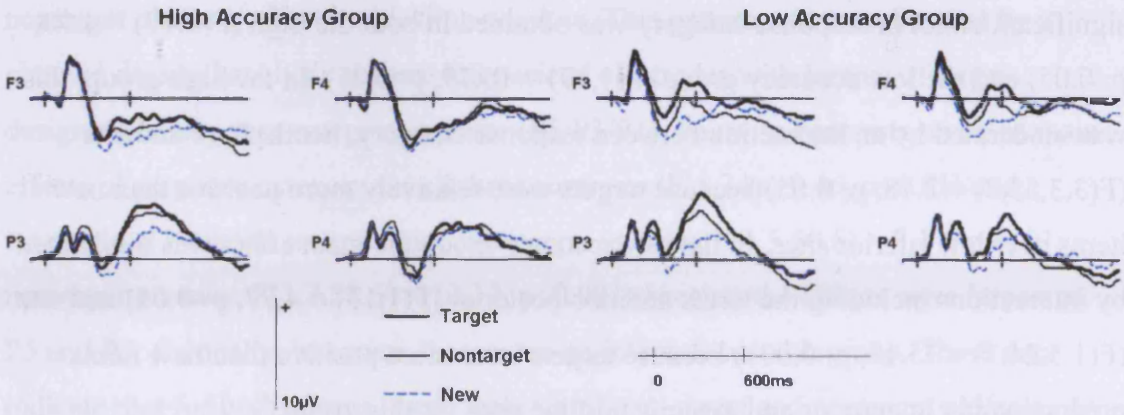

Figure 5.11: Grand average ERPs elicited by targets, nontargets and new items for the high and low accuracy groups. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

Analyses were conducted in the same four time-windows (300-500, 500-800, 800-1100 and 1100-1400ms) and at the same electrode sites used for the new and old item contrasts. ANOVAs included factors of accuracy group (high/low), response category (target/nontarget/new), anterior-posterior dimension (anterior/posterior), hemisphere (left/right) and site (inferior/mid-lateral/superior/midline/pre-superior). At the end of the chapter, Table 5.7 displays the significant results from this global analysis for all four epochs. Subsequent to interactions involving the factor of response category in the global ANOVA, all possible pairwise comparisons for levels of response category were conducted in each time window (targets/new, nontargets/new and targets/nontargets). For the sake of brevity and because they are of chief interest here, the outcomes of pairwise comparisons are reported only if they include an interaction with the factor of group, and where these occur, within-group follow-up analyses were conducted. In addition, for the sake of simplicity, only the highest order reliable interactions with the factor of response category are reported. Complete outputs for each of the paired contrasts can be found in Appendix B. Figure 5.14 (end of chapter) shows the corresponding scalp topographies of both the target and nontarget old/new effects.

300-500ms

Pairwise comparisons were conducted following the main effect of response category as well as moderating interaction terms in the global ANOVA for this time window (see Table 5.7). For the target/new contrast, a group by response category by site interaction ($F(1,34) = 5.60$, $p<0.05$) led to subsequent within-group analyses. A significant effect of response category was obtained in both the high ($F(1,17) = 4.90$, $p<0.05$) and the low accuracy group ($F(1,17) = 16.79$, $p<0.05$). In the high group, this was moderated by an interaction between response category, hemisphere and site ($F(3.3,55.7) = 2.78$, $p<0.05$) because targets were relatively more positive than new items over left inferior sites. In the low accuracy group the main effect was moderated by interactions including the terms anterior-posterior ($F(1,17) = 4.77$, $p<0.05$) and site ($F(1.5,24.7) = 15.19$, $p<0.001$) because targets were more positive than new items predominantly at anterior and towards midline sites for this group.

The outcomes of the target/nontarget contrast included group by response category ($F(1,34) = 8.95$, $p<0.01$) and group by response category by site interactions ($F(2.3,78.4) = 6.68$, $p<0.01$). Follow-up comparisons within each group revealed interactions only in the low accuracy group; a main effect of response category ($F(1,17) = 5.82$, $p<0.05$), and interactions between response category and hemisphere ($F(1,17) = 6.26$, $p<0.05$) and between response category and site ($F(2.3,39.8) = 5.62$, $p<0.01$), reflecting the fact that targets were more positive than nontargets, predominantly at left and midline sites. Combined, these statistical outcomes reflect a larger target old/new effect in the low accuracy group (compare electrode Fz in Figures 5.12 and 5.13).

500-800ms

Paired item contrasts in this time window revealed that both targets and nontargets differed significantly from new items (both $F(1,34) > 7.47$, $p<0.05$), and these main effects were moderated by four-way interactions between response category, anterior-posterior, hemisphere and site (both $F(1,34) > 4.18$, $p<0.01$), because the old/new effects were maximal at left posterior, mid-lateral sites (see P5), as well as at bilateral anterior and central midline sites to a lesser extent. There were no significant interactions including response category and group. A significant difference was observed between targets and nontargets ($F(1,34) =12.59$, $p<0.01$), because targets were reliably more positive-going than nontargets, but this effect was not moderated by factors of location or group.

The above analyses indicate that accuracy group did not moderate the size of the nontarget old/new effect in this time window. This pattern was corroborated by a planned directed analysis at three left parietal electrodes with factors of target designation, response category and site (P5/P3/P1). Pairwise contrasts revealed main effects of response category for all three contrasts ($F(1,34) >9.46$, $p<0.01$) and interactions between category and site (target vs. new, $F(1.5,50.6) = 8.11$, $p<0.01$; nontarget vs. new, $F(1.7,58.6) = 12.12$, $p<0.001$) because the effects were largest at P5 and P3. Critically, however, there were no interactions with group. These data indicate that for both groups, there were significant target and nontarget old/new effects and that the amplitude of the target ERPs were more positive than nontargets, but that accuracy group did not modulate this pattern.

It is possible that collapsing across target designations might mask differences in selective recollection for the two groups if selective recollection was also affected by the target designation. Comparison of the left parietal data separated for group and target designation, as presented in Figure 5.15 (below), suggests this might be the case. While in the low accuracy group targets appear greater than nontargets in both designations, this is not the case for the high accuracy group where targets are greater than nontargets only in the drawing target designation. Pairwise comparisons (target vs. new, nontarget vs. new, target vs. nontarget) at representative left parietal electrodes with factors of group, target designation, response category and site (P5/P3/P1) revealed an interaction between group, target designation and response category (F(1,34) = 5.07, p<0.05) for the target/new contrast only. Follow-up analyses within each group did not reveal reliable interactions with the factor of target designation, but the initial interaction indicates that the amplitude of the target old/new effect over this site was greatest in the drawing designation for the high accuracy group and in the function designation for the low accuracy group. There were no interactions including group and/or target designation for the nontarget/new or target/nontarget contrast. Despite this, separate comparisons of the two target designations for the high accuracy group showed that, whereas target and nontarget ERPs differed from one another in the drawing designation (F(1,17) = 13.21, p<0.01), this was not the case in the function designation, where the effect only approached significance (F(1,17) = 4.07, p=0.06).

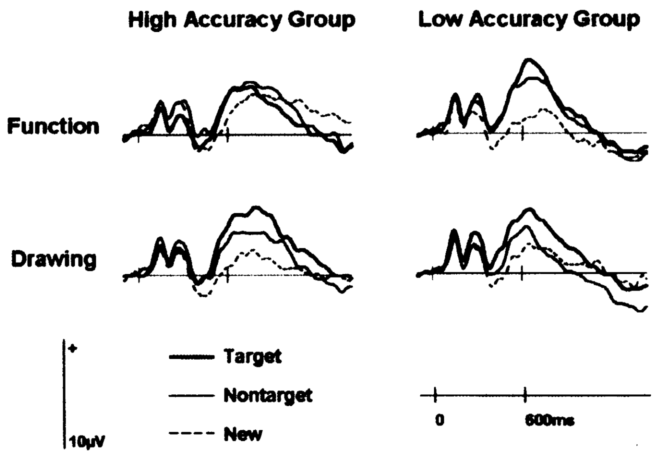

Figure 5.15: Grand average event-related potential waveforms elicited by targets, nontargets and new items in the two target designations and for both the high and low accuracy groups. Data are shown at a representative left parietal electrode, P3.

800-1100ms

In this time window, group interacted with response category in the nontarget/new contrast (group/response category/site; F(2.4,82.8) = 5.10, p<0.01), prompting within-group contrasts. In the high accuracy group, response category interacted with all three location factors (F(3,51.5) = 2.81, p<0.05) because nontargets were relatively more positive-going than new items both at left posterior sites and midline anterior sites. In the low accuracy group, response category interacted with all location factors (F(2.9,48.5) = 4.09, p<0.05) because nontargets were more negative-going than new items at right posterior sites (compare Figures 5.12 and 5.13).

1100-1400ms

The nontarget/new item contrast ($F(1,34) = 7.34$, $p<0.05$) again included an interaction between group, response category and site ($F(3,102.8) = 3.11$, $p<0.05$). In the high accuracy group, a main effect of response category ($F(1,17) = 4.57$, $p<0.05$) interacted with anterior-posterior, hemisphere and site ($F(3,50.2) = 3.16$, $p<0.05$). In the low accuracy group, response category interacted with site ($F(2.5,42.9) = 13.88$, $p<0.001$), anterior-posterior and hemisphere ($F(1,17) = 18.42$, $p<0.001$), anterior-posterior and site ($F(2.9,48.9) = 4.54$, $p<0.01$) and anterior-posterior, hemisphere and site ($F(2.8,48.9) = 3.41$, $p<0.05$). For both groups, nontargets were more negative than new items predominantly at right posterior sites, an effect that was larger and less lateralised in the low accuracy group (compare Figures 5.12 and 5.13).

Analyses of Scalp Distributions

Two separate sets of analyses were conducted on scalp distributions. The first included analyses performed in order to determine whether the scalp distributions of the ERP effects shown in Figure 5.9 change with time. To this end, separate analyses of the ERP differences between those elicited by new items and those elicited by targets were conducted. These were restricted to data from the high response accuracy group, because only in this group were there reliable differences when the ERPs were separated according to target designation. The absence of robust within-group differences also explains why analyses of scalp distributions were not conducted for nontargets. The second group of analyses was on the scalp distributions for old/new effects that interacted with the factor of group. These were performed in order to determine whether between-group interactions occurred because the distributions differed qualitatively across groups or whether they differed in terms of the magnitudes of the effects.

Analyses of Scalp Distribution of Paired Contrasts over Time

The data submitted to analysis were the difference scores from which the Figure 5.9 maps were generated. These data points were first rescaled using the max-min method to avoid confounding effects which result from variable magnitudes over conditions of interest from effects which are due to differences between the shapes of distributions (McCarthy & Wood, 1985). The data were rescaled using all possible scalp sites before the twenty sites from the standard montage were entered into the

ANOVA. Separate ANOVAs were conducted so that adjacent epochs could be compared (500-800 vs. 800-1100 and 800-1100 vs. 1100-1400ms). The factors employed were epoch (2), anterior-posterior (2), hemisphere (2) and site (5).

For the new items contrast between the 500-800 and 800-1100ms epochs, interactions between epoch and hemisphere ($F(1,17) = 7.23$, $p<0.05$) and epoch, hemisphere and site ($F(2.1,34.1) = 4.14$, $p<0.05$) came about because the effect only became left lateralised from 800-1100ms. When the 800-1100 and 1100-1400ms epochs were contrasted, interactions between epoch, anterior-posterior and site ($F(2.2,37.2) = 4.35$, $p<0.05$) and epoch, anterior-posterior, hemisphere and site ($F(2.8,48) = 2.88$, $p<0.05$) arose because the effect extended over anterior scalp sites to a greater degree in the 800-1100ms time window. These data indicate that not entirely the same neural generators were engaged throughout the recording epoch for this contrast.

The analysis of the rescaled difference scores associated with targets revealed no significant effects involving epoch or factors of site. This is consistent with the view that the same neural generators (hence the same cognitive processes) were engaged in each epoch.

Analyses of Scalp Distribution between Groups

Rescaled data were submitted to ANOVAs from the three time windows in which reliable interactions with the factor of group had occurred for each pairwise comparison. Factors included accuracy group (2), anterior-posterior (2), hemisphere (2) and site (5). The contrasts consisted of the target minus new item subtraction data in the 300-500ms window and the nontarget minus new item subtraction data in the 800-1100ms and 1100-1400ms time windows. No significant interactions between group and site factors were found for any of the contrasts, providing no evidence that previously reported interactions were due to variations in the distributions of the effects across the scalp.

Discussion

Behaviour

Participants were split into two groups depending upon their ability to successfully discriminate between the two classes of old items in both exclusion tasks.

Performance on this discrimination measure did not vary between the two retrieval tasks. Individuals in the high accuracy group were significantly more likely to make a correct response to either class of old items than those in the low group, but did not differ in their proportion of correct responses to new items. Neither were there significant differences in overall reaction times between the two groups. Despite the trend for one of the tasks to be more difficult than the other, as suggested by numerical differences in target accuracy, differences between ERPs across tasks are unlikely to reflect variations in relative difficulty because these remained consistent across groups whereas ERP indices of strategic retrieval processing did not.

ERPs elicited by New Items

ERPs elicited by new test items attracting correct responses varied according to retrieval task, but only when how well participants were able to discriminate between targets and nontargets was taken into account: the magnitude of the differences between the two classes of new item ERPs was positively correlated with target/nontarget discrimination. If the size of the differences between these ERPs is a marker of the degree to which strategic retrieval processing differed across the tasks, then the data support the view that strategic retrieval processing influences the accuracy of memory judgments.

Robust differences between ERPs elicited by classes of new test items have been reported in several studies (Dzulkifli & Wilding, 2005; Herron & Rugg, 2003a; Hornberger, Morcom, & Rugg, 2004; Hornberger, Rugg, & Henson, 2006b; Robb & Rugg, 2002), but there are no published reports of the correspondence between these differences and the accuracy of memory judgments. In the absence of such a correspondence, one plausible explanation for the ERP differences that have been reported is that they index operations influencing the speed or efficiency with which retrieved information is processed. This account is challenged strongly by two aspects of the current findings. First, the ERPs elicited by new items (specifically, correct rejections) differed reliably only for the group with superior memory performance. Second, the magnitude of ERP differences from the scalp locations at which these differences were largest correlated positively with target/nontarget discrimination. This can be seen clearly in Figure 5.10, and in combination, these data points support the claim that the *degree* to which strategic retrieval operations are engaged is beneficial to task performance.

The findings in this experiment also offer several insights into the form that the strategic retrieval processing operations identified here might take, and one of these follows from the time course of the differences between the ERPs elicited by new test items. A common finding in other studies is that differences in contrasts between new item ERPs have an extended time course, with little evidence for changes in the distribution of these ERP effects over time (e.g. Ranganath & Paller, 1999; Dzulkifli & Wilding, 2005; Dzulkifli, Sharpe & Wilding, 2004; Hornberger, Morcom & Rugg, 2004). This was not the case here, however, where the scalp distributions of the differences between the ERPs elicited by the two classes of new items changed over three successive epochs. These findings suggest the engagement of not entirely the same neural generators over time. The scalp maps in the upper panel of Figure 5.9 do show that the left occipital maximum of the effect remained consistent over time, most clearly from 800-1400ms. It is likely that changes in the overall distribution over time came about because, while some processes were maintained, additional processes possibly recruited to serve initiating and monitoring roles came on and offline throughout the epoch. The likelihood that some of these processes have an extended time course is important, especially if they continue beyond the period in which successful episodic retrieval is typically considered to occur (Yonelinas, 2002). Data from response-deadline memory paradigms show that processes which support retrieval of contextual information become available within 900ms (Yonelinas & Jacoby, 1994). Likewise, the ERP correlate of successful episodic retrieval is pronounced between 500 and 800ms after the presentation of a retrieval cue (Allan, Wilding, & Rugg, 1998; Curran, 2000).

In light of this information about the time course of retrieval, Hornberger, Morcom & Rugg (2004) proposed that temporally extended ERP differences between new test items reflect the maintenance of internal representations of retrieval cues in service of recovery of task-relevant information for old items (for related comments, see Dzulkifli, Sharpe & Wilding, 2004). This account provides a possible interpretation of the data reported here, which in turn leads to the proposal that the differences between the new item ERPs in this experiment reflect the generation of internal representations that will bias retrieval towards content that is specific to the drawing and/or the function target designation tasks, respectively. This might reflect a bias towards recovery of imagery-related information in the drawing target designation, and an emphasis on the cognitive operations involved in accessing the semantic information necessary to make function judgments in the alternate target designation.

An alternative account is that the ERP new item effects index a difference solely in the degree to which the same set of processes are engaged. For example, these effects might be equally well interpreted as reflecting a greater relative emphasis on one kind of information in one task than in the other (cf. Rugg, Allan & Birch, 2000). It is not possible to adjudicate between these accounts on the basis of paired contrasts between new item ERPs alone. Data that encourages favouring the former account, however, comes from considering the functional implications of the outcomes of the contrasts between the ERPs that were elicited by the targets and the nontargets, as well as the analyses of left parietal old/new effects for each group.

ERPs elicited by Old Items

The magnitude of the differences between the ERPs elicited by targets also predicted target/nontarget discrimination, although the sites at which these effects were evident were not the same as those for the new item ERPs. There was not robust evidence, however, for comparable differences between the ERPs elicited by nontargets. These findings suggest that higher performing participants were prioritising source information associated with targets over information associated with nontargets, and therefore suggest that the differences between the new item ERPs index operations that were engaged specifically to encourage the retrieval of different contents in the tasks where either words from the function or the drawing encoding conditions were designated as targets. Moreover, if these processes are terminated once retrieval has occurred, this explains the absence of comparable posteriorly distributed differences between the ERPs elicited by targets and by nontargets to those obtained in the contrasts between the new item ERPs.

As with all ERP data, interpretations derived from the lack of statistical differences between two classes of ERPs are restricted because of the modality's limited sensitivity to certain neural populations. Subsequently, care must be taken in interpreting the absence of robust differences between the two classes of ERPs associated with nontargets, but the pattern of data does encourage the view that the retrieval processing operations these items were subject to were broadly similar. This would make sense if differences between the ERPs elicited by targets are assumed to reflect processes that operate on task-relevant products of retrieval, and if processing of nontargets is associated with little or no information of this kind.

The engagement of processes that operate upon task-relevant information is not inconsistent with the anterior distribution of some of the differences between the ERPs elicited by targets. This pattern is reminiscent of the distribution of the right-frontal ERP old/new effect, which comprises a greater relative positivity for ERPs elicited by test items attracting correct source judgments than for ERPs associated with items that attract correct new judgments (Friedman & Johnson, 2000). This ERP effect has been linked to monitoring of task-relevant information in service of task goals (Rugg, Allan, & Birch, 2000), it has been shown to vary in magnitude according to the content of the information that is recovered (Wilding, 1999), and it has a similar time course to the differences between the target ERPs that are reported here (see Chapter 2). These correspondences suggest that at least some of the differences between the target ERPs in this experiment reflect processes that are engaged in assessing task-relevant recovered information.

An alternative interpretation of the differences between the ERPs elicited by targets, however, is that they reflect content-specific retrieval: recovery of imagery-related information in one target designation, and information associated with cognitive operations involved in generating function decisions in the other. This account can explain the correlation between the magnitude of the target ERP difference and target/nontarget discrimination simply by assuming that the more task-relevant information that is recovered, the greater the likelihood of a correct response. It is not possible to determine comprehensively between these two accounts of the target ERP effects.

The Left Parietal Old/New Effect

In previous reports of ERPs acquired in exclusion tasks, the behaviour of the left parietal old/new effect has been used to infer the degree to which recollection of old items is prioritised for targets, following the observation that, under some circumstances, the effect is reliable only for ERPs elicited by targets in each designation (Herron & Rugg, 2003b; Wilding, Fraser & Herron, 2005; Dzulkifli & Wilding, 2005). This can be an effective strategy for correct responding in this task because, when the likelihood of retrieving targets is high, recollection of this information is sufficient for correct responding. In keeping with this account, Dzulkifli and colleagues reported that across two experiments, reliable nontarget parietal old/new effects occurred only in the more difficult task, when the likelihood of target retrieval was relatively low (Dzulkifli & Wilding, 2005; Dzulkifli et al., 2006). Moreover, differences between ERPs elicited by new items were significant only in the experiment in which target accuracy was relatively high and where there was no evidence of a left parietal old/new effect for nontargets. As a consequence, where reliable divergences between new item ERPs were observed they were interpreted as reflecting processes that enable the control of recollection for targets over nontargets.

The left parietal data in this experiment provide partial support for this functional interpretation of ERP new item effects, but only when the target and nontarget old/new effects were split according to target designation. For the low accuracy group, the left parietal effect was significant for both targets and nontargets but reliably greater in amplitude for targets than nontargets, a pattern that was consistent across both target designations. For the high accuracy group, however, the parietal amplitude was only significantly greater for targets than nontargets in the drawing target designation. For this same group, there was no evidence that targets and nontargets diverged from one another in the function task. This sensitivity to target designation is consistent with an interpretation that states participants in the high accuracy group changed their retrieval strategy according to the particular retrieval task.

The amplitude of the left parietal old/new effect has been shown to correlate with the amount of information that is recollected (Wilding, 2000; Vilberg & Rugg, 2009; Chapter 2). When considered in light of the greater amplitude of the parietal effect for targets in the drawing task, this suggests an increase in the relative amount of information that participants in this group recollected about the drawing task. This contrasts with the findings in the function designation where there was evidence of comparable levels of recollection about targets and nontargets for the high accuracy group. This interpretation of the parietal data might constrain the account of the functional significance of the ERP new item effects if these were engaged predominantly in the drawing designation to stress the recovery of this type of information.

Although this line of reasoning can encompass a number of data points, it was not the case that an increase in the amplitude of the left parietal effect in the drawing designation was related to an increase in accurate responding only in that particular test phase. Instead, high performers were generally more likely to make accurate responses in both target designations. It is difficult to argue how an increase in the recovery of drawing target information would relate to an increase in accuracy in the function designation, making it unlikely that engaging a strategy that stresses the recovery of drawing details in the drawing designation is related to increases in response accuracy in both test phases. The parietal old/new effects in this task do not preclude the possibility that participants in the high accuracy group engaged qualitatively distinct strategic retrieval processes in each target designation in line with the reliable contrasts between new items and targets from the two test phases. The left parietal data do indicate, however, that it is unlikely that differences between new item ERPs reflect processes that reduce the likelihood that nontargets are recollected because there was no evidence that recollection of nontargets was greater in the low accuracy group for which there were no reliable ERP new item effects. The critical observation is that reliable relationships between response accuracy and the amplitude of the paired contrasts for new and target (but not nontarget) items indicate that changing processing in accordance with the target designation was related to overall accuracy. The implications of this pattern are clarified further below.

Strategies for Completing Exclusion Tasks

Critically, the ERPs elicited by nontargets do not diverge from each other in the same way as they do for targets, providing evidence in support of the view that participants prioritised retrieval processing relevant to source information associated with targets. In combination with the findings for the new item ERPs, these data points provide insights into how participants complete exclusion tasks.

The principal difference across the two retrieval tasks was whether items encoded in the function or the drawing conditions were designated as targets. One way to complete this task is to rely equally on the recovery of information associated with targets as well as nontargets, and this might be regarded as an optimal strategy in so far as it involves taking both potentially relevant forms of source information into account to make target/nontarget discriminations (Wilding & Herron, 2006). The ERP data reported here suggest, however, that this strategy was not adopted by all participants.

Relying on the recovery of information about targets as well as nontargets equates to employing the same strategic retrieval operations irrespective of target designation, hence ERPs elicited by new items would not vary with target designation if this account was correct. In addition, when combined with the fact that the ERPs elicited by targets but not nontargets differed according to task demands, these findings are consistent with the view that participants who performed relatively better were prioritising source information associated with targets over information associated with nontargets in order to complete the exclusion tasks. The outcomes from the analyses of paired contrasts between new items and targets converge with previous observations that the binary test distinction in an exclusion task can be made by prioritising information associated with targets, essentially reducing judgments for old items to a decision about whether there is sufficient target relevant source information available to make a target response (Herron & Rugg, 2003b; Dzulkifli & Wilding, 2005).

ERP Old/New Effects

The amplitude of two additional ERP old/new effects varied across accuracy groups. Although not related directly to the experiment rationale, it is important to catalogue these differences because of the insight this paradigm provides into the relationship between old/new effects and memory accuracy from within a single experiment. These variations took the form of relative changes in the size of old/new effects and not qualitative differences in the scalp distributions of effects. The following speculations are based upon reports from experiments in which specific behavioural manipulations have been made to determine the sensitivity of individual ERP old/new effects in order to constrain accounts of the functional significance of the effects.

In the early (300-500ms) time window, the amplitude of the anterior target old/new was reliably larger than the nontarget old/new effect in the low accuracy group. This early old/new effect has been associated with familiarity on the basis of findings in a number of memory paradigms (Curran, 2000; Yonelinas, 2002; see Chapter 2). Why should an index of familiarity be larger for targets than for nontargets only for people who performed less well on the task? One possibility is that the differences across group relate to the placement of criteria. The early mid frontal old/new has been shown to index familiarity in a graded fashion (Woodruff, Hayama & Rugg, 2006) as well as to be sensitive to the placement of criteria (Azimian-Faridani & Wilding, 2006). With this in mind, adopting a bias towards judging only items with relatively higher familiarity as 'targets' would lead to an increase in the amplitude of this old/new effect relative to that shown for nontargets. It is difficult to estimate criterion measures in the exclusion task (Bridson, Fraser, Herron & Wilding, 2006), and accordingly no behavioural indicators can be used to examine this account. A strategy that uses the relative familiarity of old items to make judgments is sub-optimal for exclusion task performance, however, because the paradigm is designed such that all old items should be associated with comparable familiarity (Jacoby, 1991).

The second old/new effect that varied in size across the two groups was the late posterior negativity (LPN) for nontargets. This negativity for nontargets onset earlier and was greater in the low accuracy group. The LPN is a robust effect onsetting around the time at which a response is made and which has been reported in a number of ERP studies of recognition memory (e.g. Johansson & Mecklinger, 2003; Herron, 2007). Understanding of what the effect most likely reflects is still incomplete, but it is not thought to be directly related to recollection because it occurs after the left parietal old/new effect and has been shown to be insensitive to the success or failure of source retrieval (Friedman, Cycowicz & Bersick, 2005). In their review of the experimental conditions under which the LPN was elicited, Johansson and Mecklinger (2003) observed that it occurred predominantly in two types of design; during tasks that require source-specifying contextual information to be bound in memory and in item recognition memory tests that engender a relatively high level of response conflict and subsequent action monitoring. The increased LPN for nontargets in the low accuracy group observed here may reflect attempts to integrate source information after recollection in light of the failure to utilise pre-retrieval processes that stress the recovery of specific target information. This would be necessary if participants who perform less well recollect a similar amount of information to higher performers - as is suggested by the pattern of left parietal old/new effects - but if this information is less differentiated.

An alternative explanation for this effect takes into account the specificity of the enlarged LPN to nontargets and the observation that the effect has previously been shown to be larger for items that elicit a degree of response conflict (Johansson & Mecklinger, 2003). It is possible that some participants encountered a greater degree of response conflict following the requirement to respond 'new' to what are essentially old items. The current data cannot at present determine between these two accounts for the between-group differences in this time window.

Concluding Comments

To summarise, participants completed two retrieval tasks with different demands. The magnitudes of the differences between ERPs elicited by new items in the tasks were taken as an index of the degree of engagement of strategic retrieval processing operations, and the size of this index correlated positively with response accuracy on the tasks. These findings indicate for the first time that the engagement of strategic retrieval processing operations indexed by ERPs benefit the accuracy of memory judgments. Moreover, the nature of the task demands under which these results were obtained, in combination with the ways in which ERPs elicited by old and by new items differed, offer insights into how strategic retrieval processing is implemented and how selective recovery of task-relevant information might come about.

Table 5.3: Mean numbers of trials per participant and response category. Ranges in parentheses.

Response Category	Target Designation	Accuracy Group High	Low
New Items	Function	40 (25-47)	43 (25-48)
	Drawing	38 (25-47)	43 (34-52)
Nontargets	Function	36 (26-45)	37 (21-49)
	Drawing	36 (17-45)	38 (27-49)
Targets	Function	35 (19-47)	34 (25-47)
	Drawing	33 (16-53)	31 (18-39)

Table 5.4: Outcomes of global ANOVAs for comparisons between ERPs associated with each response category in each time window. Key: GP = accuracy group, TD = target designation, HM = hemisphere, AP = anterior-posterior, ST = site. Outcomes are shown only for those terms that included a reliable interaction involving TD in at least one time window. * = p<0.05, ** = p<0.01, *** = p<0.001.

	300-500	500-800	800-1100	1100-1400
New Items				
GP x TD	-	-	F(1,34) = 4.23 *	F(1,34) = 4.28 *
GP x TD x AP	-	-	-	F(1,34) = 5.49 *
GP x TD x HM	F(1,34) = 4.21 *	-	F(1,34) = 4.24 *	-
GP x TD x AP x HM	-	F(1,34) = 9.48 **	F(1,34) = 5.21 *	-
Nontargets				
GP x TD x AP x HM	F(1,34) = 4.50 *	-	-	-
Targets				
TD x HM	-	-	F(1,34) = 4.18 *	F(1,34) = 8.82 **
GP x TD x HM	-	-	-	F(1,34) = 4.63 *
GP x TD x AP x ST	-	F(4,136) = 5.50 **	F(4,136) = 4.44 **	F(4,136) = 4.36 **

Table 5.5: Values for Pearson's R relating ERP new item difference score amplitudes (function minus drawing) at left posterior sites (O1, P1, P3, P5, P7) with target/nontarget discrimination. All tests were two-tailed. * = p<0.05, ** = p<0.01, *** = p<0.001.

		Epoch		
	Site	500-800	800-1100	1100-1400
All Participants	O1	0.38 *	0.47 **	0.46 **
N=36	P1	-	-	-
	P3	-	0.39 *	0.38 *
	P5	0.33 *	0.44 **	0.49 **
	P7	-	0.44 **	0.43 **
Outliers removed	O1	-	0.48 **	0.52 **
N=34	P1	-	0.43 *	0.45 **
	P3	-	0.47 **	0.47 **
	P5	-	0.47 **	0.52 **
	P7	-	0.38 *	0.37 *

Table 5.6: Values for Pearson's R relating ERP target difference score amplitudes (function minus drawing) at right frontal and parietal sites (FP2, F2, F4, F6, F8, P1, P3) with target/nontarget discrimination. All tests were two-tailed. * = p<0.05, ** = p<0.01, *** = p<0.001.

		Epoch		
	Site	500-800	800-1100	1100-1400
All Participants	FP2	-	-0.40 *	-
N=36	F2	-0.35 *	-0.42 *	-0.33 *
	F4	-	-0.36 *	-
	F6	-	-0.37 *	-0.35 *
	F8	-	-0.39 *	-0.37 *
	P1	-0.39 *	-0.54 **	-0.35 *
	P3	-	-0.45 **	-
Outliers removed	FP2	-0.44 **	-0.44 **	-0.35 *
N=34	F2	-0.39 *	-	-
	F4	-	-	-
	F6	-	-	-
	F8	-0.42 *	-0.37 *	-
	P1	-	-	-
	P3	-	-	-

Table 5.7: Outcomes of global ANOVA for old/new effects in each time window. Key: GP = accuracy group, RC = response category, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom in brackets.

	300-500	500-800	800-1100	1100-1400
RC	F(1.9,63.5) = 14.05 ***	F(1.9,65.2) = 17.65 ***	-	F(2,67.7) = 4.08 *
GP x RC	F(1.9,63.5) = 4.24 *	-	-	-
RC x AP	F(1.9,65.4) = 3.57 *	-	-	F(1.9,66.1) = 4.21 *
RC x HM	F(2.0,67.6) = 4.06 *	F(1.9,63.3) = 14.45 ***	F(2,67) = 3.86 *	-
RC x ST	F(3.6,123) = 6.39 ***	F(3.6,120.7) = 4.97 **	-	F(4.5,152.4) = 4.64 **
GP x RC x ST	F(3.6,123) = 3.98 **	-	-	-
RC x AP x HM	-	-	F(1.8,59.7) = 6.78 **	F(1.9,64.8) = 20.0 ***
RC x AP x ST	-	-	F(3.6,123.2) = 9.07 ***	F(4.1,139) = 5.07 **
RC x HM x ST	F(6.3,214.9) = 2.55 *	-	F(5.6,191.6) = 2.74 *	-
RC x AP x HM x ST	-	F(5.5,187.5) = 3.60 **	F(5.2,177.6) = 3.15 **	F(5.6,188.8) = 2.86 *

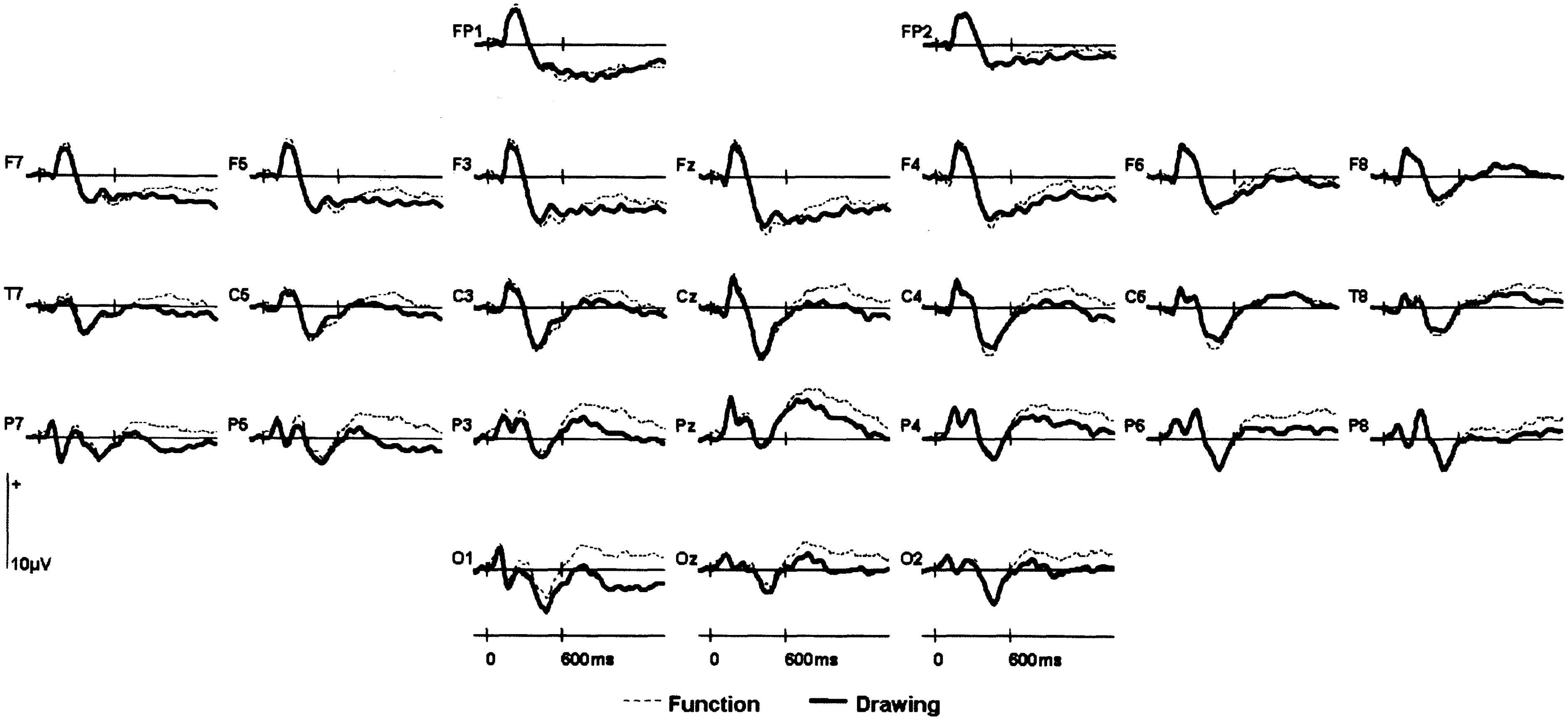

Figure 5.2: Grand average ERPs elicited by new items in the two target designation conditions for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

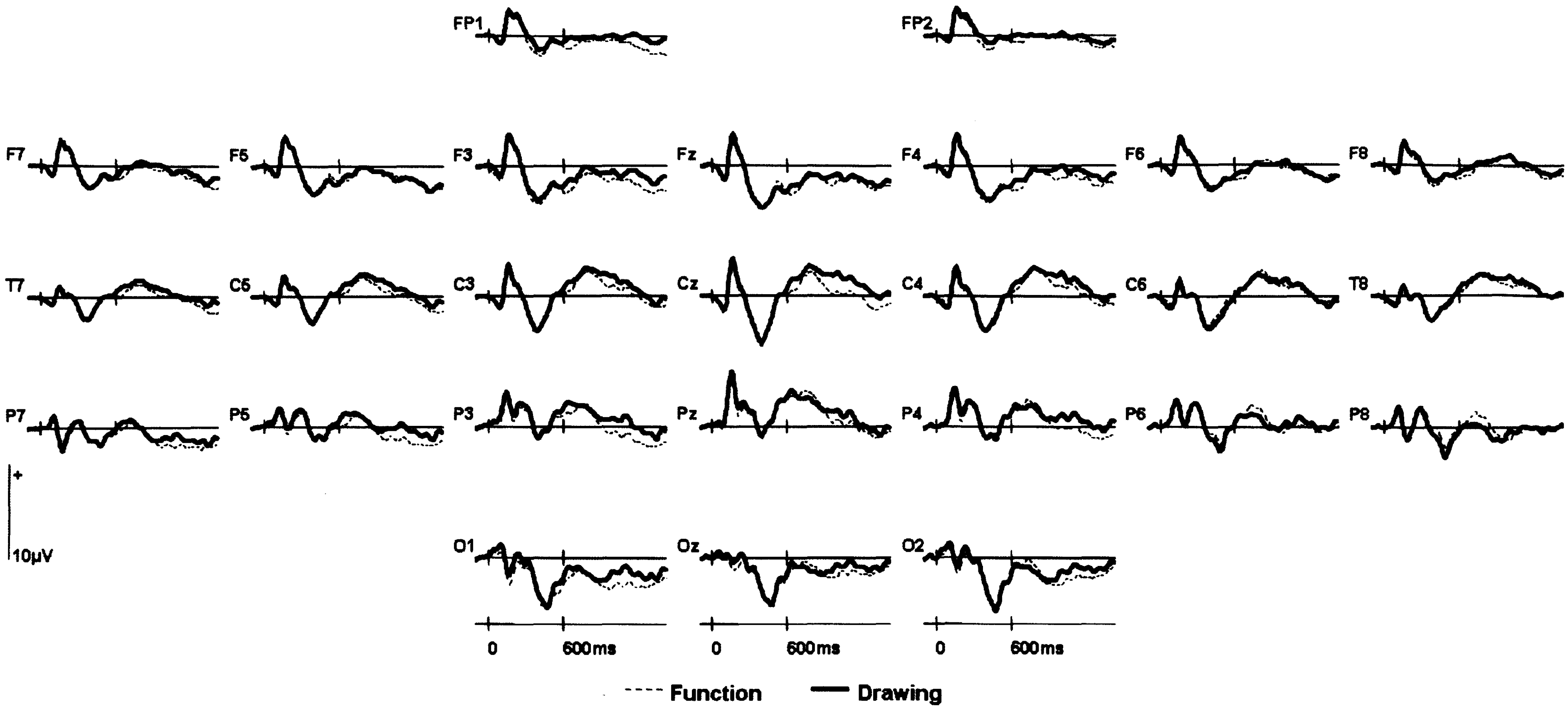

Figure 5.3: Grand average ERPs elicited by new items in the two target designation conditions for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

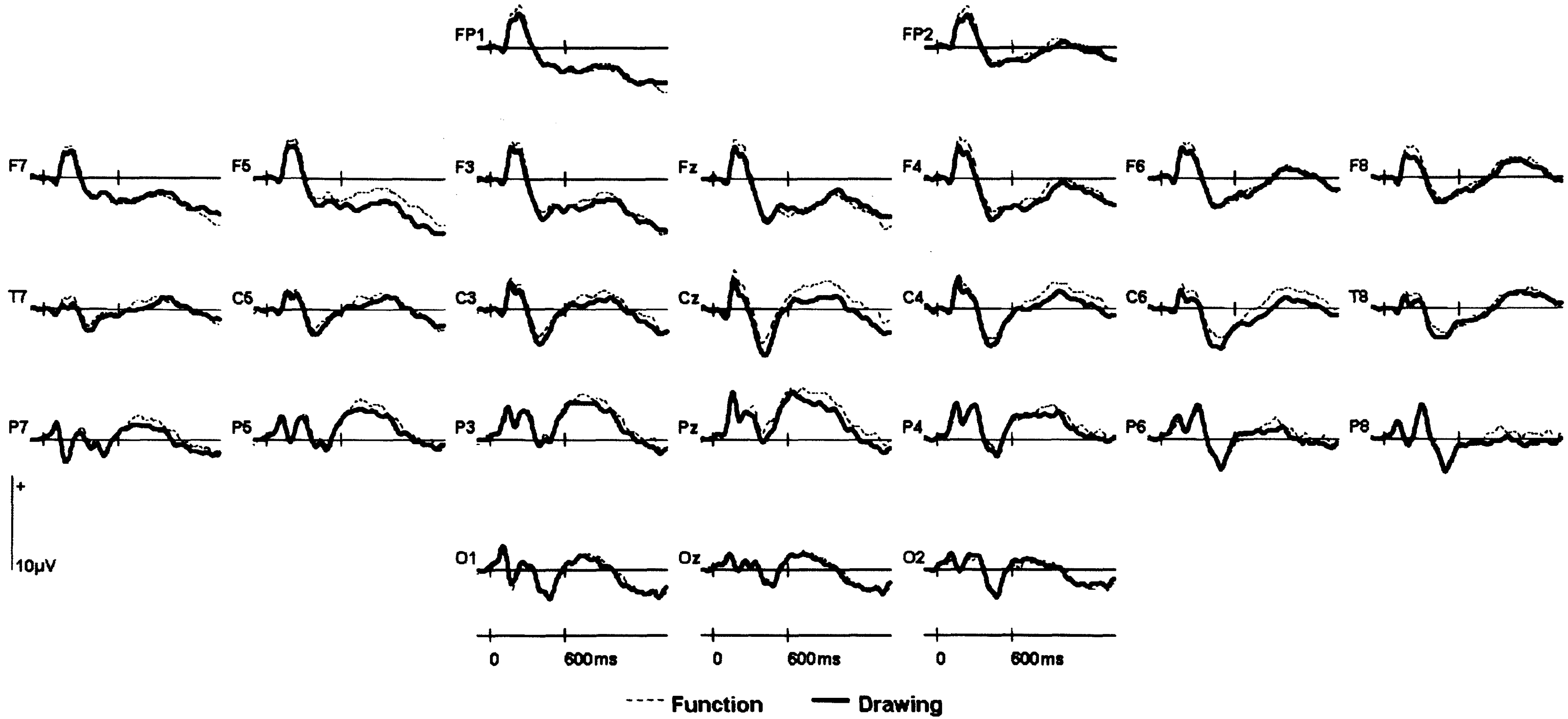

Figure 5.4: Grand average ERPs elicited by nontargets in the two target designation conditions for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

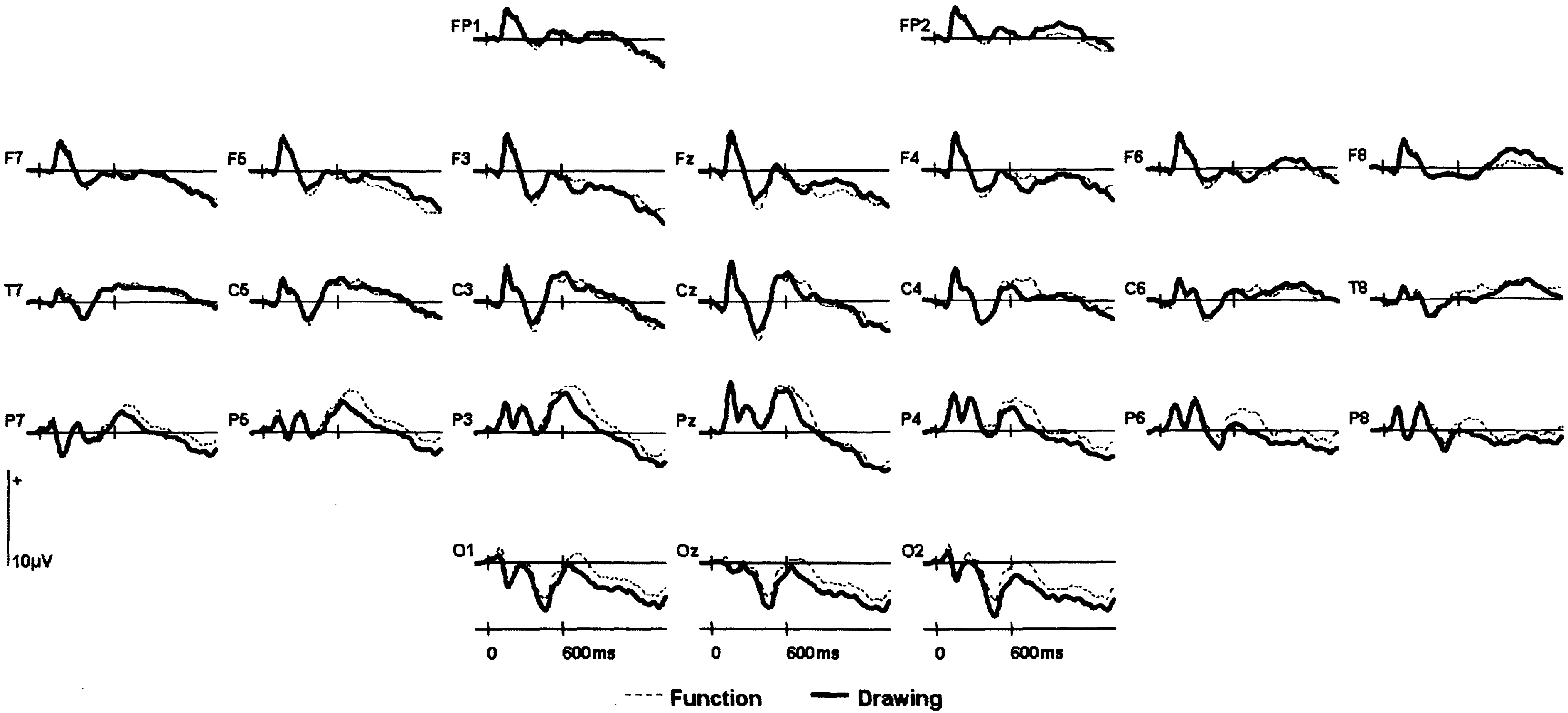

Figure 5.5: Grand average ERPs elicited by nontargets in the two target designation conditions for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

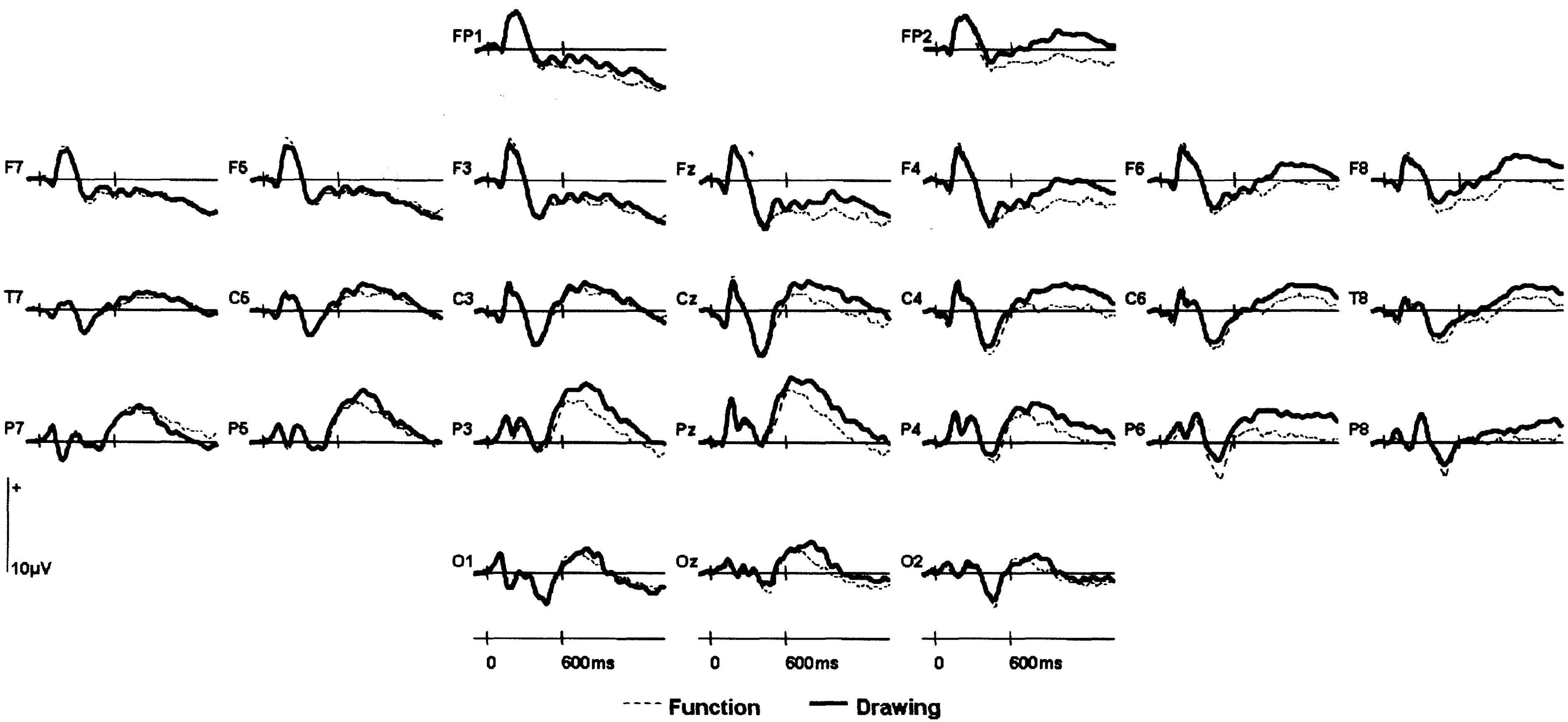

Figure 5.7: Grand average ERPs elicited by targets in the two target designation conditions for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

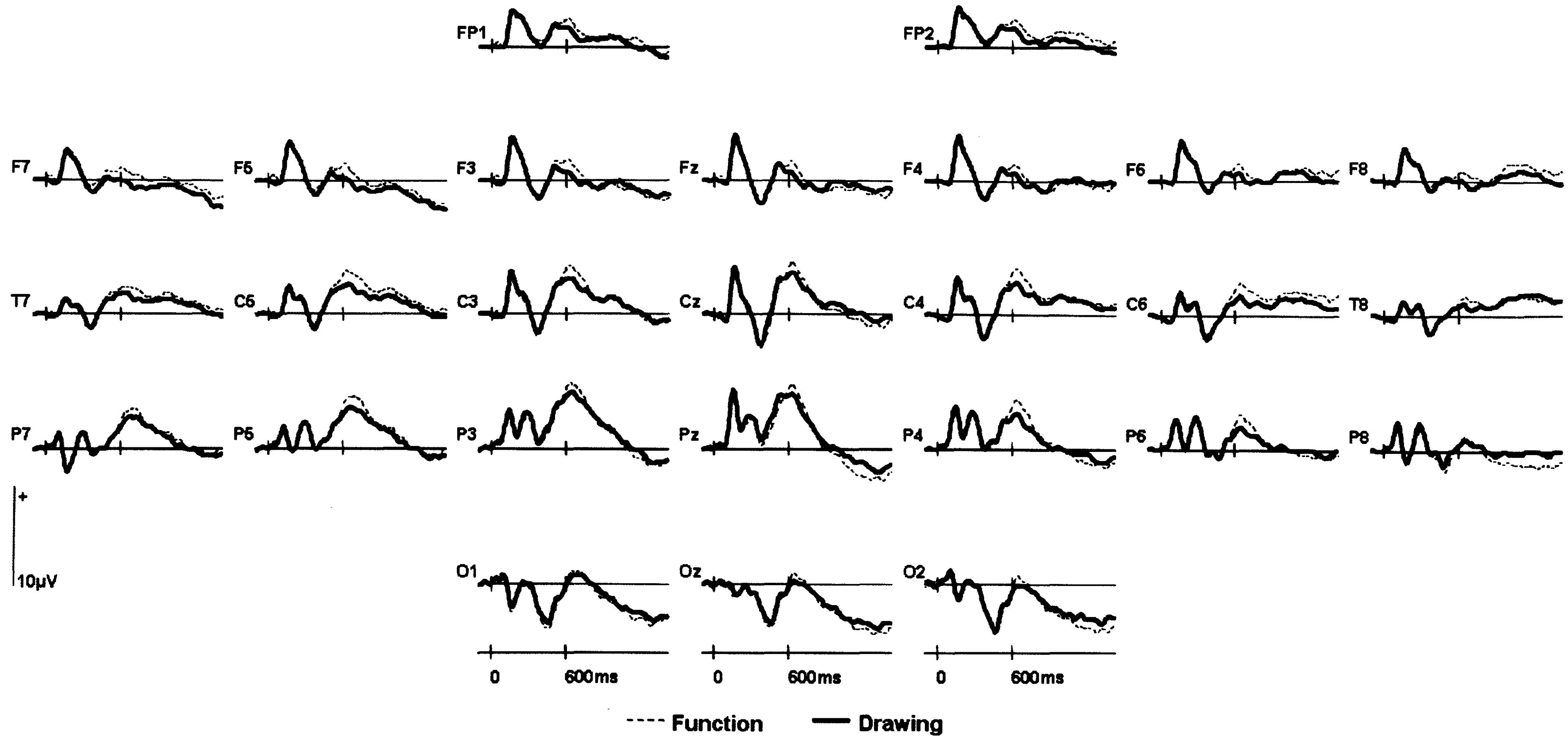

Figure 5.8: Grand average ERPs elicited by targets in the two target designation conditions for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

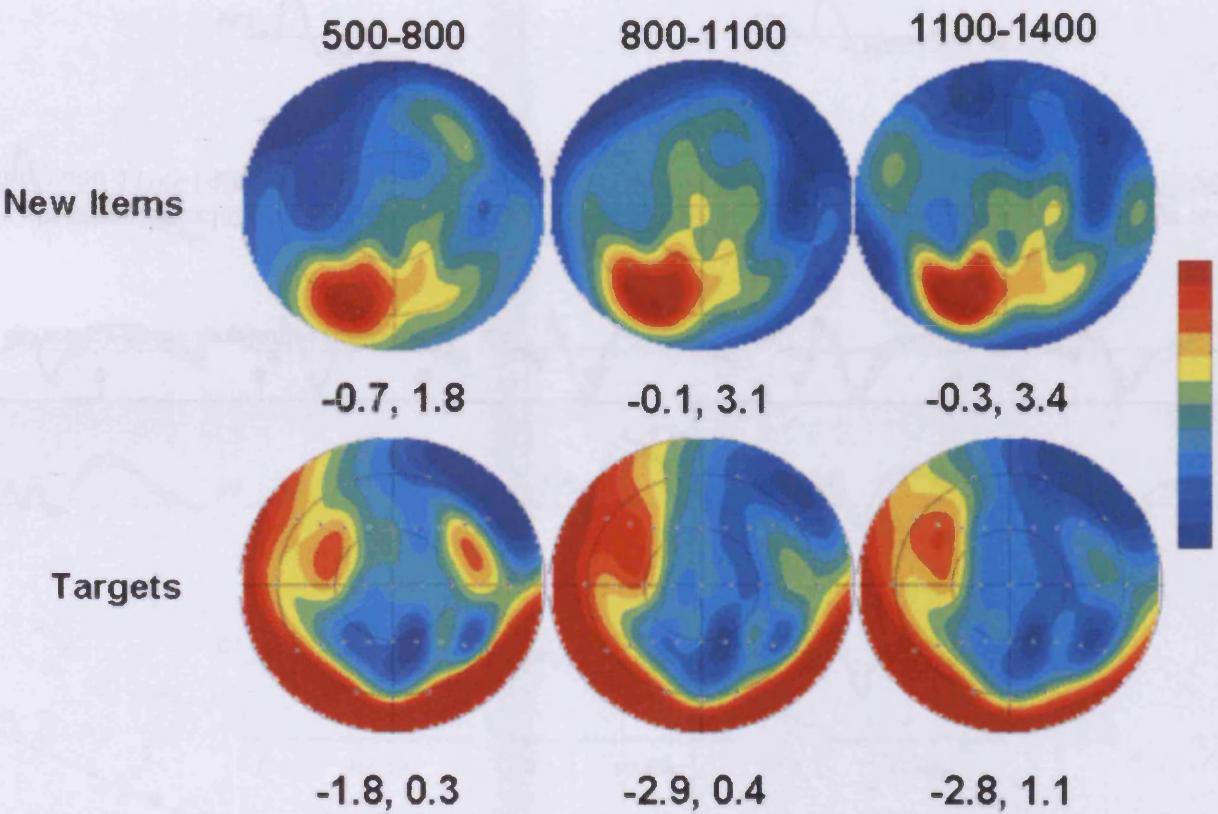

Figure 5.9: Upper panel: Topographic maps showing the scalp distributions of the differences between neural activity elicited by new test words for the high accuracy group. Lower panel: Topographic maps showing the scalp distributions of the differences between neural activity elicited by targets for the high group. Maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by items words in the drawing target designation from those in the function designation, and are shown for the 500-800, 800-1100 and 1100-1400ms time windows. Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

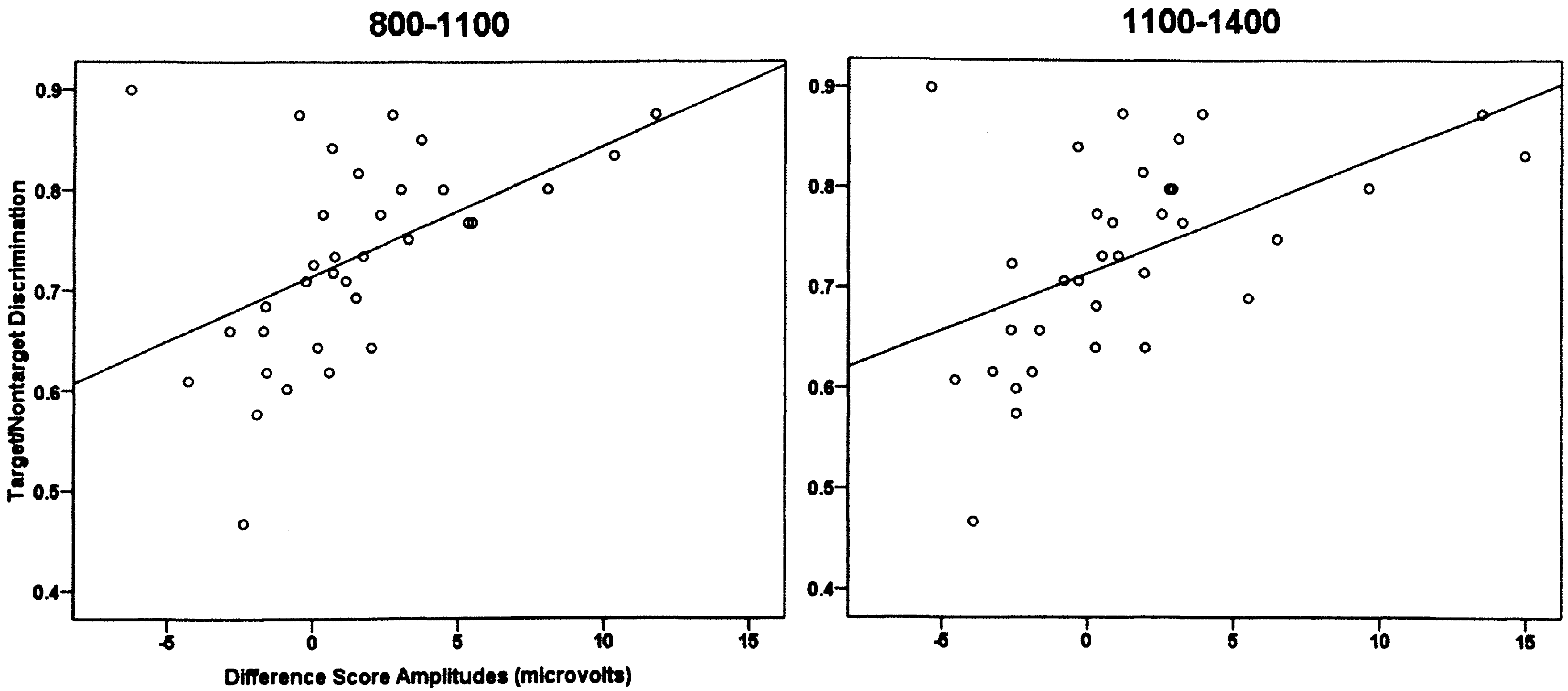

Figure 5.10: Scatterplots showing the relationship between target/non-target discrimination and new item difference score amplitudes at O1 in the 800-1100ms (left figure) and 1100-1400ms (right figure) epochs for 34 participants (two outliers removed because of poor discrimination, see Table 5.5).

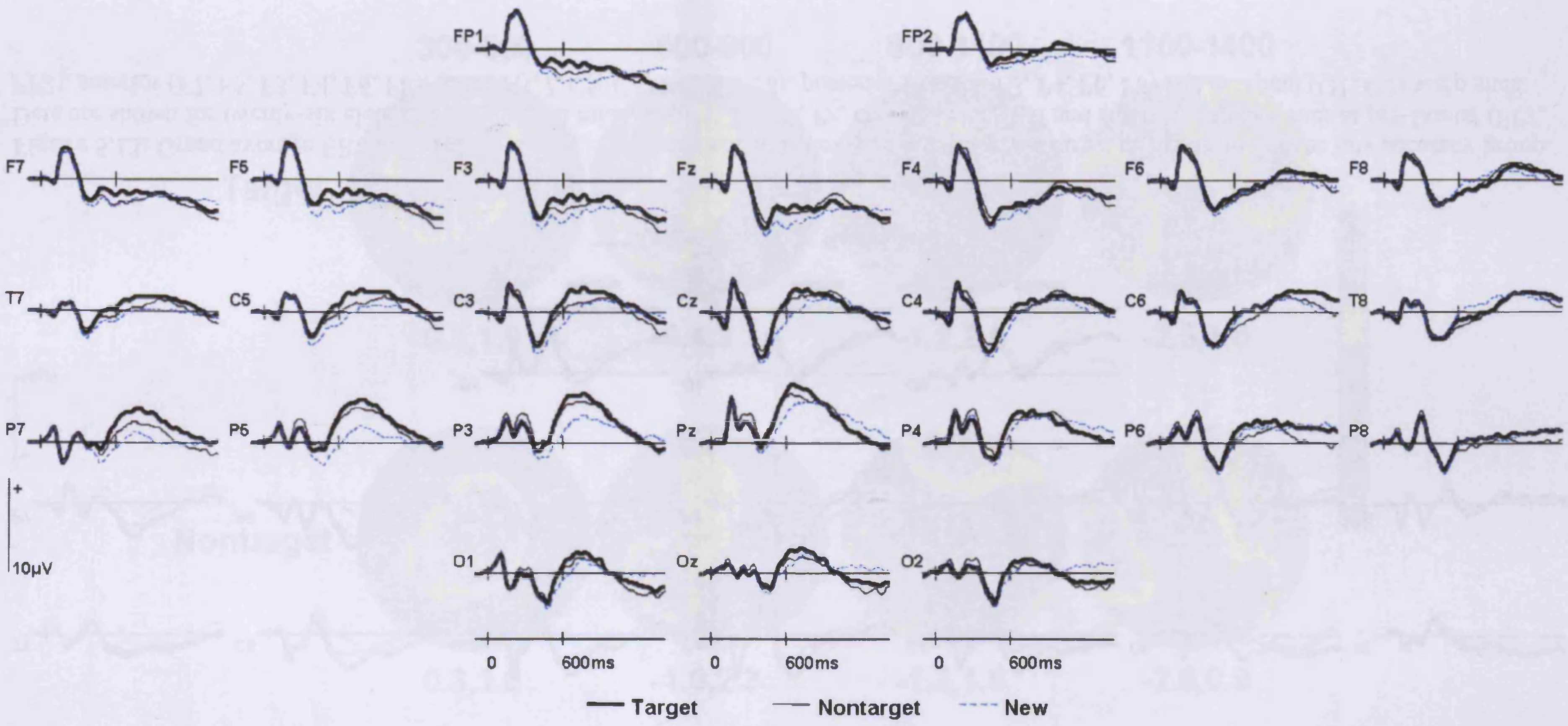

Figure 5.12: Grand average ERPs elicited by targets, nontargets and new items collapsed across target designation, for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

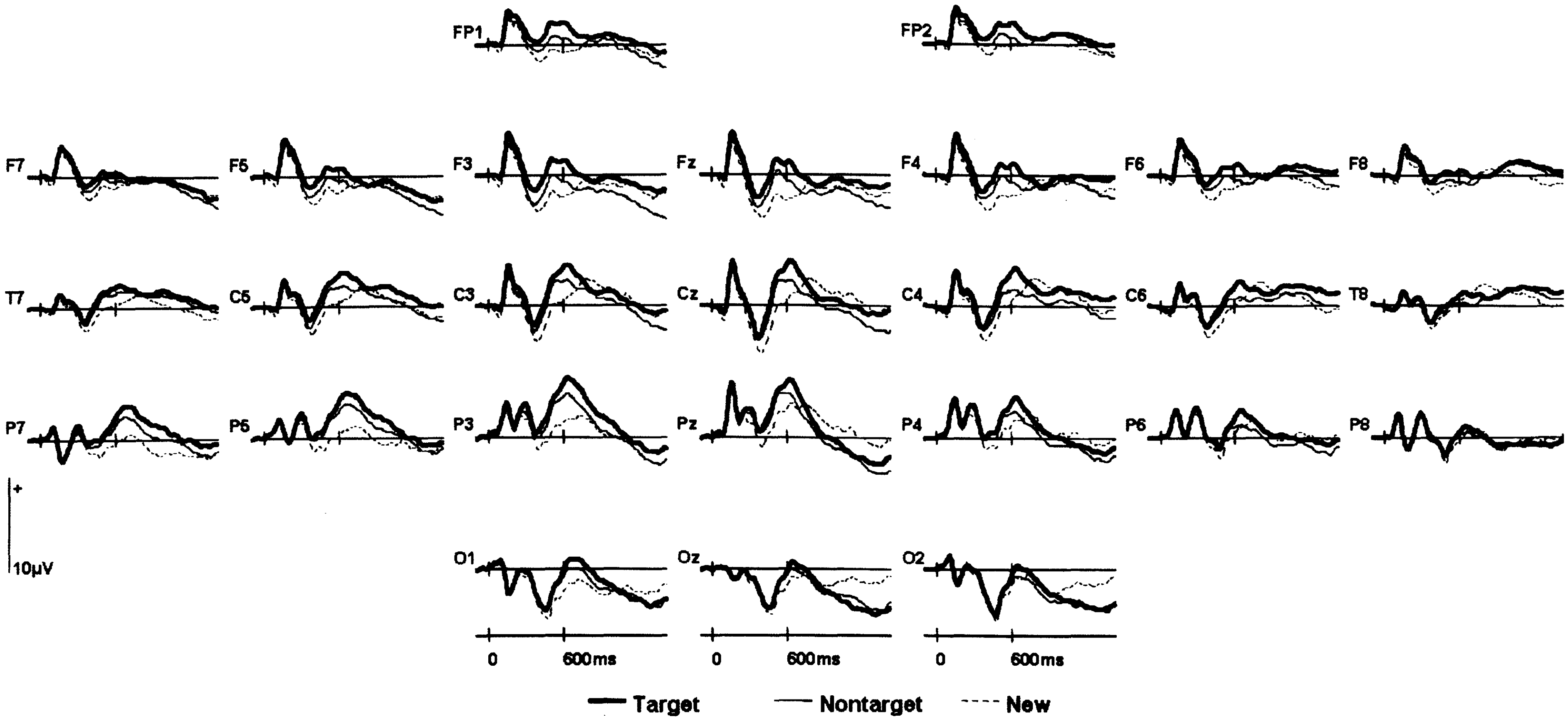

Figure 5.13: Grand average ERPs elicited by targets, nontargets and new items collapsed across target designation, for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

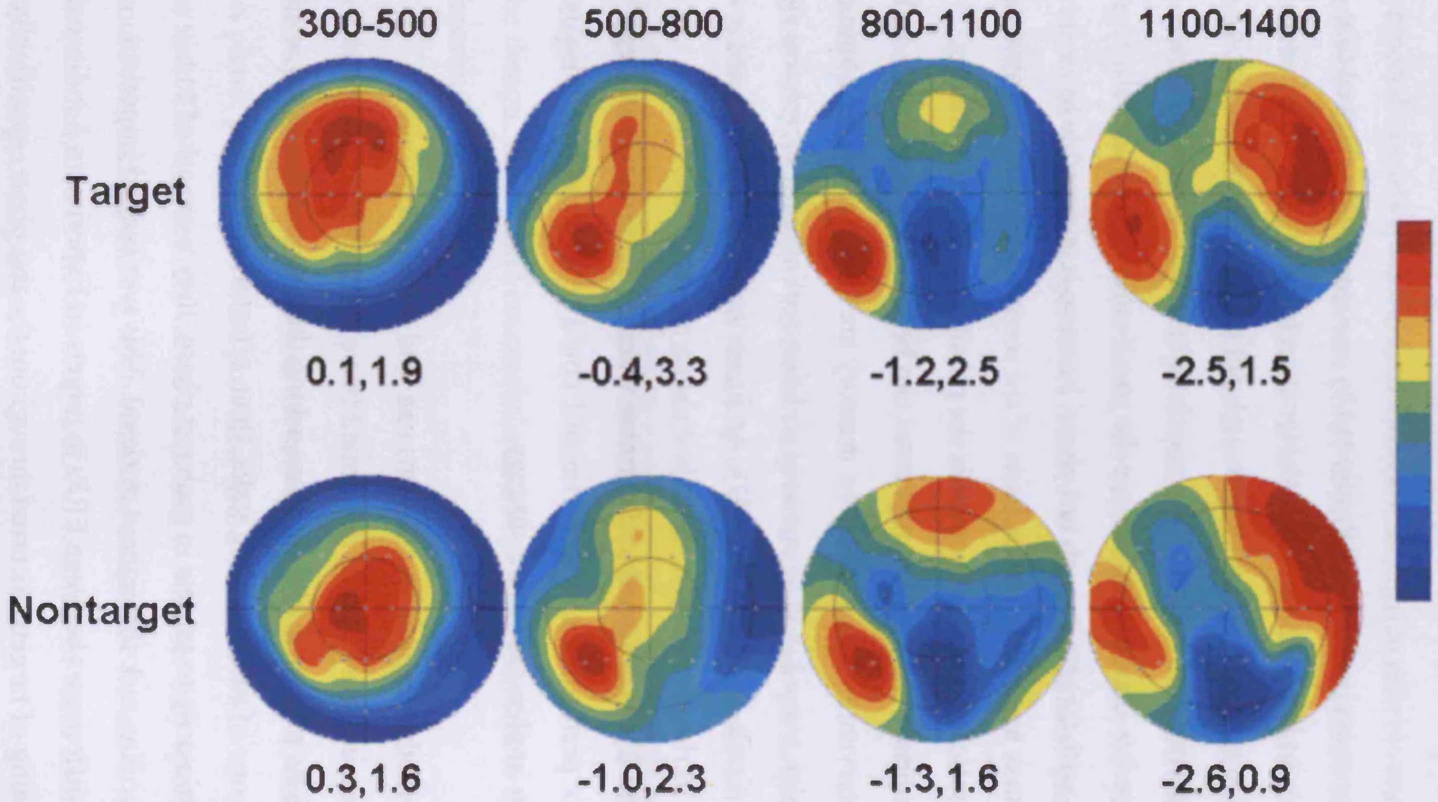

Figure 5.14: Topographic maps showing the scalp distributions of the old/new effects for targets and nontargets collapsed across target designation and accuracy group. Maps are shown for the four epochs used in all analyses (300-500, 500-800, 800-1100, 1100-1400ms). Voltage maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by items words from those for targets and nontargets. Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

Chapter 6

Experiment 2: Further Investigation of Strategic Retrieval Processing in an Exclusion Task

Introduction

In Experiment 1, the contrasts between ERPs elicited by new test items showed that processing retrieval cues in line with the target designation in each of two exclusion tasks related positively to response accuracy, although not all participants engaged strategic retrieval processing of this kind. The operations indexed by these new item contrasts were interpreted as ones that encourage the recollection of contextual information associated with targets in each test phase, because it is possible to perform the exclusion task accurately on the basis of the recovery of this information alone. One practical implication of this account is the possibility that encouraging people to employ appropriate pre-retrieval processes can benefit the accuracy of memory judgments. Interventions that can assist memory are important in the context of healthy aging, in which some kinds of memory abilities decline with increasing age (Burke & Light, 1981; Craik & McDowd, 1987). An important step in this regard is a demonstration that the retrieval strategies described above can be employed deliberately. Experiment 2 was designed to determine whether the retrieval strategy associated with superior performance in Experiment 1 could be adopted by explicitly directing participants to implement such a strategy.

In order to determine whether explicit instructions can lead to the adoption of strategic retrieval processing, participants performed two exclusion tests and were provided with instructions prior to each test phase asking them to endorse items as old only if they were from one of two encoding tasks. In an effort to encourage participants to attend primarily to targets in each test phase, they were asked to mentally repeat the encoding task throughout retrieval. This was judged important because the pattern of differences between ERPs to targets in Experiment 1 indicated that differential processing of targets occurred throughout the test phase, specifically beyond the time at which recollection occurred. The size of this effect was also related to overall performance. Both the behavioural and electrical data were contrasted with the comparable indices in Experiment 1 in which no explicit instructions about retrieval strategies were provided.

If processing retrieval cues specifically in line with targets is a flexible strategy that can be promoted by directing participants to rely upon the recovery of targets only, this should be revealed by an increase in the overall accuracy of memory judgments compared to participants in Experiment 1, alongside reliable divergences between new item ERPs from each test phase in Experiment 2. Differences between ERPs elicited by targets should also be reliable and demonstrate a divergence similar to those shown for the target effects that were positively related to response accuracy in Experiment 1. In addition, if participants are successful in selectively recollecting target over nontarget information, the degree to which the left parietal old/new effect is attenuated for nontarget items relative to targets should be greater than in Experiment 1.

Method

Participants

These were 24 (6 male) students. Data from six female participants were excluded due to excessive EOG artefacts resulting in insufficient trials per condition. The mean age of the remaining participants was 21 years (range: 18-27).

Design

The design, stimuli and counterbalanced lists were identical to those used in Experiment 1.

Procedure

The experiment procedure was the same as in Experiment 1, except that prior to each test phase, participants were provided with written instructions as to how to complete the task. The instructions varied according to whether they specified that participants should respond depending upon either the success or failure to recover information from the function or the drawing task. An example of these instructions for the function target designation is:

"During this test phase you will be presented with both function and drawing words from the study phase and some new words. I would like you to complete this task by deciding whether each item was encountered in the function task at study. If you remember details associated with the function task for a given item, press button '1'. If you can't remember any details about the function task for a given item, press button '6'. It is important for us that you try to complete the task in this way, so please remind yourself regularly to focus only on whether you can remember information about the function task. To help you focus, try repeating the encoding task (function) in your head as each item appears on the screen."

For the alternate test phase, the same instructions were provided but responses were to be made on the basis of *drawing* rather than *function* information. Twelve participants received the function designation instructions first.

EEG was recorded with the parameters outlined in the General Methods section (Chapter 4).

Results

Behaviour

Table 6.1 presents the mean proportions of correct responses to target, nontarget and new words for the two target designations. Planned paired t-tests for both target designations revealed that target responses to targets were significantly more likely than target responses to nontargets or new items (for all comparisons: $t(17) > 14.86$, $p < 0.001$).

Table 6.1: Mean proportions of correct responses to targets, nontargets and new items separated according to target designation. Corresponding reaction times are also shown. Standard deviations in parentheses.

		Response Category		
Target Designation		Target	Nontarget	New
Function	*p(correct)*	0.81 (0.09)	0.92 (0.05)	0.96 (0.08)
	RT	1343 (299)	1386 (314)	1119 (266)
Drawing	*p(correct)*	0.76 (0.08)	0.90 (0.07)	0.96 (0.04)
	RT	1427 (319)	1383 (196)	1122 (295)

Analyses of task performance for all participants were performed on correct responses to each response category using repeated measures ANOVAs. An ANOVA with factors of response category (target/nontarget/new) and target designation (function/drawing) revealed main effects of response category ($F(2,34) = 51.51$, $p<0.001$) and target designation ($F(1,17) = 11.35$, $p<0.01$). This latter effect occurred because, although numerically small, the likelihood of a correct response to any category was reliably greater in the function than the drawing designation (0.90 vs. 0.87). Follow-up analysis of the response category effect comprised all possible paired comparisons of the likelihood of correct responses to targets, nontargets and new items collapsed across target designation, using Bonferroni corrected paired t-tests (corrected alpha level $p<0.017$). A correct response to a new item was significantly more likely than a correct response to either a target (0.96 vs. 0.79; $t(17) = -8.27$, $p<0.001$) or a nontarget (0.96 vs. 0.91; $t(17) = -5.70$, $p<0.001$). A correct response to a nontarget was also more likely than a correct response to a target (0.91 vs. 0.79; $t(17) = -6.08$, $p<0.001$).

Table 6.2 shows the proportion of correct responses to each response category along with associated reaction times for the two experiments. To examine whether the instruction manipulation affected memory accuracy across Experiments 1 and 2, the proportion of correct responses to each category for participants from both experiments were subjected to a mixed model ANOVA with factors of experiment group (1/2) and response category (target/nontarget/new). A main effect of response category was again reliable ($F(2,104) = 112.16$, $p<0.001$). Accurate responding did not differ significantly across experiment groups. A planned comparison of discrimination scores (target hit – nontarget false alarm) collapsed across target designation, also revealed no significant difference between the two groups.

Table 6.2: Mean proportions of correct responses to targets, nontargets and new items for Experiments 1 and 2, collapsed across target designation. Corresponding reaction times are also shown. Standard deviations in parentheses.

		Response Category		
Experiment		Target	Nontarget	New
Exp 1	*p(correct)*	0.81 (0.10)	0.89 (0.07)	0.97 (0.03)
	RT	1250 (258)	1299 (290)	1043 (217)
Exp 2	*p(correct)*	0.79 (0.07)	0.91 (0.05)	0.96 (0.05)
	RT	1385 (290)	1385 (238)	1121 (274)

Table 6.2 indicates that there was a trend for reaction times to be longer in Experiment 2 than Experiment 1 and these were contrasted across the two experiments to determine whether this pattern was reliable. Reaction times submitted to a mixed model ANOVA with factors of experiment (1/2), target designation (function/drawing) and response category (target/nontarget/new) revealed a main effect of response category only ($F(2,104) = 103.56$, $p<0.001$). Follow-up analyses (Bonferroni-corrected alpha level $p<0.017$) were limited to reaction times in Experiment 2 because of the lack of a reliable between-experiment effect and included all possible pairwise comparisons for reaction times to the three levels of category, collapsed across task. Correct responses to new items were significantly faster than correct responses to both targets (1121 vs. 1385; $t(17) = 7.37$, $p<0.001$) and nontargets (1121 vs. 1385; $t(17) = 9.39$, $p<0.001$). Reaction times to correct responses to targets and nontargets did not differ significantly from each other.

ERP Analyses

Analysis of Paired Contrasts across Target Designations

As in Experiment 1, the analysis strategy included paired contrasts for each response category (new items, nontargets and targets) between the two target designations. This was then followed by analysis of the old/new effects to allow for a comparison with the ERP old/new effects reported in Experiment 1. For each epoch and paired contrast, a global ANOVA was conducted with factors of target designation (function/drawing), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior). ANOVAs on ERP old/new effects were conducted in the same time windows and electrode locations with the same factors, except for target designation, which was replaced by response category (target/nontarget/new). The mean numbers of trials (ranges in parenthesis) for target hits, nontarget hits and correct rejections in the function target designation were 37 (26-54), 42 (29-54) and 43 (27-55) respectively. The corresponding values for these same categories in the drawing target designation were 35 (21-51), 40 (27-55) and 44 (25-56).

ERPs elicited by New Items

As shown in Figures 6.1 (below) and 6.2 (end of chapter), the grand average of ERPs evoked by new items indicates that there are minimal differences between the two waveforms across all locations and epochs. From 800ms post-stimulus, new items evoked by drawing items are relatively more positive-going than those evoked by function items, at midline sites and at the back of the head. Despite this, there were no significant effects including the factor of target designation in any of the epochs, providing no evidence of strategic retrieval processing in this experiment.

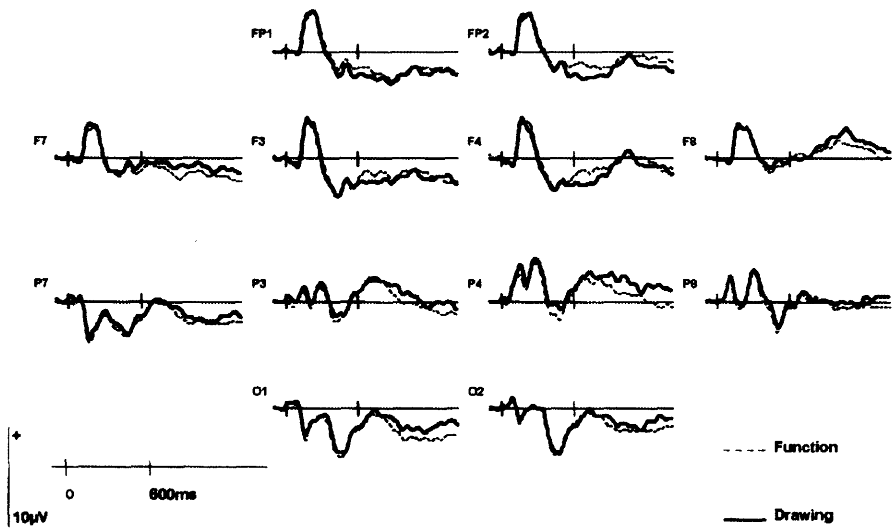

Figure 6.1: Grand average ERPs elicited by new items in the two target designation conditions. Data are shown for 12 electrode locations.

ERPs elicited by Old Items

Analysis of ERPs to old items from the two target designations are included in order to determine whether any differences map onto those observed in the higher performing group in Experiment 1. Figure 6.3 (end of chapter) depicts the grand average waveforms for nontargets in the two tasks, and shows that ERPs to nontargets in the function task are more positive-going than those from the drawing task, at midline anterior sites from 200-900ms. A reliable interaction term including the factor of target designation was found in the early 300-500ms time window only. Here, target designation interacted with anterior-posterior and hemisphere ($F(1,17) = 4.92$, $p<0.05$) because in this epoch nontargets in the function designation were more positive than those from the drawing designation across the head except at left posterior sites. No other interaction terms were significant in the remaining time windows.

Figure 6.4 (end of chapter) shows the comparable waveforms for targets in the two tasks. ERPs elicited by targets in the function designation are more positive-going than those in the drawing designation from 1000ms onwards at anterior sites as well as over the left hemisphere. In the 800-1100ms time window, target designation interacted with hemisphere ($F(1,17) = 5.25$, $p<0.05$) and anterior-posterior, hemisphere and site ($F(3.2,54.4) = 2.82$, $p<0.05$) because targets in the function designation were more positive at left hemisphere sites, especially at left inferior posterior locations whereas they were more negative-going at right posterior and left midline sites. An interaction between target designation and hemisphere ($F(1,17) =8.75$, $p<0.01$) in the final 1100-1400ms epoch occurred because this reversal of polarity for the two hemispheres continued until the end of the recording epoch. Figure 6.5 depicts the scalp distributions of the effect in these two time windows.

Analyses of ERP Old/New Effects

The grand average waveforms for ERPs associated with targets, nontargets and new items are shown below in Figure 6.6 (see also Figure 6.7 at end of the chapter). Examination of these waveforms indicates that both target and nontarget waveforms diverge from those evoked by new items at approximately 300ms, when they become relatively more positive-going than new item ERPs. This effect is most marked at frontal and prefrontal sites where the distribution remains constant throughout the recorded epoch. At central and posterior sites (see Cz, Pz,) at approximately 650ms, ERPs evoked by both classes of old item are more negative than ERPs evoked by new items (see Figure 6.7). From approximately 1100ms post-stimulus, targets are more positive-going than new item ERPs at right frontal and central sites. Nontarget ERPs diverge from target ERPs at certain electrodes (e.g. Oz, FP2) at points throughout the epoch, however, for the most part, the two classes of old item ERPs do not diverge from one another.

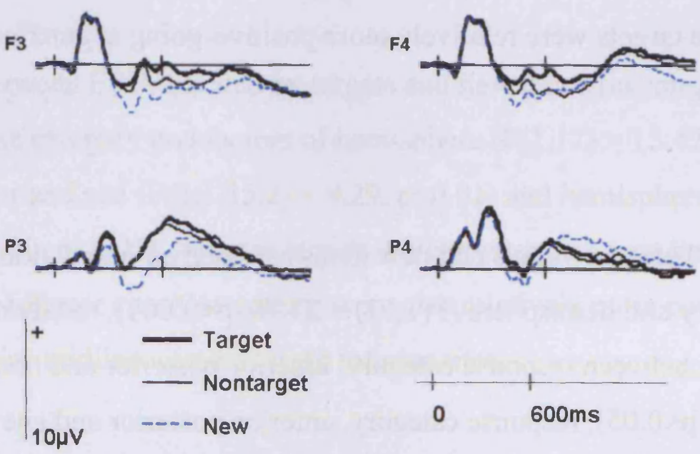

Figure 6.6: Grand average ERPs elicited by targets, nontargets and new items. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

ANOVAs with factors of experiment (1/2), response category (target/nontarget/new), anterior-posterior, hemisphere (left/right) and site (inferior/midlateral/superior/midline/pre-superior) in each time window revealed no reliable interactions between the two experiments. Subsequent analyses are therefore constrained to data from Experiment 2. Analyses are collapsed across target designation and Appendix C reports the outputs of the same analyses separated for each target designation which correspond broadly to the pattern reported below. Table 6.3 (end of chapter) shows the outcomes of the global ANOVA in each time window. Main effects of or interactions with the factor of response category in the global ANOVA occurred in every time window and were followed up by all possible pairwise comparisons between each level of response category in every epoch; target vs. new items, nontargets vs. new and targets vs. nontargets.

300-500ms

A main effect of response category ($F(1,17) = 10.04$, $p<0.01$) for the target/new contrast - because mean amplitudes for targets were more positive than for new items - was not moderated by interactions with location factors . Comparison between nontargets and new items revealed a main effect of response category ($F(1,17) = 19.05$, $p<0.001$) modified by response category/hemisphere ($F(1,17) = 8.87$, $p<0.01$) and response category/site ($F(2.2,37.5) = 6.96$, $p<0.001$) interactions. These reflect relatively more positive-going nontargets, a pattern that was greatest over the left hemisphere and towards midline and superior sites. Response category interacted with anterior-posterior and hemisphere ($F(1,17) = 4.91$, $p<0.05$) for the target/nontarget contrast, because targets were relatively more positive-going at anterior, right hemisphere sites.

500-800ms

The comparison between targets and new items revealed an interaction between response category and hemisphere ($F(1,17) = 23.70$, $p<0.001$), moderated by three-way interactions between response category, anterior-posterior and hemisphere ($F(1,17) = 7.82$, $p<0.05$), response category, anterior-posterior and site ($F(2.1,35.9) = 7.10$, $p<0.01$), and response category, hemisphere and site ($F(3.2,53.8) = 7.28$, $p<0.001$). These interactions indicate that targets were more positive than new items and that this difference was maximal at left hemisphere sites, extending to right anterior, superior sites.

Follow-up comparisons between nontargets and new items also revealed multiple interactions with factors of location. An interaction between response category and hemisphere ($F(1,17) = 14.59$, $p<0.01$) was moderated by interactions between response category, anterior-posterior and hemisphere ($F(2.8,47.2) = 4.20$, $p<0.01$) and response category, hemisphere and site ($F(3.2,55) = 4.91$, $p<0.01$), which occurred because the greater relative positivity of nontargets was largest at left superior, anterior sites. The target vs. nontarget comparison revealed an interaction between response category and anterior-posterior ($F(1,17) = 5.50$, $p<0.05$), because targets were more positive-going than nontargets at anterior sites only.

Specific analyses were conducted at three representative left parietal electrodes (P5/P3/P1). This was in order to fully examine any differences between target and nontarget ERPs in this time frame and at this location. Mean amplitudes from these electrode sites were subjected to an ANOVA with three levels of response category (target/nontarget/new) and three levels of site. The initial analysis revealed only a main effect of response category ($F(1.9,31.5) = 3.63$, $p<0.05$). Follow-up pairwise comparisons showed that while targets and nontargets differed significantly from new items (both $F(1,17) >4.82$, $p<0.05$), they did not differ significantly from one another ($F(1,17) <1$, $p=0.72$). Analyses on these same data separated according to target designation corroborated this pattern and did not differ with target designation.

800-1100ms

Comparisons between ERPs elicited by targets and new items revealed interactions between response category and factors of hemisphere ($F(1,17) = 15.47$, $p<0.01$), anterior-posterior and site ($F(2.1,35.2) = 9.29$, $p<0.01$) and hemisphere and site ($F(3.2,53.6) = 5.30$, $p<0.01$), because targets were greater than new items at anterior midline and left inferior sites. New items were also relatively more positive than targets at posterior midline sites and right inferior sites.

For nontargets and new items, the same interaction terms were reliable (response category/hemisphere, $F(1,17) = 12.12$, $p<0.01$; response category/anterior-posterior/site, $F(2.8,47) = 6.52$, $p<0.01$; response category/hemisphere/site, $F(3.2,54.9) = 3.30$, $p<0.05$) as well as an interaction between response category, anterior-posterior and hemisphere ($F(1,17) = 6.40$, $p<0.05$). These indicate that nontargets were more positive than new items at anterior midline and left inferior posterior sites. They also show that new items were more positive than nontargets over the right hemisphere principally at central and posterior, mid-lateral locations. There were no reliable interactions for the target/nontarget contrast.

1100-1400ms

For the target/new item comparison, response category interacted with anterior-posterior and hemisphere ($F(1,17) = 11.30$, $p<0.01$), as well as with anterior-posterior and site ($F(2.5,41.8) = 8.01$, $p<0.01$), because targets were greater than new items at right anterior, superior sites. New item ERPs, however, were more positive than those for targets at right superior, posterior sites. These same interactions were reliable for the nontarget/new item contrast (response category/anterior-posterior/hemisphere, $F(1,17) = 14.30$, $p<0.01$; response category/anterior-posterior/site ($F(3.2,53.7) = 5.28$, $p<0.01$). Again, targets and nontargets did not differ significantly from one another.

Analyses of Scalp Distributions

These were conducted to determine whether the distributions of the differences between ERPs to targets change from 800 to 1400ms (see Figure 6.5). The data submitted to analysis were the difference scores from which the Figure 6.5 maps were generated. These data points were first rescaled using the max-min method on data from all scalp sites in order to avoid confounding these effects that result from variable magnitudes over conditions of interest from effects which are due to differences between the shapes of distributions (McCarthy & Wood, 1985). The ANOVA included factors of epoch (2), anterior-posterior (2), hemisphere (2) and site (5) and showed no reliable effects or interactions, suggesting that the same neural generators were engaged in the two final epochs.

Discussion

Behaviour

Analysis of participants' overt responses provided no evidence of an increase in response accuracy from Experiment 1 to 2. Although there was a small increase in the likelihood of correctly rejecting a nontarget this was not significant and accordingly, target/nontarget discrimination did not improve. These results suggest that the instructions given to participants in Experiment 2 did not confer any benefits on retrieval processing over and above the processing that participants in Experiment 1 tended to engage. Analysis of ERPs time-locked to items presented at retrieval allows insight into whether the instruction manipulation affected retrieval processes and in particular whether it encouraged the adoption of strategic retrieval processing as indexed by differences between new item ERPs.

Factors that affect the Engagement of Strategic Retrieval Processing

There were no significant differences between new items at any time point or location, thus providing no evidence of the engagement of strategic retrieval processing in this study. Although interpretations that can be derived on the basis of null findings are necessarily constrained, the failure to replicate the effect from Experiment 1 indicates that encouraging individuals to only make judgments on the basis of successful recovery of this information alone did not lead to the engagement of the same operations that bias retrieval cue processing as indexed by new item ERP contrasts in Experiment 1. One obvious explanation for this is that the instructions employed here did not tap into the approach employed by participants in the high accuracy group in Experiment 1. This is pertinent in light of the data points that indicate that those participants may have predominantly encouraged the retrieval of drawing information in the relevant test phase. For example, instructions to make responses dependent only upon the recovery of target information may have caused recollection of targets. Participants were required not only to attend to whether iten were associated with the target status but also to rehearse the target designation throughout the retrieval phase. An additional requirement such as this may have tax the resources necessary for strategic retrieval. This possibility is examined on the basis of the outcomes of the analyses of the left parietal old/new effects.

The Left Parietal Old/New Effect

Directed analyses at left posterior electrode sites from 500-800ms revealed old/new effects of comparable amplitude for both targets and nontargets. There was no evidence of the selective recollection of targets. This contrasts with the findings in Experiment 1 where, regardless of overall accuracy, the left parietal effect for target was (except in the case of the high accuracy function designation) reliably greater in amplitude than for nontargets. The instructions provided to participants may therefc have reduced the likelihood that participants were able to selectively recollect target information in each test phase by taxing cognitive resources during retrieval.

Evidence consistent with a resource-depleted interpretation comes from previous reports on the employment of additional cognitive tasks and selective recollection. Dywan, Segalowitz & Webster (1998) reported contrasts of the late parietal effect to two classes of old item in one version of the exclusion task. In that paradigm, participants studied a series of items in an initial study phase before performing a second phase. This phase comprised old items as well as new items, half of which repeated. Participants were required to only ever endorse old items from the initial study phase as old (targets) and reject both repeated (nontargets) and unrepeated nev items on the same key. As has been shown in a number of paradigms (Wilding, Fras & Herron, 2005; Dzulkifli et al., 2005), a left parietal old/new effect was reliable for targets but not for nontargets. This was not the case for a second group of participan who completed the same task while also performing a digit-tracking task. For this group, old/new effects in the relevant time window were largest for nontargets relative to targets and new items. Dywan and colleagues interpreted this in terms of changes in the neural responsivity to repeated items as a function of attentional control. However, if the late positivity recorded by Dywan et al. is an instantiation of the left parietal old/new effect, then it is likely that the degree to which selective recollection of targets can occur is dependent upon the attentional resources that are available. This relates to the absence of electrophysiological correlates of selective recollection in Experiment 2 if the requirement to rehearse the designated target class introduced a strain on the attentional system, subsequently reducing the ability to adopt this strategy.

Similarly, recent reports on the sensitivity of ERP indices of selective recollection in the exclusion task tell of a relationship between individual variability in working memory capacity and left parietal indices of selective recollection (Elward & Wilding, in submission). Specifically, individuals with lower working memory capacity have been shown to demonstrate selective recollection to a lesser degree than those with a higher working memory capacity. If the task instructions provided here limited the available capacity of working memory this may lead to a reduction in selective recollection.

Explanations of this kind suggest that the available cognitive resources at retrieval affect the ability to engage in strategic retrieval processing. This might account for the findings in Experiment 1 if only those participants with sufficient cognitive retrieval resources were able to engage strategic retrieval processing. It is not possible on the basis of retrieval data alone, however, to determine the extent to which the capacity to engage strategic retrieval processing is also related to the employment of more efficient encoding mechanisms that in turn facilitate the later strategic retrieval of information. For example, if a participant encodes items in a manner that generates engrams that are sufficiently distinct for the two tasks (Nairne, 2002) this may create a context in which a strategy at retrieval can be applied more easily.

ERPs elicited by Old Items

Although there was no evidence of strategic retrieval processing in the new item ERP contrasts, reliable differences between ERPs to targets occurred in the latter half of the recorded epoch. The distribution of the target effect differs somewhat from the differences between target ERPs found for higher performing participants in Experiment 1: the effect in this second experiment is marked by more positive ERPs to targets in the drawing designation over central and right posterior sites. The same effect in Experiment 1 extended over these areas as well as towards right anterior sites, suggesting that not entirely the same processes were engaged between the two groups. The differences between targets indexed in the second experiment may reflect the engagement of a subset of the processes employed by high performers in the initial experiment.

Beginning after the window during which retrieval is thought to occur (before 900ms post-stimulus) it is likely that these differences index processes that operate upon the products of retrieval. As was the case for the comparable contrasts in Experiment 1 (see Chapter 5 Discussion), it is not possible on the basis of these data alone to clearly attribute target ERP effects to processes related to post-retrieval monitoring or indices of content-specific retrieval. It is possible, however, that because the target effects do not extend to right frontal areas in this time window in a manner that is characteristic of the right-frontal old/new effect, the current effects are more likely to index content-specific processing.

Although differences between nontarget ERPs were not reliable during and after retrieval, nontarget ERPs did diverge from one another in the earliest time window. This nontarget ERP effect was broadly distributed with a central maximum, comprising relatively more positive-going ERPs in the function target designation. Differences between nontarget ERPs were also reported in this time window for the low accuracy group in Experiment 1, although the interaction did not remain reliable in the within-group analyses. Evidence of early divergences between ERPs associated with the retrieval of different classes of contextual information has been reported previously by Johnson, Minton & Rugg (2008). One possibility is that participants used this early information to determine whether additional processing would be engaged in the case of targets but not for nontargets. Detection of nontarget information is necessary in order to inhibit further processing of nontargets in line with the task instructions. The finding, however, that these early nontarget ERP effects are common across the two experiments indicates that they are unlikely to be the result of explicit task instructions.

ERP Old/New Effects

Although left posterior amplitudes for targets were not enhanced relative to those for nontargets in the critical 500-800ms time window, there were differences between the amplitudes of old/new effects for targets and nontargets elsewhere in the electrical record. The old/new effect in the 500-800ms time window extended towards the front of the scalp where the target old/new effect was reliably larger than that for nontargets. This frontal old/new effect may reflect the adoption of additional processes recruited on the basis of attending to target information as required by the task instructions. The time course of this effect (500-800ms post-stimulus) is in line with the engagement of operations that come on-line during recollection, but are not engaged thereafter. The observation that the left parietal effect was equivalent for targets and nontargets, whereas the anterior effect in this same time window was not, precludes the interpretation that it is simply an anterior projection of the left parietal effect. The current data points indicate that selective processing of targets over nontargets did occur for this group although this did not manifest in terms of the behaviour of the left parietal effect. The time course of the effect suggests that this processing occurs at the same time as recollection and may indicate the engagement of on-line management of recollected information.

Concluding Comments

Participants were presented with the paradigm from Experiment 1 and were encouraged to adopt a strategy by which judgments were to be made on the basis of the recovery of target information only. Explicitly instructing participants to adopt this approach did not improve behavioural performance and did not lead to the adoption of strategic retrieval processing as indexed by differences between new item ERPs from the two tasks. Moreover, the left parietal old/new effects indicated that participants were unable to selectively recollect targets over nontargets at all. The data suggest that the ability to complete the exclusion task by stressing the recovery of target details may be over-ridden when instructions that interfere with task-relevant strategic retrieval processing are employed.

Table 6.3: Outcomes of global ANOVAs for old/new effects in each time window. Key: RC = response category, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom in brackets.

	300-500	500-800	800-1100	1100-1400
RC	F(1.5,25.5) =7.02 **	-	-	-
RC x HM	F(1.9,31.6) = 4.42 *	F(1.5,25.3) = 15.00 ***	F(1.6,27.6) = 11.30 **	-
RC x ST	F(3.4,57.2) = 2.82 *	-	-	-
RC x AP x HM	-	F(1.9,32.2) = 4.76 *	-	F(1.7,29.4) = 8.49 **
RC x AP x ST	-	F(3.3,56.8) = 4.80 **	F(3.6,60.9) = 6.48 ***	F(4.4,74.7) = 5.12 **
RC x HM x ST	-	F(5.1,86.6) = 4.50 **	F(4.7,79.3) = 3.48 **	-

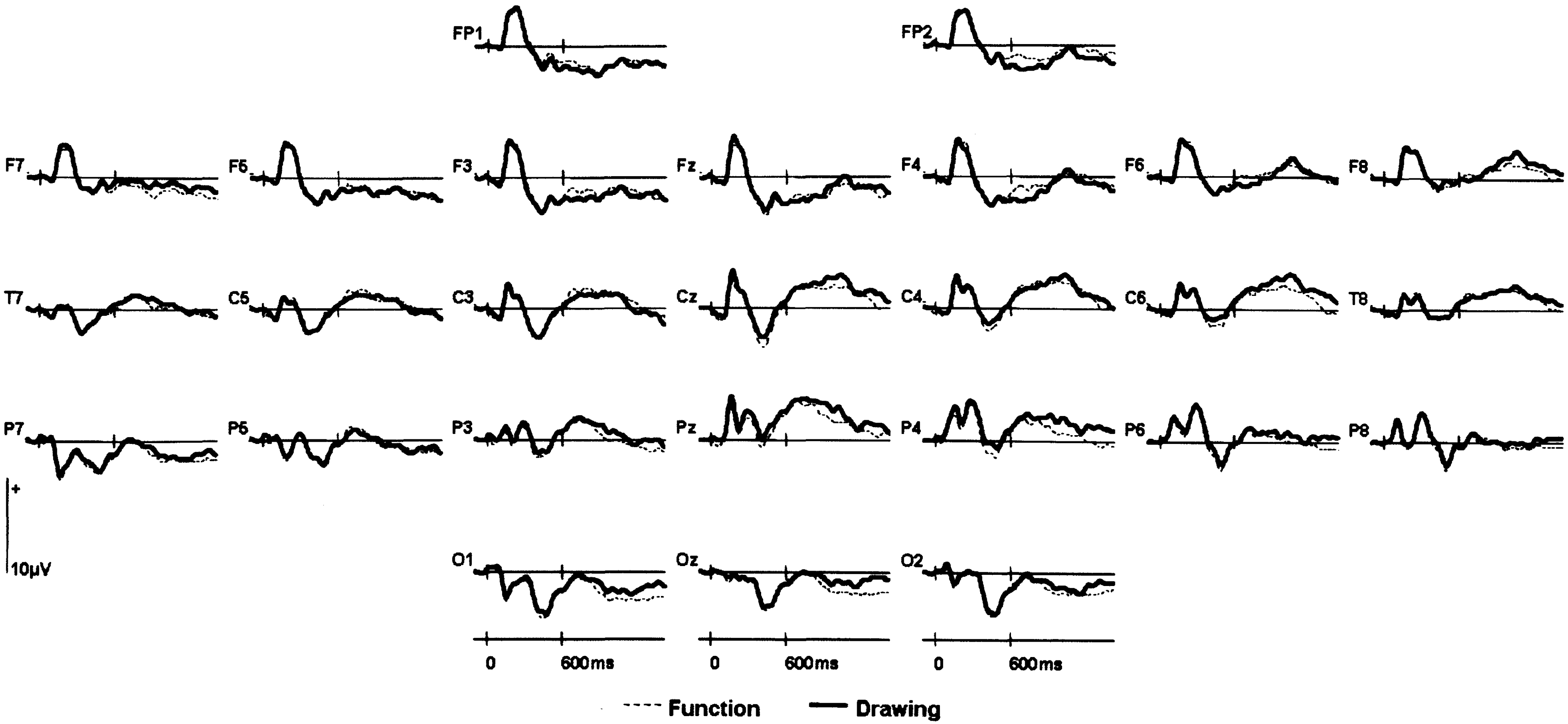

Figure 6.2: Grand average ERPs elicited by new items in the two target designation conditions. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

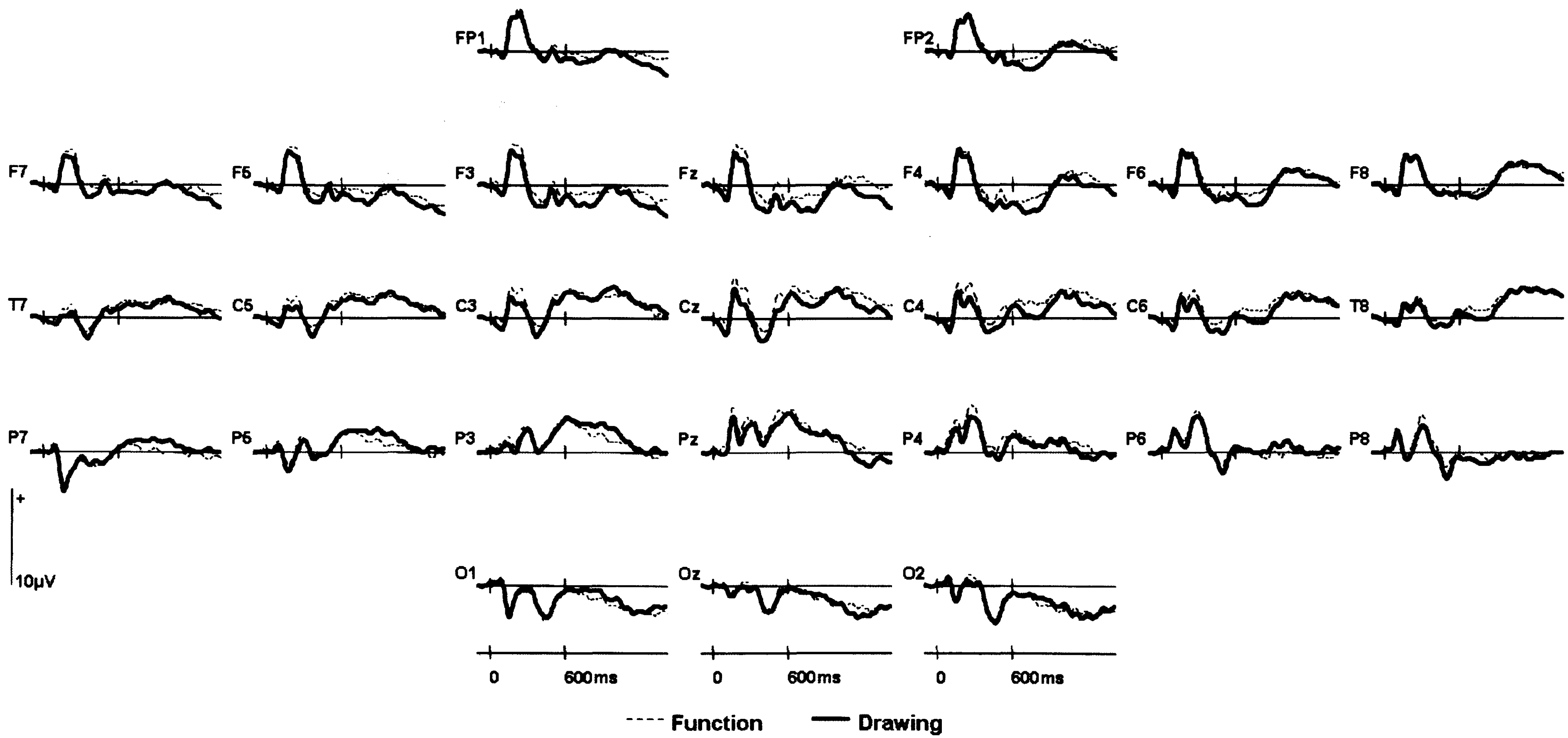

Figure 6.3: Grand average ERPs elicited by nontargets in the two target designation conditions. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

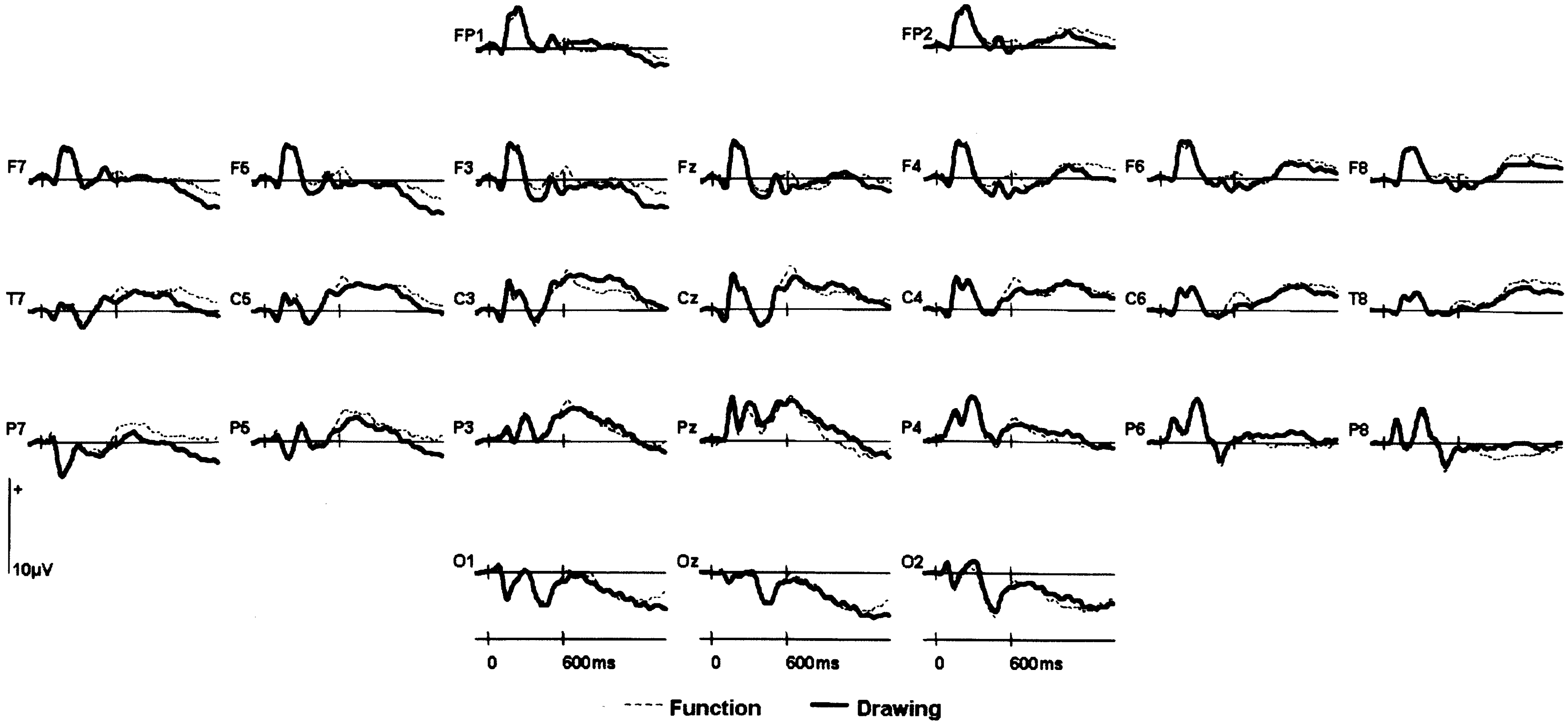

Figure 6.4: Grand average ERPs elicited by targets in the two target designation conditions. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

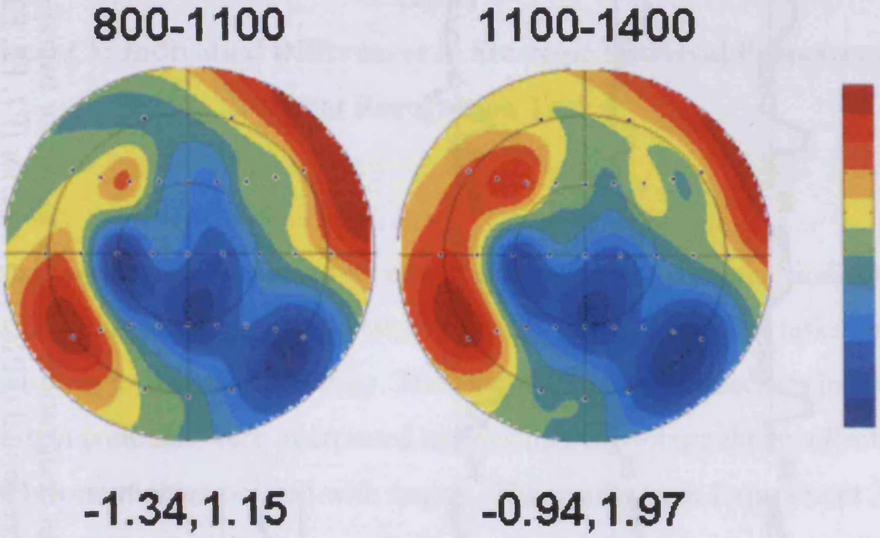

Figure 6.5: Topographic maps showing the scalp distributions of the differences between neural activity elicited by targets. Maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by words in the drawing target designation from those in the function designation, and are shown for the 800-1100 and 1100-1400ms time windows. Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

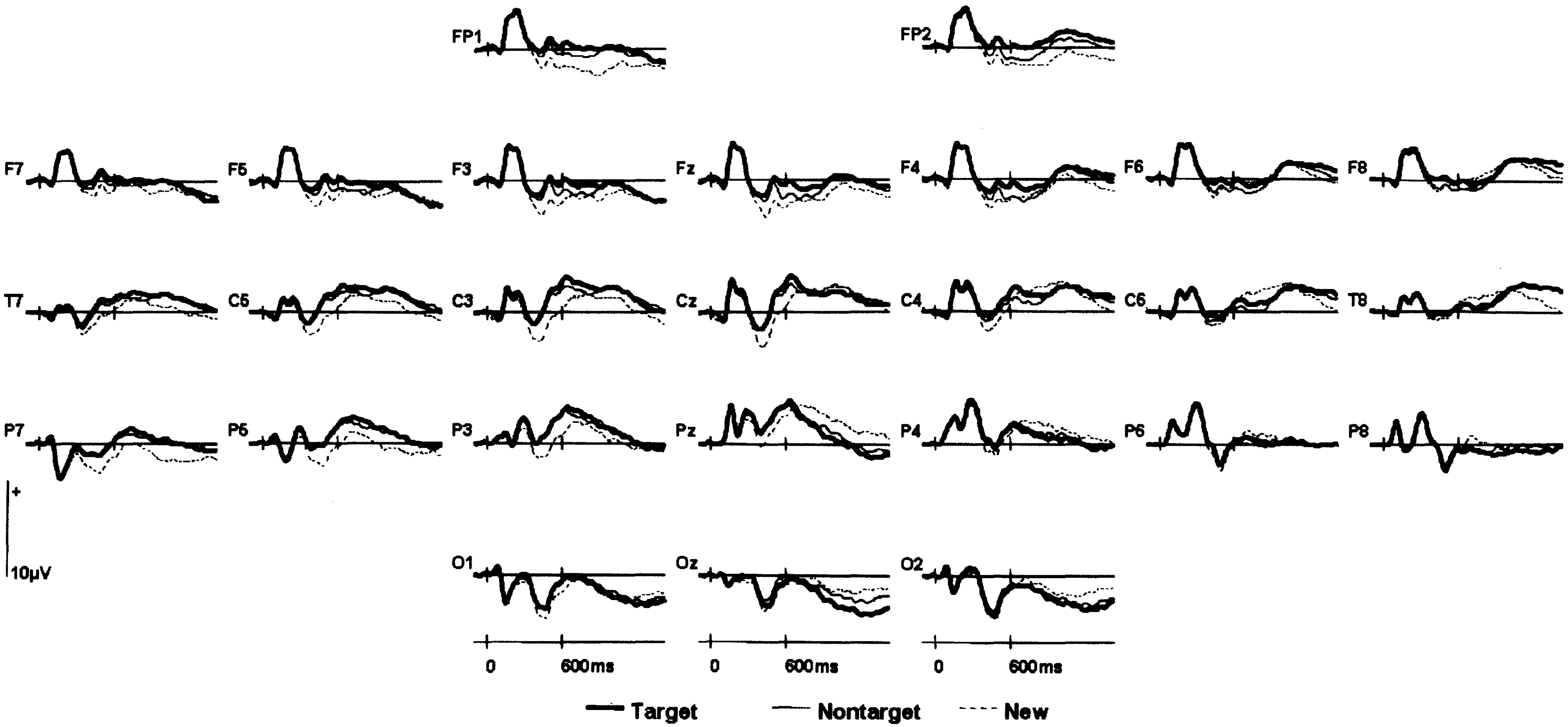

Figure 6.7: Grand average ERPs elicited by targets, nontargets and new items collapsed across target designation. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

Chapter 7

Experiment 3: Individual Differences in Strategic Retrieval Processing in an Item Recognition Task

Introduction

The contrast between ERPs elicited by new test items in Experiment 1 indicated that processing retrieval cues in line with targets in each of two exclusion tasks was related positively to response accuracy. The strategic retrieval processes indexed by these new item contrasts were interpreted as ones that encourage the recollection of contextual information associated with targets. The results from Experiment 2 indicated that asking participants to make judgments about the presence or absence of target information alone did not lead to the engagement of ERP new item effects comparable to those in Experiment 1, providing some insight into the factors that might affect strategic retrieval processing. Experiment 3 was developed to gain further insight into the conditions under which strategic retrieval processes might be engaged by investigating whether ERP new item effects will relate to accuracy in an old/new recognition memory paradigm in which recollection is no longer critical.

To this end, thirty-six participants encoded items via either the function or drawing task before they took part in two recognition memory tasks. Old words were intermixed with new in each recognition memory task, but items from only one encoding condition were presented in each block. Participants were required to determine whether each word was old or new, a judgment that can be made on the basis of familiarity or recollection because both are assumed to make independent contributions to recognition memory decisions (Yonelinas, 2002). Although in principle the majority of accurate responses can be made on the basis of familiarity in these tasks, judgments based upon recollection are likely to be associated with greater response accuracy. This is because both old and new items are associated with varying degrees of familiarity (Yonelinas, 1994), leaving opportunity for misdiagnosis if there is any degree of overlap in the distribution of old and new items (as there typically is). Only old items, however, should be associated with recollection of study phase information, thus reliance on this form of memory is likely to boost performance in this task. This differs from the exclusion task, where recollection of target information is critical for performance, rather than beneficial. The design reported here therefore provides an opportunity to determine further the conditions under which strategic retrieval processes are employed.

Reliable differences between ERPs elicited by new items from two old/new recognition test phases have been reported previously (Rugg, Allan & Birch, 2000). In that experiment, participants encoded items under deep or shallow conditions by making either an animacy or an alphabetic judgment. In two separate recognition tests in which only old/new responses were required, old items were always from one of the two encoding conditions. Reliable differences between ERPs elicited by new items from the two phases occurred from 300ms onwards, providing the first demonstration of changes in retrieval processing in an old/new recognition task. The design reported here is comparable to that design but was employed to determine whether the strategic retrieval processes related to the recollection of contextual information in Experiment 1 are especially evident in a task in which recollection is no longer essential.

ERP Old/New Effects

An additional feature of this design was that it allowed direct examination of the way in which established ERP old/new effects vary with overall response accuracy. Of particular interest was the behaviour of old/new effects generally thought to reflect familiarity and recollection, respectively: the mid frontal and left parietal ERP old/new effects (see Chapter 2). An important assumption concerning both these effects is that they can provide a graded index of the degree to which recollection and familiarity are engaged (e.g. Woodruff et al., 2006; Vilberg, Moosavi & Rugg, 2006). In this context, this can go towards informing the relative contributions of recollection and familiarity in an item recognition task and the extent to which these contributions relate to overall accuracy.

Design

Participants completed one large study phase, in which items were encoded in either the function or draw task, and two successive test phases, in each of which old items from only one of the two tasks were presented. These were intermixed with new items and participants were required to make an old/new judgment for each item. In order to bring performance off ceiling and introduce sufficient behavioural variability to tease apart electrophysiological differences it was necessary to append a number of filler items to the end of the study phase, and to extend the study-test interval. In order to determine whether ERP indices of strategic retrieval processing varied with accuracy in this design, participants were allocated to one of two accuracy groups depending upon their ability to discriminate between old and new items.

Method

Participants

These were 54 (22 male) students. Data from 12 participants (8 male) were initially excluded from analysis following unacceptably high levels of noise at a number of electrodes. Data from a further six participants were removed because of an inability to follow instructions appropriately (3) or because they failed to produce sufficient artefact-free trials for critical conditions (3). The mean age of participants who were included for analysis was 21 years (range: 18-29).

Design

The stimulus set comprised three hundred and ninety words taken from the MRC Psycholinguistic Database corpus (Coltheart, 1981). Thirty of the 390 words were set aside to provide a constant pool to be used as filler items. The remaining words were randomly allocated to six groups of 60 words. A full experiment list comprised a combination of these six groups to create one study phase and two subsequent test phases. The study phase comprised four word groups followed by the constant pool of thirty items. In each test phase, two of the old word groups were repeated along with a third to give 180 test words per test cycle. No words were repeated across cycles. Word groups were rotated fully across experiment lists, resulting in 6 complete lists, such that each item was balanced according to old/new status and encoding task at study.

Procedure

Participants first completed a short practice phase where they were familiarised with the response requirements at study. The researcher read aloud the task instructions and participants were also given written descriptions.

In the study phase, participants completed two tasks. Cues preceding each word signalled which task to complete; 'FUNCTION?' for the function task, 'DRAW?' for the drawing task. In the function task, they were asked to say aloud a function for the object denoted by the word. In the drawing task, they were asked to rate verbally how difficult it would be to draw the object denoted by the word on a 4-point scale: 'very easy', 'fairly easy', 'fairly difficult', 'very difficult'. Cues remained on the screen for 1000ms, followed by a blank screen for 500ms. The order in which encoding task cues were presented was pseudo-randomised such that no more than three consecutive words were preceded by the same cue. Each study word was presented for 300ms before the screen was blanked. Participants initiated the next trial by pressing a key on a response pad. The trial started 2000ms after this response.

Between study and test phases, participants were fitted with an electrode cap (see Chapter 4). The interval between end of study and beginning of test was fixed at 30 minutes. Each test trial began with a fixation asterisk which remained on the screen for 500ms followed by a 500ms blanked screen and then the test word for 300ms. The screen remained blank until the participant responded. The next trial began 1500ms later. In both test cycles, participants were instructed to respond using the index finger from one hand to words from the preceding study phase, and with the index finger from the other hand to new test words. Immediately prior to each test phase participants were informed that all the old words in the subsequent test were encoded in only one of the two tasks (function or drawing) performed at study. The hands used for responses were balanced across participants, and 50% of participants completed the test in which all old words were from the function task first.

EEG was recorded with the parameters outlined in the General Methods section (Chapter 4).

Results

Accuracy Groups Analysis

Behaviour

Participants were assigned to one of two groups depending upon their ability to discriminate between old and new items (Pr = p[Hit] – p[FA]; Snodgrass & Corwin, 1988). This score was collapsed across the two tasks and participants were assigned to a high or low accuracy group using a median (0.78) split. Table 7.1 shows the proportions of correct judgments to old and new words from the two tasks for all thirty-six participants as well as separated for the high and low accuracy groups. ANOVA with factors of group (high/low) and task (function/drawing) showed Pr was reliably greater in the high performing group ($F(1,34) = 56.26$, $p<0.001$) and in the function task ($F(1,34) = 12.67$, $p<0.01$). Measures of response bias (Br = FA/[1-(Hits-FA)]; Snodgrass & Corwin, 1988) were subjected to ANOVA with the same factors that were employed for the discrimination analyses. No reliable effects were obtained.

Table 7.1: Mean proportions of correct responses to old (hits) and new items (correct rejections) separated according to retrieval task. Data are shown for all thirty-six participants, as well as separated according to the two accuracy groups. Corresponding reaction times are also shown. Standard deviations are shown in parentheses.

Group	Task		Hit	Correct Rejection
	Function	*p(correct)*	0.89 (0.07)	0.92 (0.07)
		RT	912 (274)	1015 (356)
	Draw	*p(correct)*	0.84 (0.10)	0.90 (0.09)
		RT	976 (277)	1036 (327)
High Accuracy	Function	*p(correct)*	0.92 (0.04)	0.96 (0.03)
		RT	868 (176)	963 (197)
	Draw	*p(correct)*	0.90 (0.07)	0.95 (0.05)
		RT	954 (193)	1002 (184)
Low Accuracy	Function	*p(correct)*	0.86 (0.07)	0.88 (0.07)
		RT	957 (257)	1067 (355)
	Draw	*p(correct)*	0.78 (0.10)	0.86 (0.09)
		RT	998 (279)	1070 (348)

Table 7.1 also shows the mean reaction times for hits and correct rejections. An initial analysis of reaction times used a mixed ANOVA on correct responses only with factors of response category (hit/correct rejection), task (function/drawing) and group (high/low accuracy). Response times were faster for hits than correct rejections ($F(1,34) = 13.64$, $p<0.01$), and for items in the function than the drawing task ($F(1,34) = 5.13$, $p<0.05$). Response times did not differ with accuracy group.

ERP Analyses

These begin with contrasts between ERPs associated with correct rejections from the two tasks separated according to accuracy group. This is followed by analyses of ERP old/new effects collapsed across task but separated according to response accuracy. The mean numbers of trials contributing to the averaged ERPs for participants in each accuracy group and response category can be seen in Appendix D. Appendix E includes a report of the outcomes of the ERP old/new effect analyses separated for the two target designations which map onto the outcomes of the analyses reported below.

ERPs elicited by New Items

Figure 7.1 (below) depicts the grand average waveforms for ERPs elicited by correct rejections in the two tasks for the high and low accuracy group (see also Figures 7.2 and 7.3). At a number of time points and locations the waveforms in the low accuracy group diverge from one another (e.g. >700ms at central sites). In the high accuracy group, drawing new item ERPs were more positive-going around 800ms onwards at left hemisphere sites.

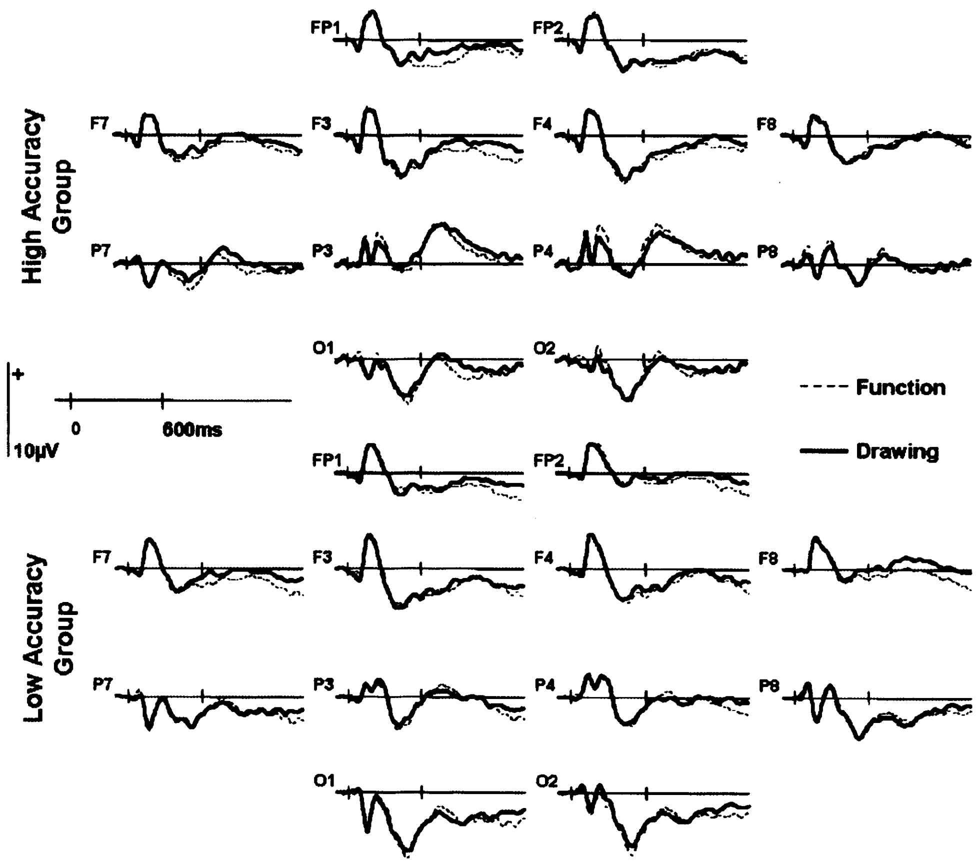

Figure 7.1: Grand average ERPs elicited by correct rejections in the two tasks for the high and low-accuracy groups. Data are shown for 12 electrode locations.

ANOVA included the between-subjects factor of accuracy group as well as within-subjects factors of task (function/drawing), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior). No interactions with the factors of task or group were reliable in any epoch. Separate within-group ANOVAs were conducted in order to reduce the likelihood of a type II error in light of the critical interest of this study; the relationship between new item ERPs and accuracy group. Interactions between task and hemisphere occurred from 500-1100ms (500-800, $F(1,17) = 4.64$, $p<0.05$; 800-1100, $F(1,17) = 4.99$, $p<0.05$) in the high accuracy group. For this group, hits in the drawing test phase were more positive-going over left hemisphere sites. No effects were reliable for the low accuracy group. Appendix F describes the data points that were used to determine whether the amplitude of new item effects correlated with participants' Pr score. There was no evidence of a significant relationship between the amplitude of the differences between new items and response accuracy at this level.

Analyses of ERP Old/New Effects

Figure 7.4 (below) shows waveforms at selected sites for ERPs evoked by hits and correct rejections collapsed across the two test phases for the high and low accuracy group (see also Figures 7.5 and 7.6). The figures show that old/new effects appear from 300ms onwards: old item ERPs are more positive-going than those elicited by new items at posterior sites. The positive-going modulation in the subsequent 500-800ms time window at left posterior sites, the left parietal old/new effect, is pronounced for both groups. For the low accuracy group, old/new effects in this time window are largest at left midline posterior sites and are less evident from 900ms until the end of the recording epoch. In the high accuracy group, old/new effects remain evident at anterior midline sites between 800 and 1100ms but become more right lateralised in the final epoch (1100-1400ms). Figure 7.7 depicts the maxima of the effects in each of the four time windows.

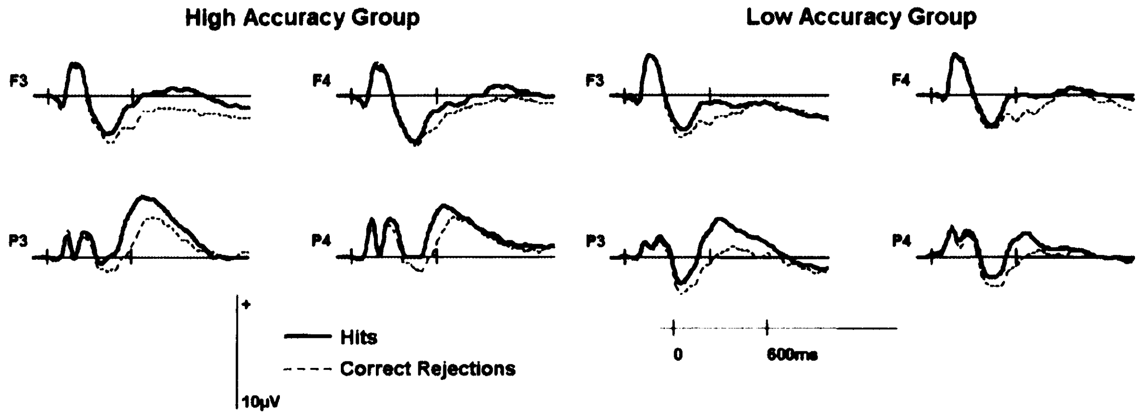

Figure 7.4: Grand average ERPs elicited by hits and correct rejections for the high and low accuracy groups. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

Old/new analyses employed the same location factors as previous analyses. The factor of task was replaced with that of response category (hit/correct rejection). The outputs of the global analyses are shown in Table 7.2, and the reasons for the reliable interactions in the table are clearly shown by the maxima of the effects as depicted in Figure 7.7. Old/new effects follow the standard pattern of those reported in recognition memory paradigms (Rugg & Curran, 2007), but the chief concern was with effects that interacted with accuracy group. Follow-up within-group analyses were conducted only in the final time window (1100-1400ms) where group interacted with response category and site (see Table 7.2). Interactions including the factors of response category, anterior-posterior, hemisphere and site ($F(3.6,61.2) = 3.61$, $p<0.05$) and response category, anterior-posterior and site ($F(2.5,42.1) = 3.79$, $p<0.05$) occurred in the high and low group, respectively. The relative positivity for old items was larger and showed a more superior distribution in the high accuracy group.

Analyses of Scalp Distributions

In order to determine whether the differences between correct rejection ERPs observed in the high accuracy group were stable over time, scalp distribution analyses were conducted. The data used in these analyses were subtraction scores (function minus drawing) taken from the 500-800 and 800-1100ms time windows and rescaled using data from all sites across the scalp. The same electrode sites that were entered into the initial ANOVA were employed once again, along with the factors of epoch (2), anterior-posterior (2), hemisphere (2) and site (5). There was no statistical indication that the distribution changed across these two time windows.

A further analysis was also conducted on the rescaled difference scores for the old/new effects in the 1100-1400ms time window in which there was an interaction between the two accuracy groups. Rescaled subtraction scores (hits minus correct rejections) were submitted to an ANOVA with factors of accuracy group (2), anterior-posterior (2), hemisphere (2) and site (5). The interaction between group and site remained reliable ($F(2.3,76.8) = 3.03$, $p<0.05$) in this analysis, in line with the superior projection of the old/new effects in the high accuracy group for this time window (see Figure 7.7).

Relative Difficulty Analyses

Responses in the function task were quicker and more accurate. A consistent behavioural difference for the two tasks allows for the possibility that contrasts between correct rejections from these two tasks index processes that relate to the greater relative engagement of effortful processes in one task rather than indices of the way in which processing of retrieval cues differs with specific task requirements (Robb & Rugg, 2002). In one investigation of the relationship between retrieval effort and strategic retrieval processes, ERP new item effects occurred only for a group of participants who performed one task at a lower level of accuracy (Dzulkifli, Sharpe & Wilding, 2004), providing evidence for the sensitivity of ERP new item effects to relative difficulty. In order to determine whether the reliable new item differences in the high accuracy group were related to relative difficulty, a similar analysis strategy was employed here. Participants were split into a high and low relative difficulty group depending upon the degree to which correct responding differed in the two tasks. Specifically, relative difficulty was operationalised by subtracting each individual's Pr value in the drawing task from Pr in the function task.

Behaviour (Relative Difficulty)

Participants in the high relative difficulty group had a larger range of relative difficulty scores (mean = 0.16; range 0.06 - 0.37) than those in the low relative difficulty group (mean = -0.02; range -0.08 - 0.06). The likelihoods of a correct response to each category for these two groups along with the associated reaction times are shown in Table 7.3 (below). ANOVA on these correct responses with factors of group (high/low relative difficulty) and task (function/draw) revealed main effects of group (F(1,34) = 8.79, p<0.01), task (F(1,34) = 18.72, p<0.001) and an interaction between the two factors (F(1,34) = 19.03, p<0.001).

Table 7.3: Mean proportions of hits and correct rejections separated according to retrieval task, for the high and low relative difficulty groups. Corresponding reaction times are also shown. Standard deviations are shown in parentheses.

Group	Task		Hit	Correct Rejection
High Rel Diff	Function	*p(correct)*	0.88 (0.08)	0.92 (0.07)
		RT	951 (258)	1041 (338)
	Draw	*p(correct)*	0.78 (0.10)	0.86 (0.09)
		RT	1011 (275)	1062 (329)
Low Rel Diff	Function	*p(correct)*	0.90 (0.06)	0.92 (0.07)
		RT	874 (182)	989 (240)
	Draw	*p(correct)*	0.90 (0.07)	0.94 (0.06)
		RT	941 (200)	1010 (223)

Bonferroni-corrected t-tests (corrected alpha level p<0.0125) revealed that function Pr values differed from draw Pr values in the high relative difficulty group only (t(17) = 4.62, p<0.001). Pr values in the draw task were significantly higher in the low than high relative difficulty group (t(34) = 4.15, p<0.001) whereas Pr values for the function task did not statistically differ for the two groups, confirming the impression that the difference between the groups was predominantly due to variability in responding in the drawing task. Br did not differ across groups. Analysis of reaction times included factors of group (high/low relative difficulty), response category (hit/correct rejection) and task (function/drawing), again revealing faster responses for hits (F(1,34) = 13.59, p<0.01) and items in the function task (F(1,34) =5.12, p<0.05), but no interaction with relative difficulty group.

ERP Analyses

ERPs elicited by New Items (Relative Difficulty)

Figures 7.8 and 7.9 depict grand average waveforms for correct rejections in the two tasks for the high and low relative difficulty groups respectively (see also Figure 7.10 below). Divergences between ERPs to new items in the two tasks appear at left frontal sites from 300 until 1400ms in the high relative difficulty group. More pronounced differences between ERPs appear at central sites from 100ms until the end of the recording epoch in the low relative difficulty group. Correct rejection ERPs in the drawing task were more positive-going for the high relative difficulty group but relatively more negative for the low relative difficulty group.

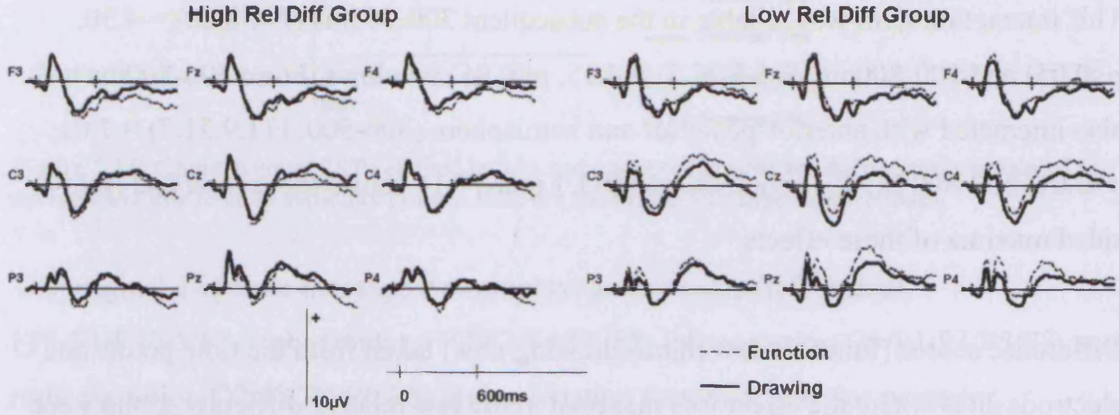

Figure 7.10: Grand average ERPs elicited by correct rejections in the two tasks for the high and low relative difficulty groups. Data are shown for 9 electrode locations at left, midline and right hemisphere sites over frontal (F3, Fz, F4), central (C3, Cz, C4) and, posterior (P3, Pz, P4) scalp sites.

In order to provide coverage of the distribution of differences in both the high and low relative difficulty groups, a different electrode montage was used for this set of analyses (see Appendix G for analyses on the standard montage which broadly replicate the pattern reported below). This montage covered six regions of interest each comprising four electrode sites; left-frontal (F1/F3/F5/F7), right-frontal (F2/F4/F6/F8), left-central (C1/C3/C5/C7), right-central (C2/C4/C6/C8), left-posterior (P1/P3/P5/P7) and right-posterior (P2/P4/P6/P8). In order to help indicate the earliest point at which correct rejections differed, an earlier 100-300ms time window was included for analysis, providing five analysis epochs (100-300, 300-500, 500-800, 800-1100, 1100-1400). Analyses included the between-subjects factor of relative difficulty group (high/low) and within-subjects factors of task (function/drawing), hemisphere (left/right), anterior-posterior (anterior/central/posterior) and site (inferior/mid-lateral/superior/midline). The mean numbers of trials contributing to the averaged ERPs for participants in each relative difficulty group and response category can be seen in Appendix D.

Effects were reliable only in the first three time windows, and the outcomes of the global ANOVA for these epochs are shown in Table 7.4. Following interactions with the factor of group in each epoch, separate within-group ANOVAs were conducted for that epoch. Reliable effects were observed only in the low relative difficulty group. In the early 100-300ms window for this group, a main effect of task ($F(1,17) = 5.34$, $p<0.05$) was moderated by an interaction with site ($F(1.2,20.5) = 6.71$, $p<0.05$). This interaction term was reliable in the subsequent 300-500ms ($F(1.2,20) = 4.30$, $p<0.05$) and 500-800ms ($F(1.5,25.5) = 4.15$, $p<0.05$) windows. From 300-800ms task also interacted with anterior-posterior and hemisphere (300-500, $F(1.9,31.7) = 7.01$, $p<0.01$; 500-800 $F(1.9,32.5)$ 8.36, $p<0.01$). Figure 7.11 shows the central and right-sided maxima of these effects.

Difference scores (function new minus drawing new) taken from the time points and electrode sites where the effect was maximal in the low relative difficulty group were extracted for each individual and compared against the behavioural index of relative difficulty (function Pr minus drawing Pr). This was calculated for the three time windows (100-300, 300-500, 500-800ms) where the effect was reliable and the electrode sites where it was maximal (Cz, C2, C4, C6, Pz, P2, P4, P6). The outcomes of these analyses are presented in Table 7.5 and indicate reliable negative correlations primarily at central sites from 100-800ms (all significant R-values < -0.34). This was also reliable when relative difficulty was correlated with the average difference in amplitude between new item ERPs for the entire 100-800ms epoch ($r = 0.47$, $p<0.01$; see Figure 7.12). The overall pattern shows that the greater the difference between processing of new items, the more similar Pr for the two tasks was.

Analyses of ERP Old/New Effects (Relative Difficulty)

It is possible that ERP old/new effects for the two tasks also differ with the degree to which individuals' performance varied across the two tasks. In order to determine whether this was the case, additional old/new analyses were conducted with factors of task (function/draw) and group (high/low relative difficulty). Figure 7.13 (below) shows ERPs to hits and correct rejections in the function and drawing tasks for the two groups (see also Figures 7.14 and 7.15). In both groups, the waveforms for the two tasks appear to diverge at a number of time points from 600ms onwards.

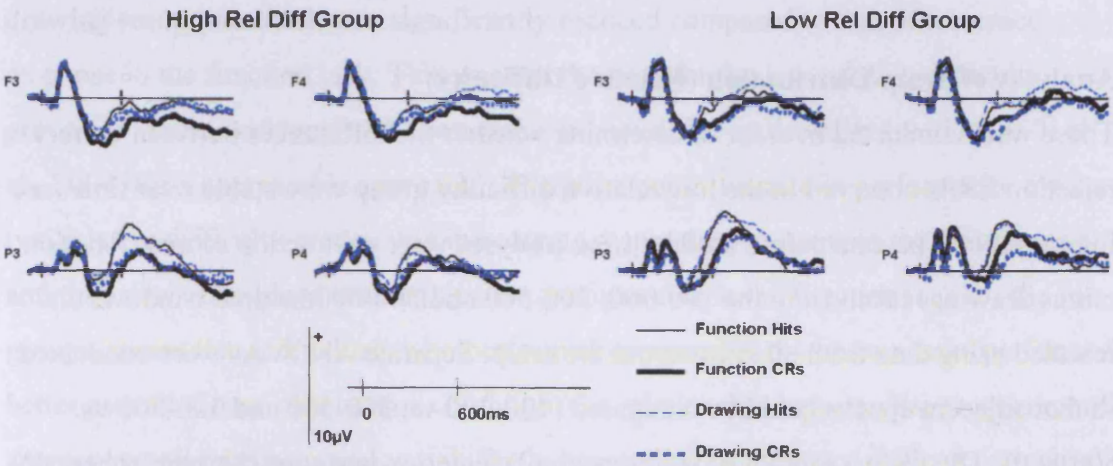

Figure 7.13: Grand average ERPs elicited by hits and correct rejections for the two tasks separated for the high and low relative difficulty groups. Data are shown for four superior electrodes.

The original electrode montage was employed once more (left-frontal, FP1/F1/F3/F5/F7; right-frontal, FP2/F2/F4/F6/F8; left-posterior, O1/P1/P3/P5/P7; and right-posterior, O2/P2/P4/P6/P8) giving location factors of anterior-posterior, hemisphere (left/right) and site (inferior/mid-lateral/superior/midline/pre-superior). Table 7.6 shows the outcomes of analyses in the four time windows in which they were conducted (300-500, 500-800, 800-1100, 1100-1400). The principal reason for these analyses was to determine whether the old/new effects for the two tasks varied with relative difficulty group and Table 7.6 indicates such an interaction (group/task/response category/anterior-posterior/hemisphere) occurred in the 500-800ms time window. In order to break this interaction term down, analyses were focused separately at each of the four regions of interest (ROI: left-frontal, right-frontal, left posterior and right posterior), leaving only factors of group, task, response category and site. For each ROI, main effects of response category (for all $F(1,34) > 9.44$, $p<0.01$) were moderated by interactions between response category and site (for all $F(>2.5,85.3) > 3.35$, $p<0.05$). Old/new effects increased in magnitude at sites closest to the midline in all ROIs except the left posterior ROI where the effect was largest at the superior site, P3. Group interacted with task, response category and site only in the left posterior ROI ($F(3.4,116.3) = 2.63$, $p<0.05$). The mean amplitudes at parietal sites (P5/P3/P1) in this time window are displayed in Figure 7.16 and demonstrate the reason for this interaction clearly. In the high relative difficulty group, the amplitude of the draw effect was reduced relative to the amplitude of the function effect. In the low relative difficulty group, however, the amplitude of the draw parietal effect was larger than the function parietal effect.

Analyses of Scalp Distribution (Relative Difficulty)

These were conducted in order to determine whether the differences between correct rejection ERPs observed in the low relative difficulty group were stable over time (see Figure 7.11). The data points used in these analyses were subtraction scores (function minus drawing) taken from the 100-300, 300-500 and 500-800ms time windows and rescaled using data from all sites across the scalp. Separate ANOVAs were conducted so that adjacent epochs could be compared (100-300 vs. 300-500 and 300-500 vs. 500-800). The factors employed were epoch (2), anterior-posterior (3), hemisphere (2) and site (4). For the correct rejections contrast between the 100-300 and 300-500ms epochs, an interaction between epoch, hemisphere and site ($F(2.3,39.2) = 4.42$, $p<0.05$) came about because the effect extended more towards left inferior sites in the earlier time window. There were no reliable interactions between epoch and factors of site when the data from the 300-500 and 500-800ms epochs were contrasted.

Discussion

Behaviour

In order to determine whether strategic retrieval processing was related to response accuracy in a recognition memory task, thirty-six participants performed two recognition memory tests in which all old items were associated with one encoding operation (function or drawing). All participants performed well in both study phases, but were subsequently split according to their ability to discriminate between old and new items, creating a high accuracy group in which correct responses were significantly more likely than in the low accuracy group. The presence of ERP new item effects was then assessed across these groups.

A consistent behavioural advantage was found for responses in the function task. This relative benefit for performance on one task allows for the possibility that any differences between new item ERPs from the two tasks may index variation in the relative engagement of effortful processes (Rugg & Wilding, 2000). In order to determine whether any ERP new item effects that were sensitive to accuracy also varied according to relative difficulty, a second set of analyses were conducted. This was done by creating two groups between which relative difficulty was manipulated: in the high relative difficulty group, the likelihood of a correct response in the drawing recognition task was significantly reduced compared to that of a correct response in the function task. This was not the case for the low relative difficulty group for whom accuracy in the two tasks did not differ statistically (see Dzulkifli et al., 2004, for a comparable approach). The principal difference in performance for the two relative difficulty groups was in accurate responding to items in the drawing task, and this, when combined with equivalent performance in the function task for the two groups, meant that individuals who performed comparably on the two tasks performed better overall. These observations highlight the relationship between the proportion of correct overall responses and variability in responding in the more difficult (drawing) task.

Strategic Retrieval Processing in an Item Recognition Task

When new item ERPs were separated according to retrieval task and response accuracy, small yet reliable differences were found from 500-1100ms in the high accuracy group only. For this group, new items in the drawing test phase were more positive-going over the left hemisphere. The absence of comparable effects in the low accuracy group is consistent with the view that participants who processed new test items according to the study history of old items in each test phase performed better overall at the task. This pattern indicates that ERP new item effects relate to accuracy in a recognition memory task as well as an exclusion task (Experiment 1). Moreover, the effect provides further insight into the functional interpretations of the processes indexed in Experiment 1.

In both its polarity and distribution, the new item ERP effect found for the high accuracy group differs from the comparable contrasts reported in Experiment 1. Marked qualitative differences rather than evidence of similar yet smaller effects indicate the engagement of a unique set of strategic processes in the recognition task. The observation that the pattern of accuracy-related strategic retrieval processes are not the same in Experiments 1 and 3 where conditions at encoding were almost identical, supports the interpretation that the retrieval effects do not simply reflect processes that occur somewhat automatically as a consequence of recovering different types of information. Instead when these effects occur they are likely to do so because of the demands that are imposed at retrieval.

This insight raises the issue of what these different processes might index in the paradigm employed in Experiment 3. Although the effects were associated with response accuracy they were small and were not detected at the whole group level. This pattern corresponds with the reduced requirement to recover contextual information in this paradigm. One possibility is that the effect indexes processes engaged in the recovery of content-dependent familiarity, in light of the fact that familiarity can be used to make correct judgments in the recognition (but not the exclusion) task. Such a proposal is not consistent with the commonly held assumption that familiarity is an amodal global-matching process (Rugg & Yonelinas, 2003) and therefore should not vary for different types of contents (Johnson, Minton & Rugg, 2008). Another possibility therefore is that the new item ERP effect indexes differential reliance upon familiarity as opposed to recollection in the two tasks. Assuming the two processes are independent of one another (Jones 1987; Yonelinas & Jacoby, 1995) and that the ease of recollecting these two item types differs to some extent, flexibly changing the degree to which participants rely upon familiarity in each task may be a useful strategy for successful responding.

Despite the small size and ambiguous nature of these ERP new item effects, they provide at least preliminary evidence that ERP new item effects relate to accuracy in a task in which recollection is not critical. In addition, a second new item ERP effect, indirectly related to overall accuracy, demonstrated a stronger relationship with the behavioural data in this paradigm.

Strategic Retrieval Processing and Task Difficulty

ERPs were separated according to retrieval task and relative difficulty by the allocation of participants to groups depending upon their relative performance in the two tasks. While there was no statistical evidence that new item ERPs differed for participants in the high relative difficulty group, this was not the case for those who performed comparably across the two tasks. For this low relative difficulty group, ERPs associated with new items in the function task were relatively more positive-going from 100-800ms. The central distribution of this effect was stable over time, and although Figure 7.10 suggests that these differences were extended later into the recording epoch, further analysis did not confirm this impression. A reliable relationship was observed between the extent to which each individual processed new items differently in the two test phases (amplitude difference in microvolts) and the degree to which performance on the two tasks was matched. Together these findings provide additional evidence of the sensitivity of ERP new item contrasts to variations in task difficulty (Robb & Rugg, 2002; Dzulkifli et al., 2004).

It is difficult, however, to straightforwardly accommodate this pattern with existing reports of new item ERP markers of task difficulty; in other studies, reliable ERP new item effects occurred when behavioural markers indicated one task was more difficult than the other (Robb & Rugg, 2002; Dzulkifli et al., 2004). In this experiment, processing of new item ERPs changed across test phases only for a group of participants who performed similarly on the two tasks, suggesting that the effect is functionally related to the engagement of processing that equates performance in the two tasks. It was primarily accuracy in the drawing task that differentiated the high and low relative difficulty groups and in accordance with this, the greater the degree to which processing of new items differed in the two tasks, the higher accuracy on the drawing task tended to be. This effect is likely to be associated with processes engaged in the recovery of drawing information. Such processes may operate by ensuring that retrieval cues are processed in a manner that encourages them to interact with engrams that contain perceptual (drawing) information. One way of achieving this is to maintain an internal representation of the targeted items (Hornberger, Morcom & Rugg, 2004). The observation that the distribution of the effect did not differ from 300 to 800ms (see Figure 7.8) is consistent with this because it indicates that the same neural generators were engaged over successive time points.

Elsewhere in the electrical record there is also evidence that individuals in the low relative difficulty group recollected relatively more drawing information than the high relative difficulty group did. This comes from examination of the pattern of old/new effects in the 500-800ms time window. As is commonly reported, old/new effects in this time window were largest at left posterior sites, signalling the presence of the left parietal old/new effect. Although reliable for both tasks, the relative amplitude of the effect for the two tasks varied across groups: Figure 7.16 shows that for the high relative difficulty group the amplitude of the effect was greatest in the function task, whereas for the low relative difficulty group the amplitude of the effect was greatest in the drawing retrieval task. It is likely that changes in the size of this effect reflect the recovery of variable amounts of information associated with the two tasks in line with reports that the amplitude of the left parietal old/new effect increases in a graded manner according to the amount of information that is recollected (Wilding, 2000; Vilberg, Moosavi & Rugg, 2006). The parietal data in Experiment 3 highlight the influential role of recollection in simple item recognition tasks by showing a relationship between the amplitude of the left parietal effect and response accuracy in a recognition task. These findings correspond to some extent with the parietal data reported in Experiment 1 because the findings from both experiments indicate that a group of participants who engaged in differential or strategic retrieval processing across test phases recollected relatively more information in the drawing task.

The combined between-groups analyses reported here revealed two electrophysiologically dissociable processes associated with contrasts between ERPs elicited by new items in the two recognition tasks. One effect that was reliable only for the group of high performing participants showed a relative positivity for new items in the drawing task over left hemisphere sites from 500-1100ms (see Figure 7.1). A second effect that was associated with relative difficulty comprised a relative positivity for function new items from 100-800ms over central sites (see Figure 7.10). The marked dissimilarities between the timings, polarities and distributions of the two effects make it unreasonable to suggest that the effects index identical processes, although both are associated with increases in overall response accuracy.

In sum, a pronounced centrally distributed new item ERP effect from 100-800ms was related to variability in performance on the drawing task, and most likely indexes the engagement of processes that increase the recovery of information related to this task. The group for whom the new item ERP effect was reliable appeared to engage recollection to a greater degree in the drawing task, an interpretation based on the behaviour of the left parietal old/new effect. These data indicate a relationship between the engagement of strategic retrieval processes and the recovery of source specifying information. In addition, they further emphasise that strategic retrieval processes which facilitate the retrieval of contextual information play an important functional role in recognition memory tasks.

ERP Old/New Effects and Response Accuracy

Old/new effects demonstrated the pattern reported in most memory recognition tasks (Friedman & Johnson, 2000; Rugg & Curran, 2007) with reliable effects in all four time windows. Neither the amplitude of the early mid frontal old/new effect or the left parietal effect (in the 500-800ms window) varied between the high and low accuracy groups. One reason for this null result may be the small level of behavioural variability overall, reducing the power of the design for teasing apart the neural correlates of variations in the engagement of processes that affect recognition memory. It is also likely (as indicated by the outcomes of the relative difficulty analyses) that variability in performance was related to the degree to which drawing information was recollected, an aspect of the data old/new effects that are not separated for the two recognition tasks are insensitive to (although Appendix E reports that there was no evidence that old/new effects from 300-800ms were modulated by retrieval task for the high and low accuracy groups).

Collapsed old/new effects were sensitive, however, to accuracy in the final 1100-1400ms time window. An analysis on rescaled data revealed distinct scalp topographies for the two groups and comparison of right-frontal electrodes in Figures 7.5 and 7.6 indicates that this occurred because the effect in the low accuracy group appeared at only a subset of the electrode sites at which it was present in the high accuracy group. Right frontal effects in this time window have been associated with operations that act upon the products of retrieved information (Allan et al., 1998; Hayama et al., 2008), not least because they are largest in tasks that require additional source monitoring (Johnson et al., 1993; Senkfor & Van Petten, 1998). In line with this, studies using simple recognition memory tasks with high accuracy do not always report late right-frontal effects (e.g. Swick, Senkfor & Van Petten, 2006, although see Allan et al., 1998). One functional account of the right frontal old/new effect relates it to the monitoring of the outcomes of retrieval in order to ensure responding is appropriate (see Chapter 2), and is supported by a greater right frontal effect for old items associated with relatively impoverished information (Rugg, Allan & Birch, 2000). In the current experiment, there was no direct evidence that the overall amount of information that was recollected varied for the high and low accuracy groups. Nonetheless, individuals who monitor this information to a greater extent may be more likely to make an accurate response as a result of doing so.

Concluding Comments

Participants completed two recognition memory tasks in each of which all old items were associated with the same study history. This design was employed to determine whether electrophysiological indices of strategic retrieval processes would relate to accuracy in a recognition task. For all participants, behavioural responding was superior in the function task. Small differences between new item ERPs from each test phase appeared for the subset of participants who made relatively more correct responses. The size of an earlier occurring new item ERP effect was related to the extent to which performance on the two tests was matched. Specifically, engaging in this earlier set of processes was related to an increase in magnitude of the electrical index of recollection for drawing information and an improvement in accuracy on the associated task. The findings provide further support for the relationship between strategic retrieval processing and the recovery of contextual details.

Table 7.2: Outcomes of global ANOVAs for old/new effects in each time window. Key: GP = accuracy group, RC = response category, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom in brackets.

	300-500	500-800	800-1100	1100-1400
RC	F(1,34) = 17.27 ***	F(1,34) = 8.63 ***	F(1,34) = 6.41 *	-
RC x AP	-	F(1,34) = 8.63 **	-	-
RC x HM	-	F(1,34) = 7.94 **	F(1,34) = 5.41 *	-
RC x ST	-	F(2,66.9) = 11.67 ***	-	-
GP x RC x ST	-	-	-	F(2.3,76.8) = 3.03 *
RC x AP x HM	-	-	-	F(1,34) = 5.28 *
RC x AP x ST	-	-	F(2.8,96.1) = 4.30 **	F(2.8,96.8) = 5.14 **
RC x HM x ST	-	-	F(3.2,107.3) = 2.793 *	-

Table 7.4: Outcomes of global ANOVAs for relative difficulty contrasts for ERP new item effects in each time window. Key: GP = relative difficulty group, TS = task, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$. Degrees of freedom in brackets.

	100-300	300-500	500-800
GP x TS	F(1,34) = 6.04 *	-	-
GP x TS x ST	F(1.2,41) = 5.27 *	-	-
TS x AP x HM	-	F(1.6,55.3) = 3.95 *	-
GP x TS x AP x HM	-	-	F(1.9,65.1) = 6.83 **
GP x TS x AP x ST	F(3.4,116.1) = 2.59 *	-	-
GP x TS x HM x ST	-	F(2.1,72.2) = 3.28 *	-

Table 7.5: Values for Pearson's R relating ERP new item difference score amplitudes (function minus drawing) at right central and parietal sites (Cz, C2, C4, C6, Pz, P2, P6, P4) with the index of relative difficulty. All tests were two-tailed. * = p<0.05, ** = p<0.01, *** = p<0.001.

	Epoch		
Site	100-300	300-500	500-800
Cz	-0.42*	-0.43**	-0.45**
C2	-0.48**	-0.43*	-0.41*
C4	-0.46**	-0.37*	-0.34*
C6	-0.38*	-0.34*	-
Pz	-0.54**	-0.38*	-
P2	-0.49**	-	-
P4	-0.47**	-	-
P6	-	-	-

Table 7.6: Outcomes of global ANOVAs for old/new effects separated according to relative difficulty group and retrieval task. Key: GP = relative difficulty group, TS = task, RC = response category, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$. Degrees of freedom in brackets.

	300-500	500-800	800-1100	1100-1400
RC	F(1,34) = 17.93 ***	F(1,34) = 27.88 ***	F(1,34) = 8.45 **	-
RC x AP	-	F(1,34) = 7.65 **	-	-
RC x HM	-	F(1,34) = 6.16 **	-	-
RC x ST	-	F(2.1,71.3) = 7.76 **	-	-
GP x RC x HM	F(1,34) = 6.25 *	-	-	-
TS x RC x HM	F(1,34) = 5.30 *	F(1,34) = 8.74 **	F(1,34) = 5.57 *	F(1,34) = 5.27 *
RC x AP x HM	-	-	-	F(1,34) = 6.03 *
RC x AP x ST	-	-	F(2.7,93.4) = 2.80 *	F(2.6,89.3) = 3.83 *
GP x TS x RC x AP x HM	-	F(1,34) = 4.61 *	-	-

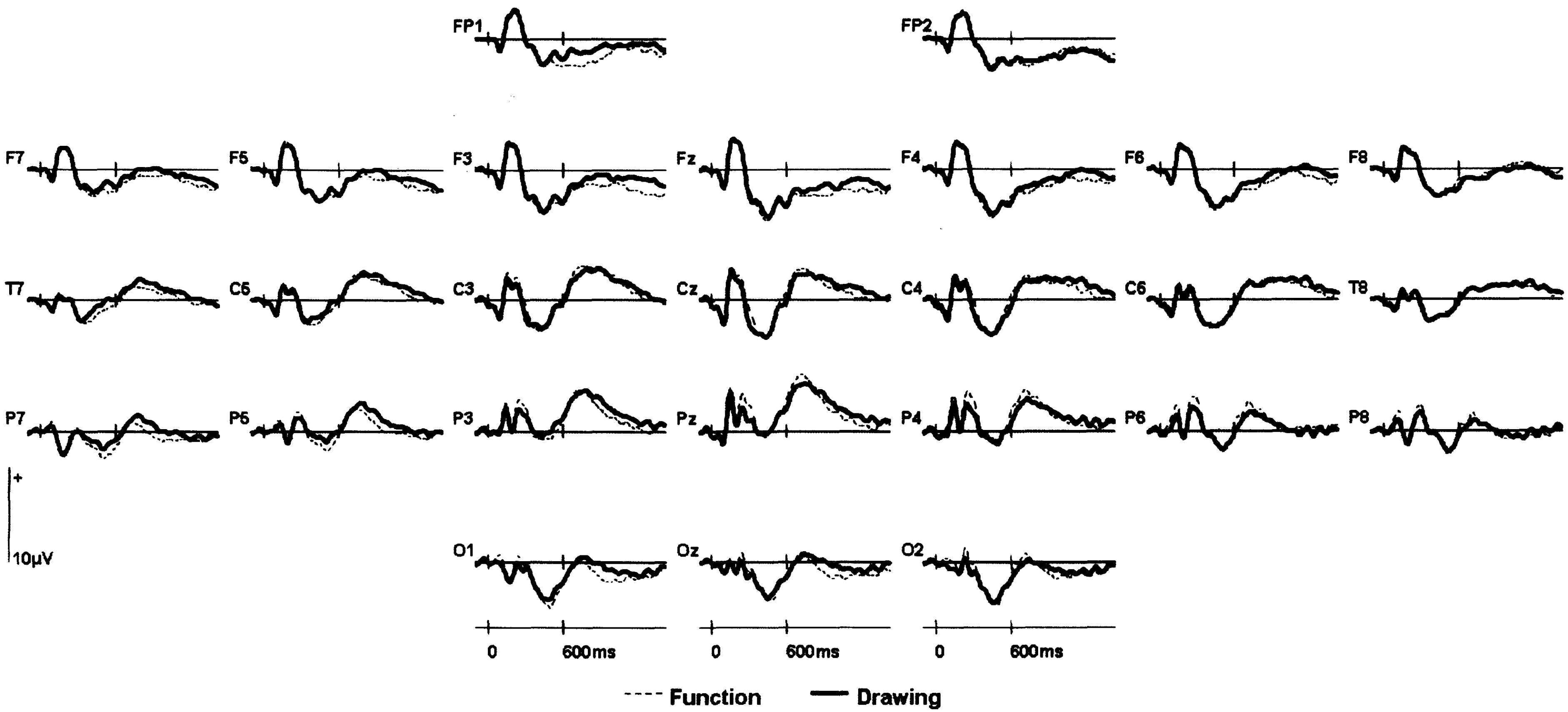

Figure 7.2: Grand average ERPs elicited by correct rejections in the two retrieval tasks for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

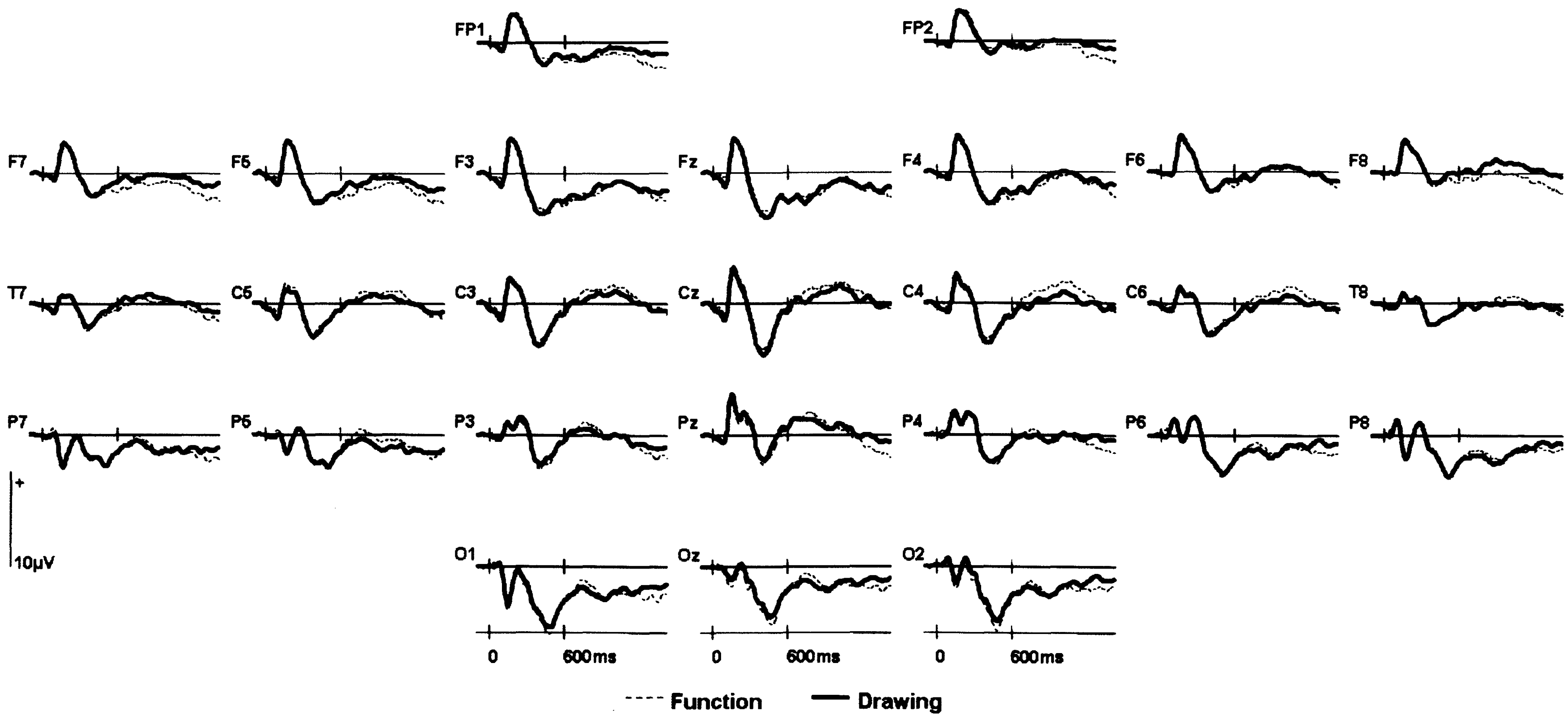

Figure 7.3: Grand average ERPs elicited by correct rejections in the two retrieval tasks for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

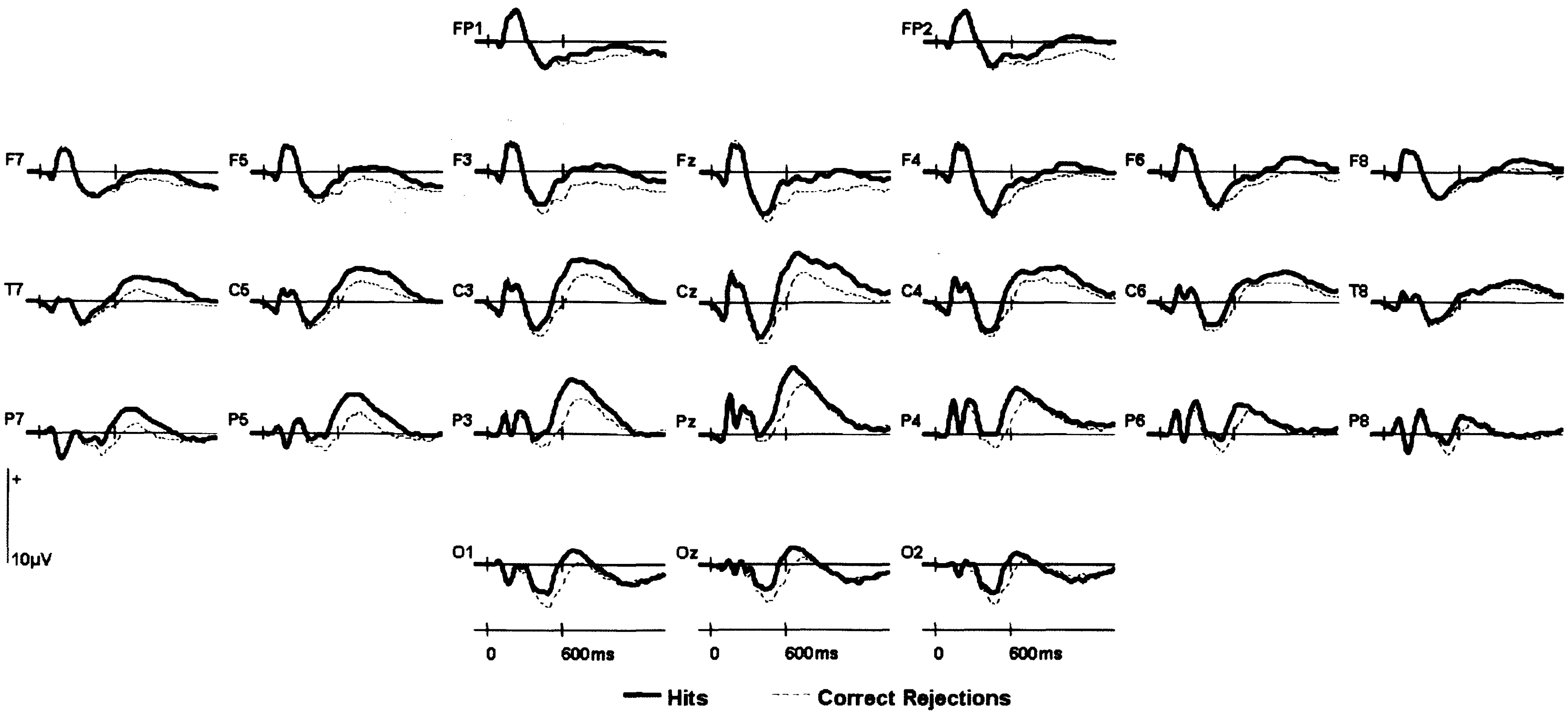

Figure 7.5: Grand average ERPs elicited by hits and correct rejections collapsed across the two retrieval tasks for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

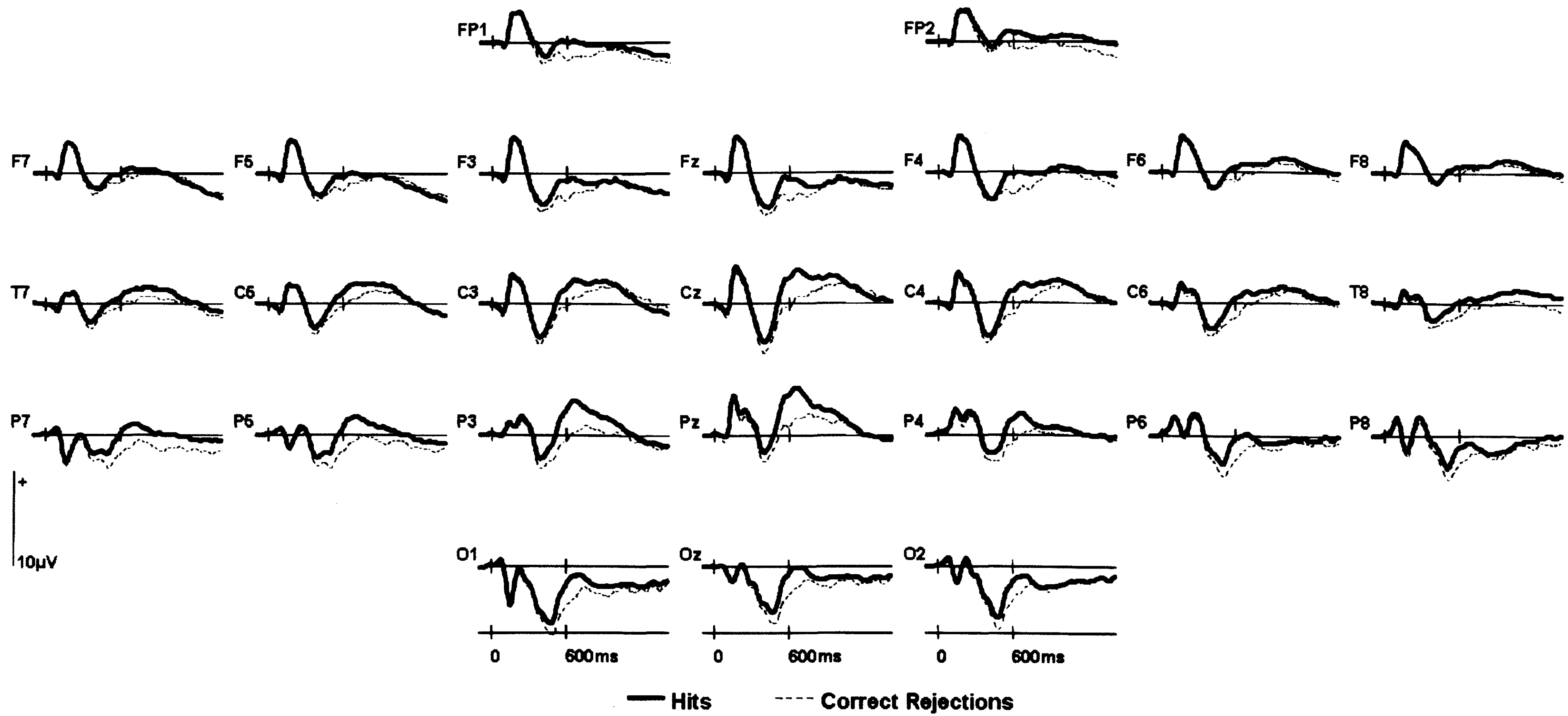

Figure 7.6: Grand average ERPs elicited by hits and correct rejections collapsed across the two retrieval tasks for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

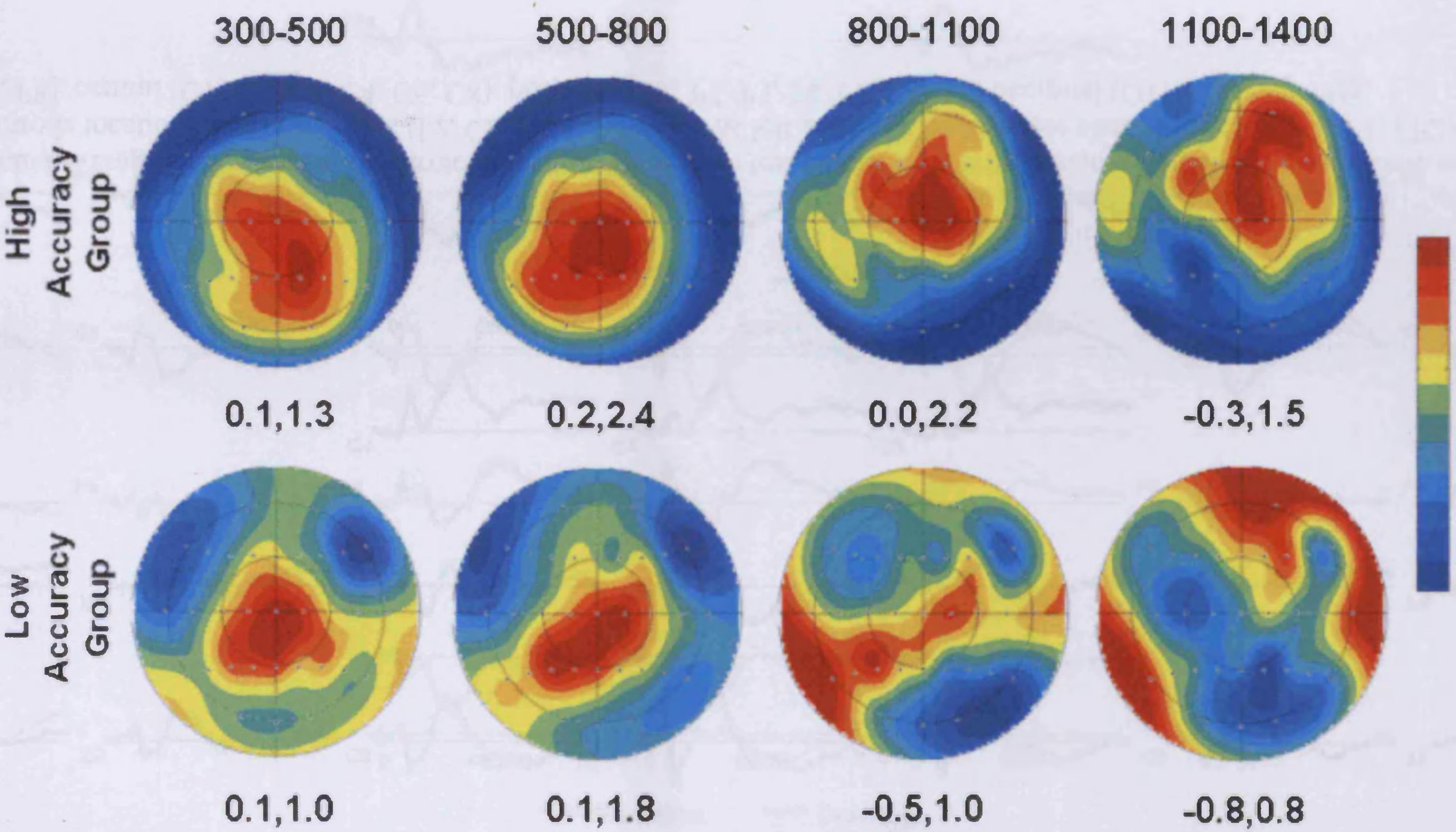

Figure 7.7: Topographic maps showing the scalp distributions of the differences between neural activity elicited by hits and correct rejections for the high and low accuracy groups. Maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by new items from those elicited by hits, and are shown for four time windows (300-500, 500-800, 800-1100, 1100-1400). Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

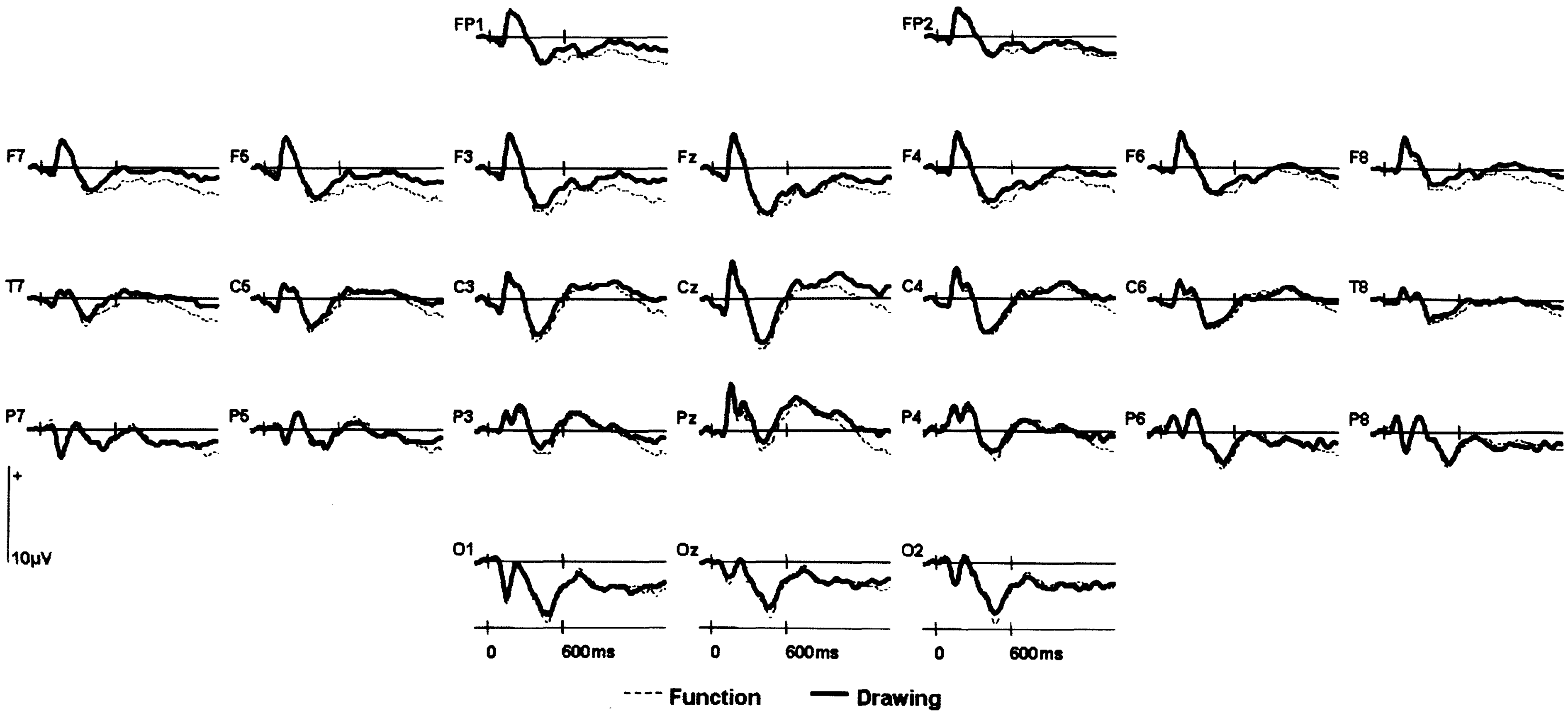

Figure 7.8: Grand average ERPs elicited by correct rejections in the two test phases for the high relative difficulty group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

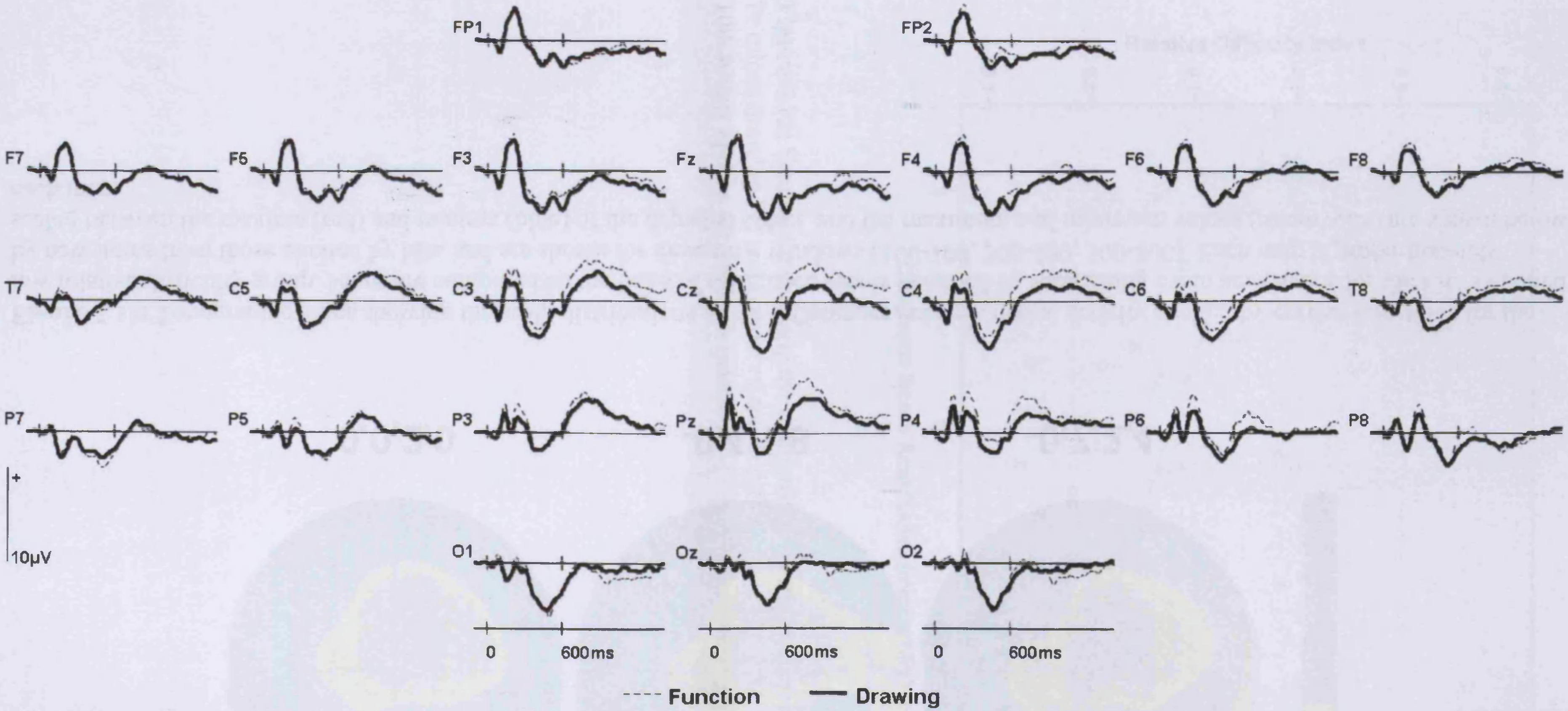

Figure 7.9: Grand average ERPs elicited by correct rejections in the two test phases for the low relative difficulty group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

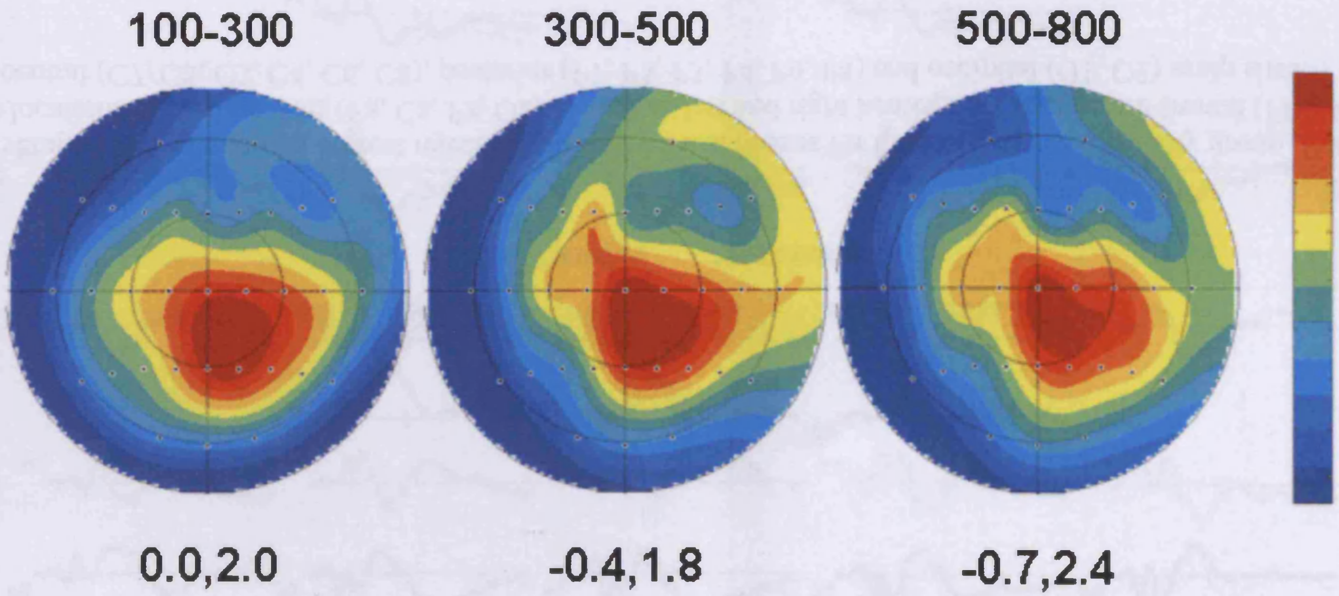

Figure 7.11: Topographic maps showing the scalp distributions of the differences between neural activity elicited by correct rejections for the low relative difficulty group. Maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by new items from those elicited by hits, and are shown for three time windows (100-300, 300-500, 500-800). Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

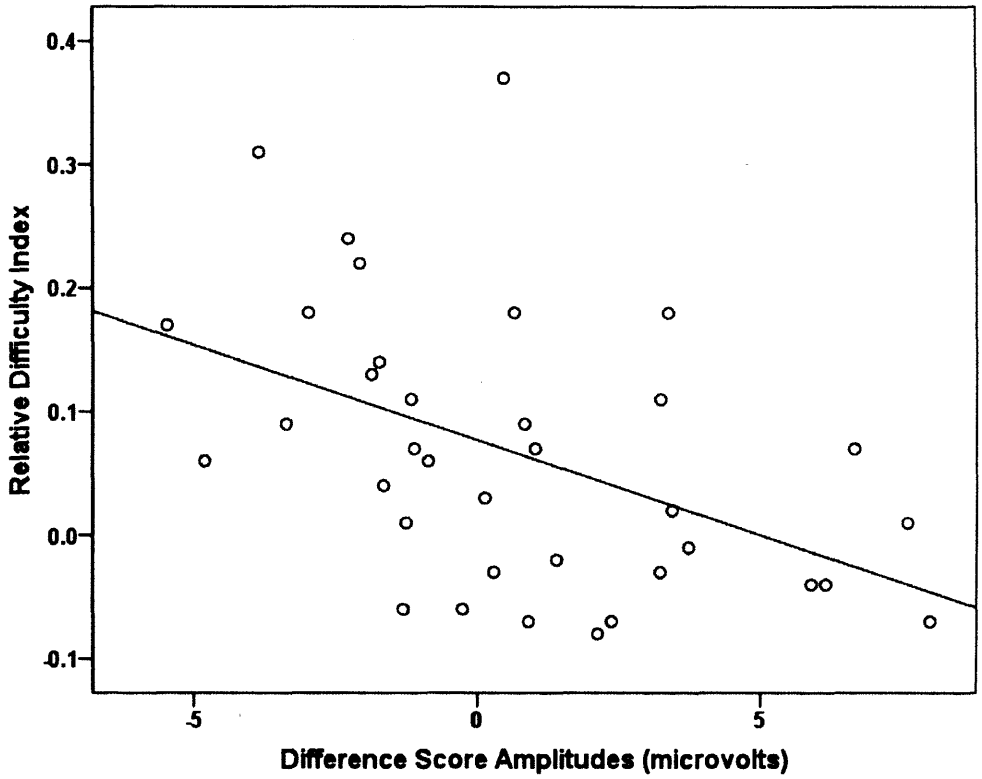

Figure 7.12: Scatterplot showing the relationship between relative difficulty (function Pr minus drawing Pr) and correct rejection difference score amplitudes at Cz in the 100-800ms epochs for 36 participants.

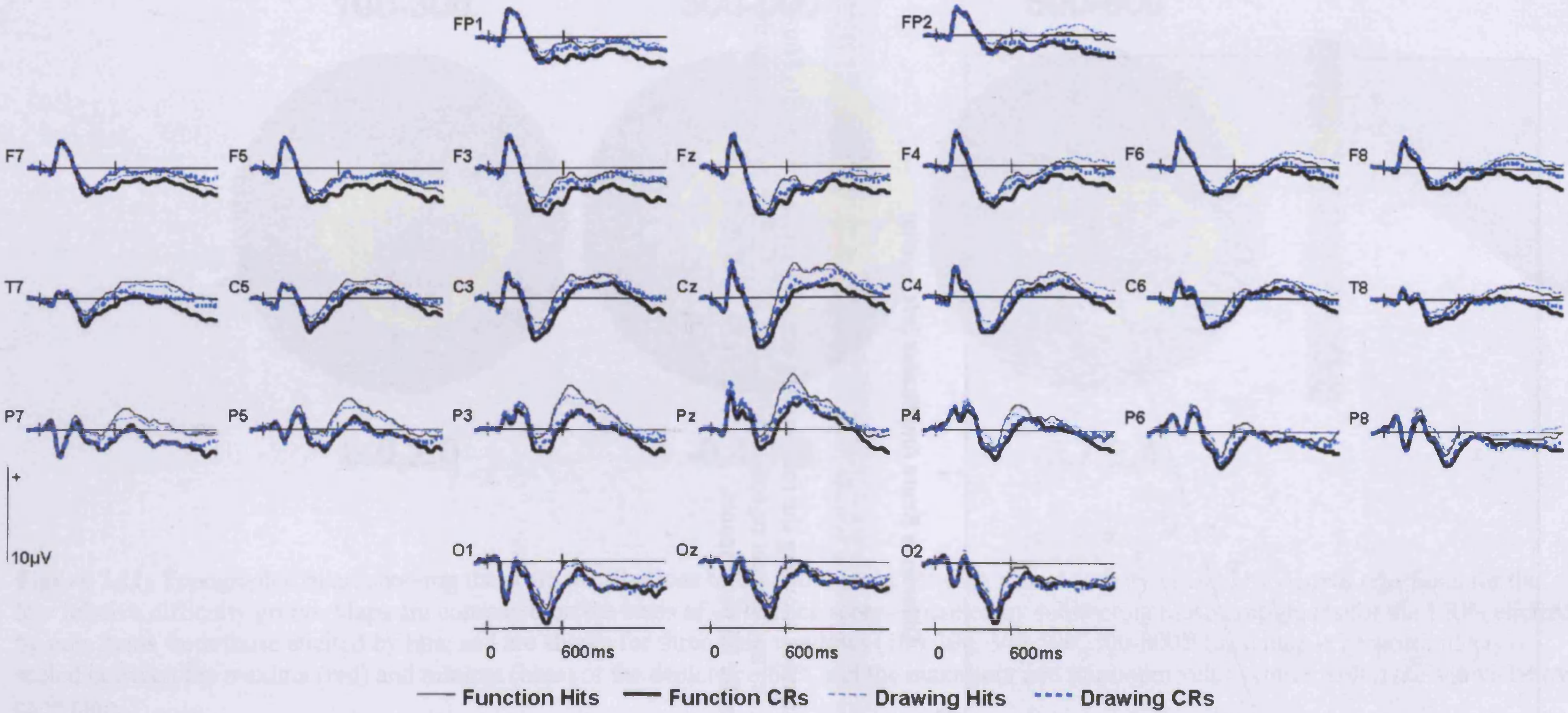

Figure 7.14: Grand average ERPs elicited by hits and correct rejections (CRs) in both test phases for the high relative difficulty group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

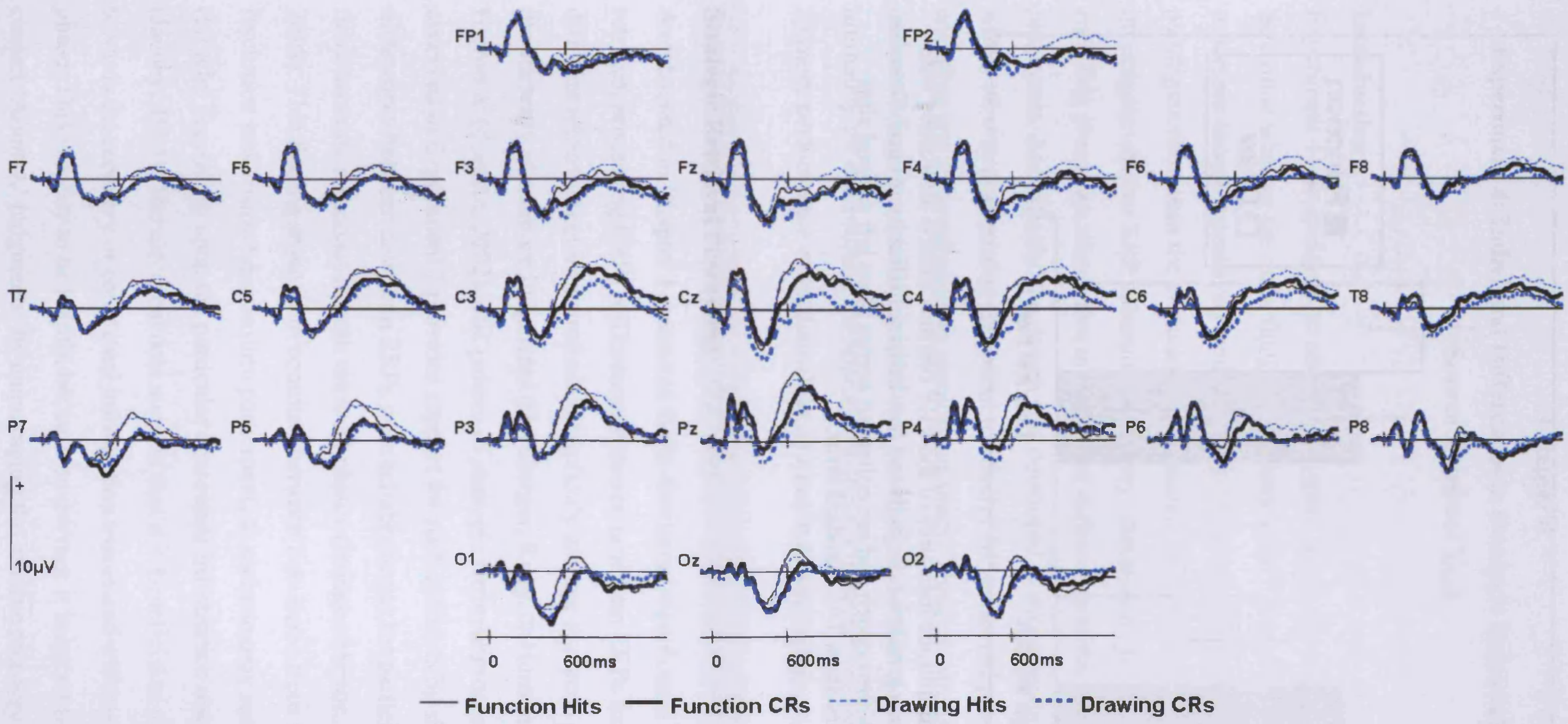

Figure 7.15: Grand average ERPs elicited by hits and correct rejections (CRs) in both test phases for the low relative difficulty group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

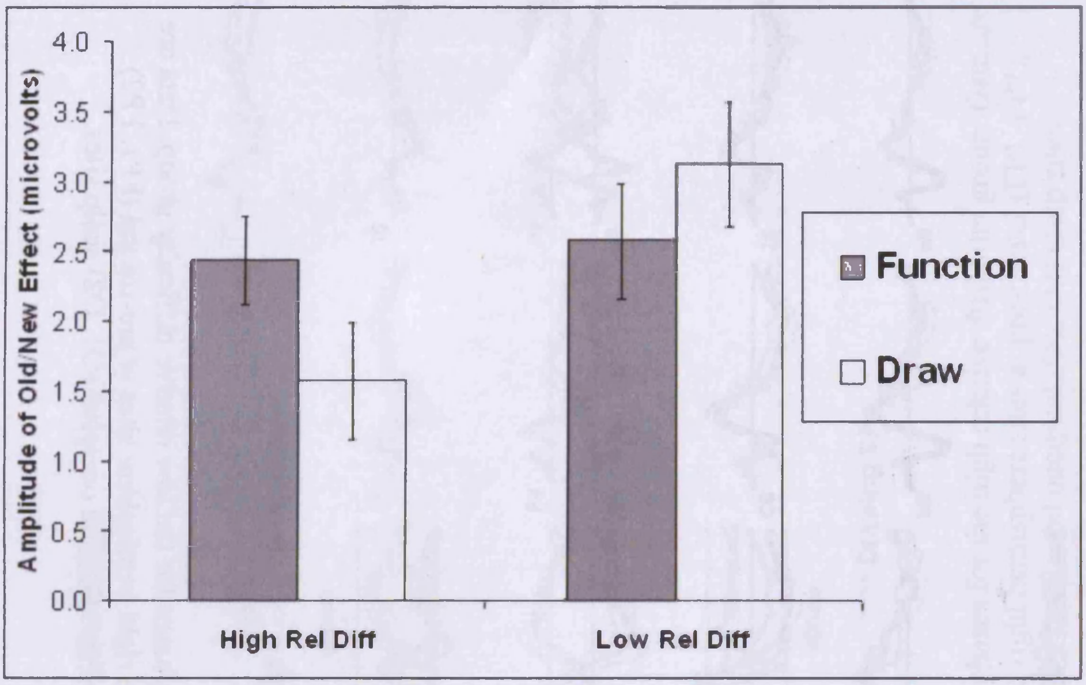

Figure 7.16: Mean amplitude measures of the ERP old/new effects associated with the function and drawing task for the high and low relative difficulty groups. Data are shown for the 500–800ms epoch and are collapsed across three left parietal sites (P5/P3/P1). Error bars show 1+/- standard error.

Chapter 8

Experiment 4: Individual Differences in Strategic Retrieval Processing in a Source Retrieval Task

Introduction

Experiment 4 was designed to address two main issues. First, it was designed to determine whether the main finding in Experiment 1 - that strategic retrieval processes correlate positively with response accuracy - generalises to source retrieval paradigms other than the exclusion task. Second, this experiment was designed to investigate whether ERP subsequent memory effects, thought to index critical encoding processes, also relate to individual differences in the accuracy of memory judgments. Accordingly, the design was developed to accommodate both questions with a view to determining the extent to which ERP indices of processes engaged at encoding and retrieval relate to memory accuracy. These questions are important for understanding the relationships between encoding and retrieval operations, and ultimately for determining the appropriate loci for interventions that may improve memory performance or mediate deterioration in normal aging.

Strategic Retrieval Processing

As recounted in Chapter 1, accounts of the functional significance of strategic retrieval processing ERPs (differences between new item ERPs from test phases with different retrieval requirements) often implicitly assume that such processes benefit the accuracy of memory judgments (Hornberger, Rugg, & Henson, 2006; Rugg, Herron & Morcom, 2002). The pattern of strategic retrieval processing ERPs observed in Experiment 1 provides support for such accounts by showing that differences between new item ERPs were reliably larger for participants who made more accurate responses in both retrieval phases (Bridger, Herron, Elward & Wilding, 2009). This finding arose from contrasts between new items from two exclusion tasks. Exclusion task instructions require participants to endorse only some old items as old (targets) depending upon the particular contextual information associated with them (Jacoby, 1991). The electrical data suggest that it is beneficial to direct processing towards the recovery of contextual information associated with targets in each test phase. This is likely to be helpful because on average it helps participants to make correct 'A/not-A' judgments, by encouraging the relative recovery of 'A' information.

If some 'A' information is recovered, an affirmative response can be made, but if none is returned then a negative response can be given.

In line with this, strategic retrieval processes are also likely to relate positively to response accuracy in other tasks that also require participants to respond according to the contextual information associated with each item. The following paradigm was developed in order to determine whether this is the case. Participants took part in a number of study-test blocks in which they interacted with items associated with two orthogonally-manipulated contextual features. Items were presented on the left or the right side of the screen (*location* feature) and in addition, participants performed one of two cognitive tasks on each item (*operation* feature); a pleasantness judgment or a drawing difficulty judgment. All items from each study phase were repeated in the following test block interleaved with new items, and participants had to make an initial old/new judgment and a combined feature/confidence judgment for all items to which an initial old judgment was made. For half of the test blocks the second feature judgment was made according to the item's study location while for the remainder the judgments were made according to the study operation.

The critical contrast was between ERPs elicited by new items from these two retrieval phases to ascertain, firstly, whether participants processed retrieval cues differently depending upon the class of source information required, and secondly, whether the amplitude of these differences varied according to response accuracy. This latter point was addressed by splitting participants into two groups depending upon their relative response accuracy. If directing the processing of retrieval cues towards a particular class of source information is beneficial to the recovery of relevant and differentiated source details there should be a positive relationship between the adoption of strategic retrieval processing (as indexed by ERPs) and the accuracy of source judgments. In addition to this analysis it was also possible, as in Experiments 1 and 3, to investigate the ways in which ERP old/new effects vary with overall response accuracy in a source retrieval task.

Subsequent Memory ERPs

The findings reported in Experiments 1 and 3 indicate that processing engaged during retrieval is related to the recovery of contextual information and increases in response accuracy. One possibility is that the ability to adopt strategic retrieval processing is dependent upon the efficiency or manner in which participants initially encoded items. If this is the case then determining the strategies employed during retrieval is likely to provide only a partial understanding of the factors which influence response accuracy. In line with this, many theories of episodic memory stress the importance of the way in which stimuli are initially processed as a determinant of overall memory performance. Support for these theories comes from data on the engagement of encoding strategies in individual differences research (for a review see Richardson, 1998). These include behavioural demonstrations that particular rehearsal strategies are related to later recall (Shaughnessy, 1981; Geiselman, Woodward & Beatty, 1982) and that certain operations such as imaginal or verbal encoding strategies are differentially related to performance (McDaniel & Kearney, 1984). A number of findings are in line with Craik & Lockhart's emphasis on the role of semantic or 'deep' processing for memory performance (Craik & Lockhart, 1972, see Chapter 1) by indicating that individuals who engage elaborative processes perform better on memory tasks with verbal material than those who do not report using such strategies (Shaughnessy, 1981; Camp, Markley & Kramer, 1983). Neuroimaging data consistent with this comes from one fMRI study in which activity in neural regions associated with the engagement of strategies such as verbal elaboration was correlated with overall memory accuracy (Kirchhoff & Buckner, 2006).

A number of memory models also stress the importance of the relationship between encoding and retrieval processes on response accuracy, such as those that highlight the recapitulation of specific encoding processes at retrieval (Thomson & Tulving, 1970; Morris, Bransford & Franks, 1977; Kent & Lamberts, 2008). It is because of the intimate relationship between the engagement of processes at encoding and retrieval that it is necessary to develop designs that allow examination of the cognitive operations that participants engage at both of these critical stages in order to determine the ways in which they interact to affect memory judgments.

In studies in which ERPs have been used to investigate memory encoding the focus has been on a class of contrasts called subsequent memory (SM) effects (Paller, Kutas & Mayes, 1987; Friedman & Johnson, 2000; Wilding & Sharpe, 2003). SM effects arise from contrasts between ERPs recorded during the initial presentation of items that are either later remembered or forgotten. The assumption is that reliable differences between these classes of ERPs index operations that determine whether an item will be accurately responded to subsequently, and thus these contrasts provide an appropriate starting point for an investigation into the neural bases of individual differences in encoding processing as indexed by ERPs.

Subsequent memory effects have been shown to vary according to the way in which stimuli are processed (Otten & Rugg, 2001) as well as the phenomenal experience accompanying the knowledge that an item has been encountered previously (e.g. Duarte, Ranganath, Winward, Hayward & Knight, 2004). Relatively little is known, however, about the way in which the processing indexed by these contrasts contributes to later memory. If the processes indexed by SM effects determine whether an item is remembered or not, then one possibility is that individuals who tend to make more correct memory judgments do so because they engage in these processes more often and to a greater degree than other participants. If this is the case then the relative amplitude of subsequent memory effects should be larger for those participants who make more correct source judgments. There may also be a relationship between the greater engagement of these processes and ERP indices of strategic retrieval processing. To determine whether this is the case, ERPs recorded during the initial presentation of items in each study phase were sorted subsequently depending upon whether they were associated with confident operation and location source judgments. Participants were again split into groups depending upon the proportion of correct source judgments they made, and where reliable SM effects were observed, analyses were conducted to determine whether the amplitude of these effects varied with accuracy.

Method

Participants

These were 40 (8 male) students. Four participants (2 male) were excluded because they contributed insufficient artefact-free trials for the critical contrast, due to excessive EOG artefacts. The mean age of the remaining participants was 21 years (range 18-25).

Design

Three hundred and thirty-six words were used in this experiment. Words were allocated randomly to sixty mini-lists containing 6 words each. Mini-lists were combined to create 10 sets, with each set comprising the stimuli for one study-test block. Within each set, 24 words (4 mini-lists) were to be shown at study and 36 (all 6 mini-lists) were to be shown at test. The 4 mini-lists to be shown at study corresponded to all the possible combinations of study task and location. Three complete experiment lists were created by rotating (within each block) whether words were encountered at test only or at study in the pleasantness or drawing conditions. Two additional lists were created from each of these three initial lists by rotating whether words were to be new or encountered on the left or right of the screen at study. This procedure resulted in the formation of 9 complete experiment lists. Lateralisation of stimulus presentation was controlled such that words were shown on the same side consecutively no more than three times.

Procedure

Each study trial began with a 750ms cue specifying which of two tasks were to be conducted on the subsequent word. The cue 'PLEASANT?' required participants to judge whether they found the following word pleasant or unpleasant, and the cue 'DRAW?' required a judgment about how easy the object denoted by the word would be to draw. After each operation cue, a blank screen was presented for 500ms before an asterisk presented to the left or the right came onscreen for 300ms. The screen was blanked for a further 500ms before a word was presented for 300ms. The screen was blanked again while participants made two responses to each item. The first response corresponded with the cognitive operation previously cued and the second judgment was to specify which side of the screen the word had been presented on. After these responses a 1000ms blank screen was presented before a final centred asterisk appeared for 500ms.

At test, all items were presented in the centre of the screen. A test trial began with a 300ms asterisk, followed by a 500ms blank screen and the test word for 300ms. The screen was blanked while participants made their initial old/new judgment. After this response, the screen remained blank for a further 1000ms before a 300ms question mark prompted a four-way response judgment. Two distinct source retrieval instructions were provided and participants were instructed which to perform before each test block. When instructed to follow the operation instructions participants made a four-way '*confident pleasantness*', '*think pleasantness*', '*think drawing*' and '*confident drawing*' judgment. When told to follow the location instructions, the response options were '*confident left*', '*think left*', '*think right*' and '*confident right*'.

Participants engaged in two practice phases prior to the experiment in order to familiarise themselves with the hand-response mapping when either location or operation information was to be retrieved. Participants were not informed of which retrieval instructions to perform until immediately before each test block.

EEG was recorded with the parameters outlined in the General Methods section (Chapter 4). ERPs were recorded time-locked to the onset of words at both study and test.

ERP Analysis Strategy

In order to interrogate ERP data according to accuracy differences, participants were split into two groups depending upon the proportion of correct source judgments that they made. Specifically, participants were separated according to the conditional probability that they made a correct source judgment (hereon referred to as a *hit-hit*) regardless of response confidence and retrieval task. This split was performed separately for the analysis of ERPs in the study and test phase, because eight participants generated insufficient trials for the former analysis due to a low proportion of misses. As a result, the data from only 28 participants were included for the SM analyses. The size of each class of ERP effects - differences between new item ERPs, ERP old/new effects and differences between remembered and forgotten ERP items - were contrasted across the high and low accuracy groups. In order to determine whether any differences in the amplitude of ERP effects across groups extend to the level of each individual, the amplitude of each participant's new item effects, old/new effects and subsequent memory effects were also correlated with the probability with which a correct source judgment was made The exact data points employed for each of these correlation analyses are described in Appendix I.

Due to limited trial numbers, ERP old/new effects were constrained to contrasts between high confidence hit-hits and correct rejections. These analyses were performed in the same four epochs used for all other analyses, and where a significant interaction including the factors of accuracy group and response category occurred, further analyses were conducted within each group.

For the subsequent memory analysis, ERPs were allocated to 'remembered' and 'forgotten' bins. Items in the remembered category consisted solely of those to which correct source judgments had been made with high confidence (cf. Otten & Rugg, 2001). Trials in the 'forgotten' category consisted of all items to which incorrect old/new and source responses were made, as well as items for which correct source judgments were made with low confidence. This approach is in line with data from studies which indicate a significant proportion of low confidence responses consist of guesses (Otten & Rugg, 2001). Recording the confidence with which participants make recognition memory judgments allows these guesses, which would otherwise be distributed across both remembered and forgotten response categories, to be specifically allocated to the forgotten group, increasing the power of the ERP contrasts to detect real processing differences (Wilding & Sharpe, 2003).

Results

Behaviour

Study

Participants always made an operation response before a location response. First responses were reliably longer than second responses (1276 vs. 683ms, $t(27) = 6.56$, $p<0.001$). Responses were faster for subsequently remembered words (operation: 1266 vs. 1316ms; location: 652 vs. 713ms) but these differences were not significant (both $t(27) < 1.67$).

Test

Table 8.1 (below) shows the mean proportions of correct rejections as well as the proportions of source/confidence responses for all old items correctly termed old (hits) separated for the two retrieval tasks. Table 8.2 (below) shows the proportions of correct responses to these five response categories, collapsed across retrieval task but separated for the high and low accuracy groups. Appendix H shows the same data for the 28 participants who contributed sufficient trials for the subsequent memory contrasts. Behavioural analyses are reported for all 36 participants below because the pattern demonstrated by the 28 participant group was the same (and is reported in Appendix H).

Table 8.1: Mean proportions of correct rejections, hit-hits and hit-misses separated according to retrieval task and high and low confidence. Standard deviations are shown in parentheses.

	Retrieval Task	
	Operation	Location
P(CR)	0.94 (0.07)	0.94 (0.06)
P(Hit-hit: high)	0.73 (0.14)	0.55 (0.19)
P(Hit-hit: low)	0.15 (0.11)	0.29 (0.15)
P(Hit-miss: high)	0.07 (0.09)	0.05 (0.07)
P(Hit-miss: low)	0.05 (0.04)	0.10 (0.07)

An initial ANOVA on Pr values (p[hit] – p[FA]) with factors of group (high/low), and retrieval task (operation/location) showed that correct responding was greater in the high group ($F(1,34) = 9.84$, $p<0.01$) but did not differ for the two tasks. Mean Br values for the high accuracy group were 0.47 and 0.54 for the operation and location tasks, respectively. The comparable Br scores were 0.41 and 0.49 for the low accuracy group and these scores did not differ reliably across group or retrieval task. Hits were submitted to a mixed ANOVA with factors of group (high/low), retrieval task (operation/location), source accuracy (hit-hit/hit-miss) and response confidence (high/low). High confidence responses were more likely than low confidence responses ($F(1,34) = 56.03$, $p<0.001$) and hit-hits more likely than hit-misses ($F(1,34) = 1795.76$, $p<0.001$). The latter effect was moderated by an interaction between source accuracy and group ($F(1,34) = 35.73$, $p<0.001$), because the likelihood of making a correct source judgment was superior in the high accuracy group. There were also further interactions between retrieval task and response confidence ($F(1,34) = 86.56$, $p<0.001$), source accuracy and response confidence ($F(1,35) = 156.82$, $p<0.001$) as well as a three-way interaction between retrieval task, source accuracy and response confidence ($F(1,34) = 27.26$, $p<0.001$).

Table 8.2: Mean proportions of correct rejections, hit-hits and hit-misses separated according to accuracy group and high and low confidence. Standard deviations are shown in parentheses.

	Accuracy Group	
	High	Low
P(CR)	0.95 (0.05)	0.93 (0.07)
P(Hit-hit: high)	0.68 (0.16)	0.62 (0.20)
P(Hit-hit: low)	0.24 (0.15)	0.21 (0.16)
P(Hit-miss: high)	0.03 (0.03)	0.09 (0.10)
P(Hit-miss: low)	0.06 (0.04)	0.09 (0.07)

Bonferroni-corrected t-tests (corrected alpha level $p<0.003$) were conducted within and across tasks in order to break this interaction down. All contrasts were significant (minimum $t(35) = 3.37$, $p<0.003$) except for the following: high confidence hit-misses did not differ for the two tasks, and hit-misses in the operation task did not differ with response confidence. These analyses show that participants used the confidence scale differently for the two tasks, and were more likely to make high confidence hit-hits in the operation task, as shown in Table 8.1.

Table 8.3 (below) shows the reaction times associated with correct responses for the response categories presented in Table 8.1. Analysis of reaction times also comprised two ANOVAs. An initial ANOVA conducted upon hits and correct rejections with factors of accuracy group (high/low), retrieval task (operation/location) and response category (old/new), showed that correct responses to new items were faster than correct responses to old items ($F(1,35) = 7.93$, $p<0.01$). A second ANOVA on hits, with factors of group (high/low), retrieval task (operation/location), response accuracy (hit-hit/hit-miss) and response confidence (high/low) revealed a main effect of response confidence ($F(1,34) = 39.90$, $p<0.01$) because initial old/new judgments to items attracting high confidence source judgments were made more quickly (1027 vs. 1407). There was also a main effect of retrieval task ($F(1,34) = 5.15$, $p<0.05$) because responses were faster in the location task. There were no reliable effects involving group.

Table 8.3: Mean reaction times for correct rejections and hits. For hits, reaction times are separated according to source accuracy (hit-hits or hit-misses), retrieval task and high and low confidence. Standard deviations in parentheses.

	Retrieval Task	
	Operation	Location
CR	1037 (257)	990 (217)
Hit-hit: high	1059 (247)	968 (231)
Hit-hit: low	1333 (443)	1182 (345)
Hit-miss: high	1011 (302)	1182 (336)
Hit-miss: low	1401 (641)	1222 (523)

To summarise the behavioural data, correct source judgments were more likely in the high than the low accuracy group. Although participants used the confidence scales differently in the two retrieval tasks, source accuracy was not affected by retrieval task. Responses were quicker for correct rejections than hits, as well as for responses later given with high rather than low confidence. Responses given in the location task were also quicker than those given in the operation task.

ERP Analyses

The first of the following sections deals with the contrasts between ERPs elicited by new items from the operation and location retrieval tasks, in order to determine whether there are any reliable differences between them and if so whether the size of these effects relates to response accuracy. The subsequent section presents the contrasts between the amplitudes of ERP old/new effects in a number of time windows across the high and low accuracy groups. The final section deals with ERPs elicited by words presented at study, separated according to the responses given to these items when re-presented at test. The size of reliable subsequent memory effects were also contrasted across high and low accuracy groups.

ERPs elicited by New Items

Figure 8.1 (below) depicts the grand average waveforms elicited by correct rejections in the two retrieval tasks for both accuracy groups (see also Figures 8.2 and 8.3). For both groups, a frontal negativity is slightly enhanced for correct rejections from the operation task from around 300-500ms. A centro-parietal positivity from 500-900ms is somewhat larger for correct rejections in the location task for the high group at midline sites, whereas it is relatively larger for operation correct rejections for the low accuracy group. Towards the end of the recording epoch (~900ms), for the high accuracy group, a greater relative positivity for new items in the location source task appears predominantly at right hemisphere sites. There is a trend for this in the low accuracy group as well, although the distribution is more anterior with a slight left lateralisation.

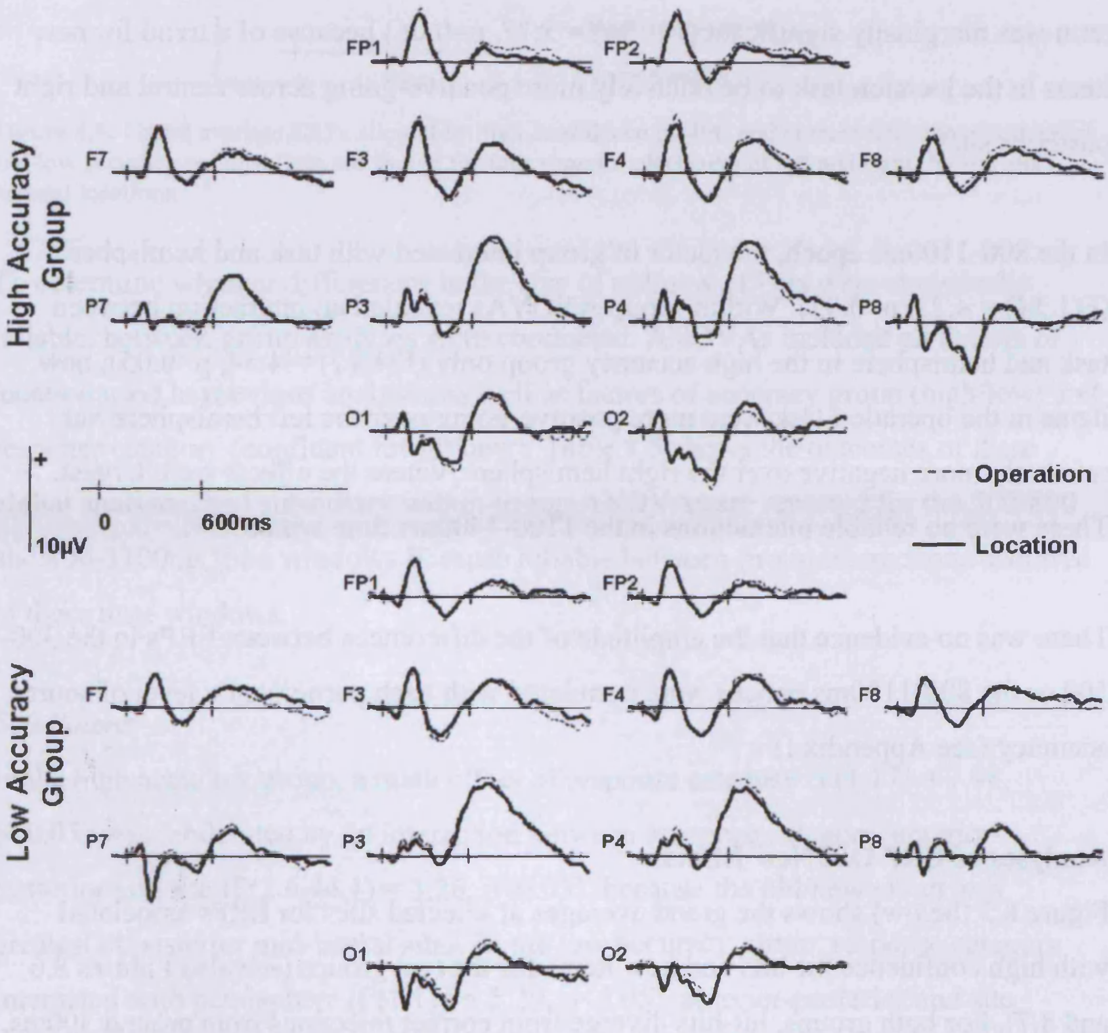

Figure 8.1: Grand average ERPs elicited by correct rejections in the two retrieval tasks for the high and low accuracy groups. Data are shown for 12 electrode locations.

Table 8.4 shows the mean numbers of trials contributing to the grand average ERPs for each participant and response category. For each epoch, a global analysis was conducted with factors of accuracy group (high/low), retrieval task (operation/location), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior). Reliable interactions including the factor of retrieval task indicate the engagement of differential retrieval cue processing across tasks.

In the first (300-500ms) time window, an interaction between retrieval task, anterior-posterior and hemisphere was significant ($F(1,34) = 4.22$, $p<0.05$). The scalp maps in Figure 8.4 show that this interaction occurred because new items in the operation task were relatively more negative-going at left centro-anterior sites, whereas they were more positive at posterior sites. In the 500-800ms time window, this same interaction term was marginally significant ($F(1,34) = 3.77$, $p=0.06$) because of a trend for new items in the location task to be relatively more positive-going across central and right posterior sites.

In the 800-1100ms epoch, the factor of group interacted with task and hemisphere ($F(1,34) = 4.23$, $p<0.05$). Within-group ANOVAs revealed an interaction between task and hemisphere in the high accuracy group only ($F(1,17) = 4.54$, $p<0.05$); new items in the operation task were more positive-going over the left hemisphere but relatively more negative over the right hemisphere, where the effects were largest. There were no reliable interactions in the 1100-1400ms time window.

There was no evidence that the amplitude of the differences between ERPs in the 300-500 or the 800-1100ms epochs were correlated with each participant's level of source accuracy (see Appendix I).

Analyses of ERP Old/New Effects

Figure 8.5 (below) shows the grand averages at selected sites for ERPs associated with high confidence hit-hits and new items for the two groups (see also Figures 8.6 and 8.7). For both groups, hit-hits diverge from correct rejections from around 300ms, predominantly at centro-parietal sites. This divergence takes the form of a greater positivity for hits than correct rejections until 600ms, when hits become more negative-going at central and posterior sites. A left parietal positive deflection around 600ms is greater for hit-hits in the low accuracy group. A late posterior negativity (LPN) for old items appears from 700ms remaining until the end of the recorded epoch, in the low accuracy group only. Towards the end of the recorded epoch, old items are more positive than new items at right frontal sites, and this effect is larger for the high accuracy group.

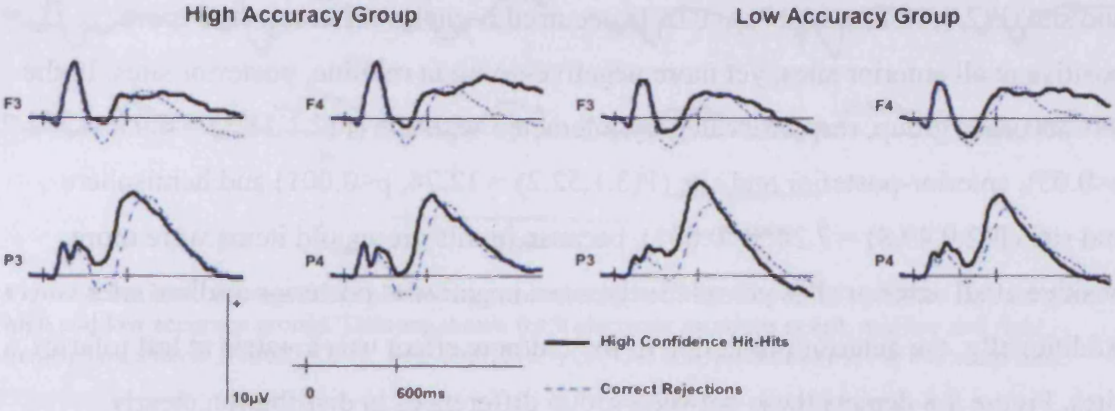

Figure 8.5: Grand average ERPs elicited by high confidence hit-hits and correct rejections for the high and low accuracy groups. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

To determine whether differences in the size of old/new effects were statistically reliable, between-group analyses were conducted. ANOVAs included all factors of location used in previous analyses as well as factors of accuracy group (high/low) and response category (confident hit-hit/new). Table 8.5 shows the outcomes of these global analyses, and subsidiary within-group ANOVAs are reported for the 500-800 and 800-1100ms time windows because reliable between-group interactions occurred in these time windows.

500-800ms

In the high accuracy group, a main effect of response category ($F(1,17) = 7.98$, $p<0.05$) was moderated by an interaction between response category, anterior-posterior and site ($F(2.6,44.1) = 3.26$, $p<0.05$), because the old/new effect was greatest at posterior mid-lateral sites. In the low accuracy group, response category interacted with hemisphere ($F(1,17) = 5.29$, $p<0.05$), anterior-posterior and site ($F(2.9,49.9) = 2.87$, $p<0.05$) and hemisphere and site ($F(2.9,48.8) = 6.12$, $p<0.01$), because the effect for this group was maximal at inferior posterior sites and was left lateralised.

800-1100ms

In the high accuracy group, a response category and site interaction ($F(2.2,38) = 5.56$, $p<0.01$), moderated by an interaction between response category, anterior-posterior and site ($F(2.9,49.1) = 10.17$, $p<0.001$) occurred because old items were more positive at all anterior sites, yet more negative-going at midline, posterior sites. In the low accuracy group, response category interacted with site ($F(2.1,35.1) = 4.95$, $p<0.05$), anterior-posterior and site ($F(3.1,52.2) = 12.74$, $p<0.001$) and hemisphere and site ($F(2.9,49.8) = 7.24$, $p<0.001$), because in this group, old items were more positive at all anterior sites yet relatively more negative at posterior midline sites. Additionally, the anterior projection of the old/new effect was greatest at left inferior sites. Figure 8.8 depicts these between-group differences in distribution clearly.

Appendix I describes the data points that were used to determine whether these differences extended to the level of the individual participant. There was no evidence to support this.

Analyses of Subsequent Memory Effects

Figure 8.9 (below) shows ERPs to remembered and forgotten operation task items for the high and low accuracy groups (see also Figures 8.10 and 8.11). For both groups, ERPs begin to diverge around 300ms post-stimulus predominantly at anterior locations but becoming more widespread later in the recorded epoch. ERPs associated with remembered operation items were more positive-going than forgotten items, a pattern that remains until the end of the recorded epoch. The effect is larger and has a more anterior distribution in the high accuracy group, especially from 900-1100ms (see Figure 8.9).

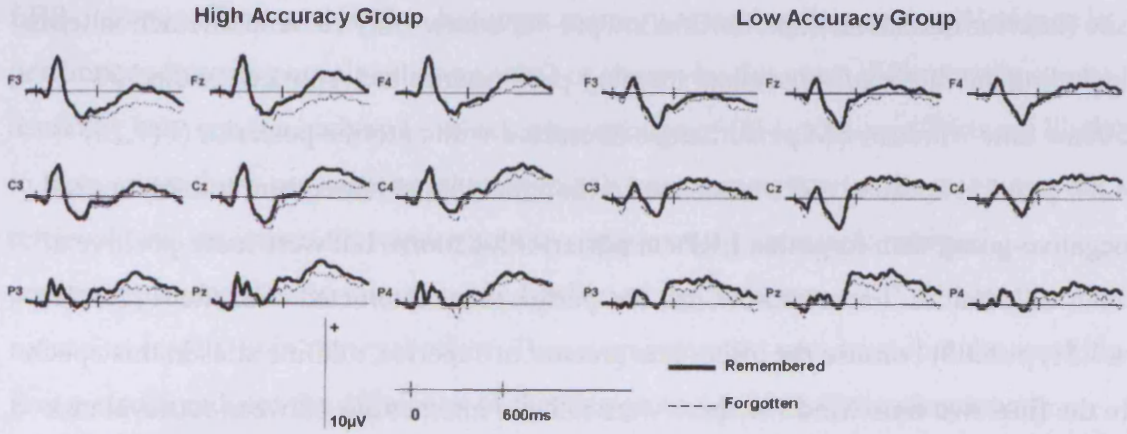

Figure 8.9: Grand average ERPs elicited by remembered and forgotten in the operation task for the high and low accuracy groups. Data are shown for 9 electrode locations at left, midline and right hemisphere sites at frontal (F3, Fz, F4), central (C3, Cz, C4) and, posterior (P3, Pz, P4) scalp sites.

Figure 8.12 (below) shows SM contrasts for the high and low accuracy group in the location task (see also Figures 8.13 and 8.14). Divergences occurred from around 300ms post-stimulus and for both groups take the form of more positive-going ERPs to forgotten than remembered items. In the high accuracy group, this effect is distributed predominantly at right hemisphere sites and remains until the end of the recording epoch. A similar distribution is present for the low accuracy group although the effect has a more posterior distribution.

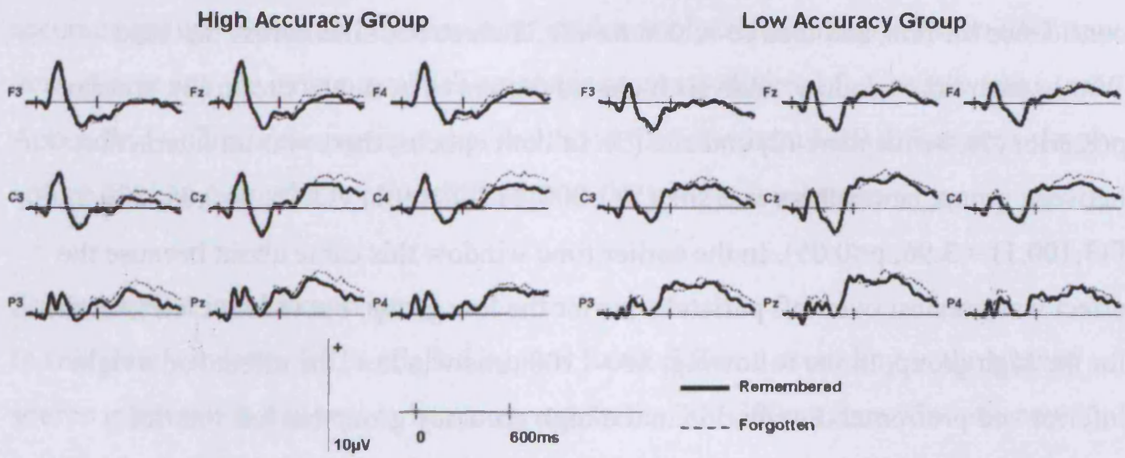

Figure 8.12: Grand average ERPs elicited by remembered and forgotten in the location task for the high and low accuracy groups. Data are shown for 9 electrode locations at left, midline and right hemisphere sites at frontal (F3, Fz, F4), central (C3, Cz, C4) and, posterior (P3, Pz, P4) scalp sites.

Within each time window, analyses included factors of accuracy group (high accuracy/low accuracy), retrieval task (operation/location), subsequent memory (SM) performance (remembered/forgotten), anterior-posterior, hemisphere (left/right) and site (inferior/midlateral/superior/midline/pre-superior). Only reliable interaction terms including the factor of subsequent memory performance are reported. In the 300-500ms time window, SM performance interacted with anterior-posterior ($F(1,26) = 4.84$, $p<0.05$) because ERPs associated with remembered items were reliably more negative-going than forgotten ERPs at posterior locations, but were more positive at anterior locations. From 500-800ms, SM performance interacted with site ($F(2.7,71) = 3.51$, $p<0.05$) because the effect was greatest at superior, midline sites in this epoch. In the final two time windows there were reliable interactions between retrieval task and SM performance (800-1100, $F(1,26) = 6.23$, $p<0.05$; 1100-1400, $F(1,26) = 4.46$, $p<0.05$). These interactions occurred because remembered ERPs were relatively more positive than forgotten ERPs in the operation task but relatively more negative-going in the location task. Subsequent memory effects did not interact with accuracy group in any time windows. This was corroborated by the null outcomes of correlational analyses of these same effects (see Appendix I).

Analyses of Scalp Distributions

These were performed on the old/new distributions for the two groups in the 500-800 and 800-1100ms time windows. The data submitted to these analyses were difference scores, computed by subtracting new item ERPs from those elicited by high confidence hit-hits, and then re-scaled for all 32 electrode sites across the head. Within each time window, analysis included factors of accuracy group (2), anterior-posterior (2), hemisphere (2) and site (5). In both epochs, there was an interaction between group, hemisphere and site (500-800, $F(2.9,100.1) = 3.16$, $p<0.05$; 800-1100, $F(3,100.1) = 3.96$, $p<0.05$). In the earlier time window this came about because the effect was greatest over left parietal sites for the low group, but was not left lateralised for the high group. In the following, 800-1100 time window, the effect had a right inferior and prefrontal distribution in the high accuracy group but left inferior distribution in the low accuracy group (see Figure 8.8).

Discussion

Behaviour

Participants were split into two equal sized groups depending upon the proportion of correct source judgments they made. These groups were used to determine whether there were any differences in the size of ERP indices of strategic retrieval processes, ERP old/new effects and ERP subsequent memory effects with accuracy. Variance in performance across participants was small as shown by the mean difference in source accuracy between the high and low accuracy groups of 0.11. Ceiling effects are likely to have arisen from precautions taken to match source accuracy for the two types of retrieval task, an important requirement in experiments of strategic retrieval processing undertaken to minimise the likelihood that new item ERP differences reduce to correlates in retrieval effort. This is an important provision, but the resulting low variance reduces the efficiency of this design as a vehicle for teasing apart electrical differences across accuracy groups.

Although the proportions of correct source responses did not differ for the two retrieval tasks, participants' use of the confidence scale did differ; correct source judgments were more likely to be made with high confidence in the operation retrieval task. Changes in the confidence with which judgments are made may be taken as an indicator of differences in the difficulty of the two retrieval tasks. It is unlikely, however, that the differences between new item ERPs observed in this design relate directly to between-task differences in difficulty, for two reasons. Firstly, differences between new item ERPs from 800-1100ms were reliable only in the high accuracy group while use of the confidence scale was the same for both accuracy groups. Secondly, there was no evidence of a relationship between ERP new item effects and the extent to which response accuracy differed for the two tasks (see Appendix I). This argues against the likelihood that new item ERP differences simply reduce to changes in the relative difficulty of the two retrieval tasks.

Strategic Retrieval Processing

In two time windows, ERPs elicited by new items differed according to the type of source information that was to be recovered. In the 300-500ms time window, new item ERPs in the operation retrieval task were more negative-going at left anterior sites, but relatively more positive-going over right hemisphere sites. This effect was independent of participants' response accuracy. A later effect in the 800-1100ms time window was reliable only for the subset of participants who made relatively more correct source responses. For these participants, the effect was characterised by relatively more positive-going new item ERPs in the location retrieval task at right posterior sites. Unlike the accuracy-related indices of strategic retrieval processing reported in Experiment 1, the magnitude of the differences between new item ERPs at right posterior sites did not significantly relate to participants' individual response accuracy. Despite this, the between-group differences in the later time window indicate that participants who continue to process retrieval cues in line with contextual information later in the epoch performed better on the source retrieval task.

The earlier occurring differences between new item ERPs were insensitive to participants' response accuracy, and may reflect processing concerned with the shifting of attention towards certain contextual features (Hillyard & Münte, 1984). Early differences between new items from retrieval tasks with different task requirements have been previously reported even in tasks in which episodic retrieval is not required explicitly (Hornberger et al., 2006), and such divergences suggest that participants are able to draw upon contextual features even at early processing stages. This early effect may indicate that some ERP indices of strategic retrieval processing are not engaged to a variable degree across participants, although the low behavioural variability in this study may have obscured between-group differences. The second effect that was present only for high performers, however, demonstrated a right posterior distribution, indicating the engagement of an additional set of processes by these participants. It is not clear whether these index the later onset of additional attention mechanisms or processes that encourage the re-instatement of the same operations that were engaged at encoding, in line with evidence that recapitulating such processes encourages retrieval of certain information (Morris, Bransford & Franks, 1977; Kent & Lamberts, 2008). Nonetheless, the data indicate that participants who continue to process classes of new items differently later in the epoch made more accurate source memory judgments.

The mean amplitude differences between new item ERPs were very small (approximately half a microvolt), a pattern that differs markedly from the sizeable indices of strategic retrieval processing observed for high accuracy participants in the exclusion task in Experiment 1. The most marked difference between response requirements in the exclusion task and the source retrieval paradigm here is that source judgments are required about all items in the exclusion task. In the design employed here, participants were only explicitly required to retrieve source information for items judged to be old. If participants use a strategy in which they attempt to recover source information only once they have determined whether an item is old, then it is less likely that new item ERP differences indexing processes important for accurate source judgments will be detected between retrieval tasks (Wilding, 1999). Only one of the 36 participants explicitly reported such a strategy in a post-test questionnaire, but this does not preclude the likelihood that other participants did so to some degree, or perhaps somewhat automatically. Further experiments in this vein should be designed to enable contrasts between new items from test phases of source retrieval paradigms in which participants make one three-way judgment (e.g. new/sourceA/sourceB), in order to determine whether the pronounced ERP new item effects reported in Experiment 1 are particular to the retrieval conditions imposed in the exclusion task.

ERP Old/New Effects

The scalp distribution of the parietal effect in the 500-800ms time window demonstrated a left lateralization in the low accuracy group only. Rescaled scalp analysis in this epoch suggested that not entirely the same neural processors were engaged for the two groups. Over left parietal sites where the effect was maximal in this epoch, the amplitude was greater in the low accuracy group. The left parietal effect has consistently been associated with recollection (e.g. Woodruff, Hayama & Rugg, 2006), and increases in its amplitude have been associated with the recollection of greater amounts of information (Wilding, 2000; Vilberg & Rugg, 2009). The recovery of more diagnostic source information is likely to be associated with superior performance in a source retrieval paradigm, making it somewhat surprising that the group who performed relatively poorly should demonstrate a more pronounced left parietal effect. One possibility is that whereas this group recollected more information overall, only a proportion of the retrieved material was pertinent to the relevant task. If lower performers are recollecting a larger proportion of non-criterial information then it would be necessary to engage post-retrieval mechanisms to a relatively greater degree in order to extract the relevant information to make appropriate source judgments.

Functional accounts of frontal old/new effects in the subsequent time window have been related to post-retrieval mechanisms of this kind (Friedman & Johnson, 2000), and between-group variations in the amplitude of this old/new effect may provide insight into the engagement of these processes. Notably, the frontal old/new effect in this 800-1100ms epoch was larger in the high relative to the low accuracy group. Late frontal ERP old/new effects are likely to index a host of heterogeneous functions (e.g. Friedman & Johnson, 2000) but are often thought to index processes downstream of recollection related to the requirement to make source judgments, because they are most often reported in source retrieval paradigms (Cruse & Wilding, 2009). The observation that this effect is greater in the high accuracy group suggests that participants who engage in such processing to a greater degree are more likely to make accurate source judgments, perhaps because this effect signals the continued monitoring of task-relevant source features. This observation, however, rules out accounts of late frontal effects that associate the effect with inhibition of task-irrelevant information because it is larger for a group who are less likely to require such operations, on the basis of the findings for the left parietal old/new effect. The critical findings for the late frontal ERP effects were changes in sensitivity to accuracy group across epoch, supporting the assertion that frontal ERP effects are likely to index a diverse group of processes in these tasks (Duncan & Owen, 2000), some of which relate to variability in performance.

The second (between-group) difference in the 800-1100ms time window was a larger late posterior negativity (LPN) in the low relative to the high accuracy group. The time course of the LPN also relates it to processes that operate downstream of recollection and the effect is thought to index multiple processes (Herron, 2007), including the reinstatement of contextual information (Mecklinger, Johansson, Parra, & Hanslmayr, 2007). The engagement of processes such as these is likely to be of benefit when recollected information is poorly differentiated. Akin to the interpretation for the enhanced left parietal old/new effect for the low accuracy group proposed above, this assumes that an increase in the amount of information that is recollected does not necessarily mean more task-relevant source-specifying details are recollected. One possibility, therefore, is that engaging these processes is a compensatory measure following the recovery of insufficiently distinct/relevant details. It is unlikely that this effect is related to processes associated with response conflict because they were elicited by items to which high confidence correct source judgments were made.

Subsequent Memory Effects

Reliable subsequent memory (SM) effects were observed from 300ms until the end of the recording epoch. Importantly, SM effects were only observed when demands at retrieval were taken into account; the effects took the form of more positive-going remembered ERPs in the operation task, but more negative-going remembered ERPs in the location task, relative to forgotten items. The amplitude of the operation SM effects appeared to be somewhat larger in the high accuracy group, but there was no statistical evidence that the size of either effect differed with accuracy group.

There are several design factors, however, that may have contributed to the failure to find reliable between-group differences in the analyses of the SM effects. These factors include, but are not limited to, the low variability in memory accuracy across the two groups, and the smaller sample size for this analysis than for the retrieval data analyses. Detection of SM effects requires contrasts between two ERP conditions compared across two tasks, a process that is likely to contribute additional noise that is not present when single condition between-task contrasts are made, such as those used to index strategic retrieval processing in new item ERP contrasts at test. Furthermore, elements of the design that were implemented to enhance the signal: noise ratio of retrieval ERPs reduced the sensitivity of the design to subsequent memory ERP effects. Specifically, the relatively high rates of source accuracy that were adopted to promote matching accuracy for the two tasks had the effect of reducing the overall proportion of forgotten trials, influencing negatively the signal: noise ratio. It is also the case that variation in the use of the confidence scale across the two retrieval tasks suggests that not all low confidence correct source responses were guesses, especially in the location retrieval task, in turn reducing the likelihood of obtaining between-group SM differences.

The most appropriate design for investigations along these lines will involve the use of tasks that promote greater behavioural variability, alongside lower overall levels of response accuracy, as well as response categories which ensure that trials are allocated to the most appropriate categories to obtain robust SM effects (Wilding & Sharpe, 2003). In particular, it may be necessary to use a paradigm in which items are associated with only one of two sources because this would allow for comparison of SM effects that are specific to a certain encoding task, without collapsing over specific source information such as left/right as was necessary in the current design. It may be that there are both qualitative as well as quantitative differences in the pattern of SM effects across accuracy groups. A critical future goal is to develop designs that allow measurement of the way in which processes at encoding and retrieval engage with one another.

That having been said, although SM effects were not found to differ in size for the two accuracy groups, the polarity of the differences between remembered and forgotten items reversed according to the instructions implemented at retrieval. This difference indicates that participants drew upon distinct aspects of encoding episodes to make judgments about these different sources. Otten & Rugg (2001) have previously reported SM effects that differ with the tasks employed at encoding. The authors interpreted these different encoding effects as evidence that qualitatively distinct neural processes supported memory for these two classes of information. The current findings emphasize that SM effects can also vary according to retrieval demands even when study conditions are kept constant. This is likely to come about because the different retrieval requirements tapped into unique elements of the neural processes that were engaged at the time of encoding, highlighting the interactive relationship between encoding and retrieval processes.

Concluding Comments

A number of source memory tasks were employed to begin untangling the role that processes engaged at both retrieval and encoding play in the accuracy of memory judgments. Participants completed a series of study-test blocks in which they initially encountered words associated with two orthogonally manipulated pieces of contextual information: both a cognitive operation and a specific screen location. Items were presented again at test along with new items, and for old items participants were required to make a further source/confidence judgment. Within each test block, these source judgments only ever required the recovery of information about one of the two contexts (operation or location). ERPs associated with new items from these two test phases differed in two nonconsecutive time windows. The later manifestation of these differences was reliable only for participants who made relatively more accurate source judgments, in line with accounts which state that the strategic retrieval processes indexed by such contrasts relate beneficially to the recovery of mnemonic information.

The amplitude differences between the ERP indices of subsequent memory were not found to vary with participants' accuracy. Subsequent memory ERP effects did, however, differ according to the type of information that was to be retrieved. This design and its associated findings stress the complexity of developing paradigms that allow conjoint measurement of neural markers of encoding and retrieval processes as well as the importance of fully describing the relationship between the two for ensuing memory judgments.

Table 8.4: Mean numbers of trials per accuracy group and response category. Range in parentheses. Trial numbers for remembered and forgotten categories are shown only for the twenty-eight participants with sufficient forgotten trials (N=14 in each accuracy group).

		Accuracy Group	
Response Category	Retrieval Task	High	Low
Correct Rejections	Operation	45 (36-54)	43 (25-56)
	Location	46 (19-56)	43 (25-58)
Confident Hit-hits	Operation	71 (29-96)	62 (38-93)
	Location	56 (26-88)	45 (23-81)
Remembered	Operation	65 (47-89)	53 (32-85)
	Location	46 (22-67)	41 (23-78)
Forgotten	Operation	27 (16-48)	33 (16-64)
	Location	46 (22-74)	48 (23-76)

Table 8.5: Outcomes of global ANOVAs for comparisons between ERPs associated with high confidence hit-hits and correct rejections in each time window. Key: GP = accuracy group, RC = response category, HM = hemisphere, AP = anterior-posterior, ST = site. Outcomes are shown only for those terms that included a reliable interaction involving the factor RC in at least one time window. * = p<0.05, ** = p<0.01.

	300-500	500-800	800-1100	1100-1400
RC	F(1,34) = 50.27 **	F(1,34) = 7.73 **	-	-
RC x AP	F(1,34) = 5.18 *	F(1,34) = 5.95 *	F(1,34) = 4.68 *	F(1,34) = 30.60 **
RC x HM	F(1,34) = 15.66 **	-	-	-
RC x ST	F(2.1,71.4) = 14.02 **	-	F(2.3,77) = 10.31 **	F(2.8,94.9) = 7.71 **
RC x AP x HM	-	-	-	F(1,34) = 17.99 **
RC x AP x ST	-	F(3,101.9) = 5.94 **	F(3.2,107.3) = 22.68 **	F(3.2,108) = 23.69 **
RC x HM x ST	F(3.1,106.4) = 5.25 **	-	F(3,100.9) = 3.66 *	F(3.1,105.7) = 2.94 *
GP x RC x HM x ST	-	F(2.9,100.1) = 3.17 *	F(3,100.9) = 3.97 *	-

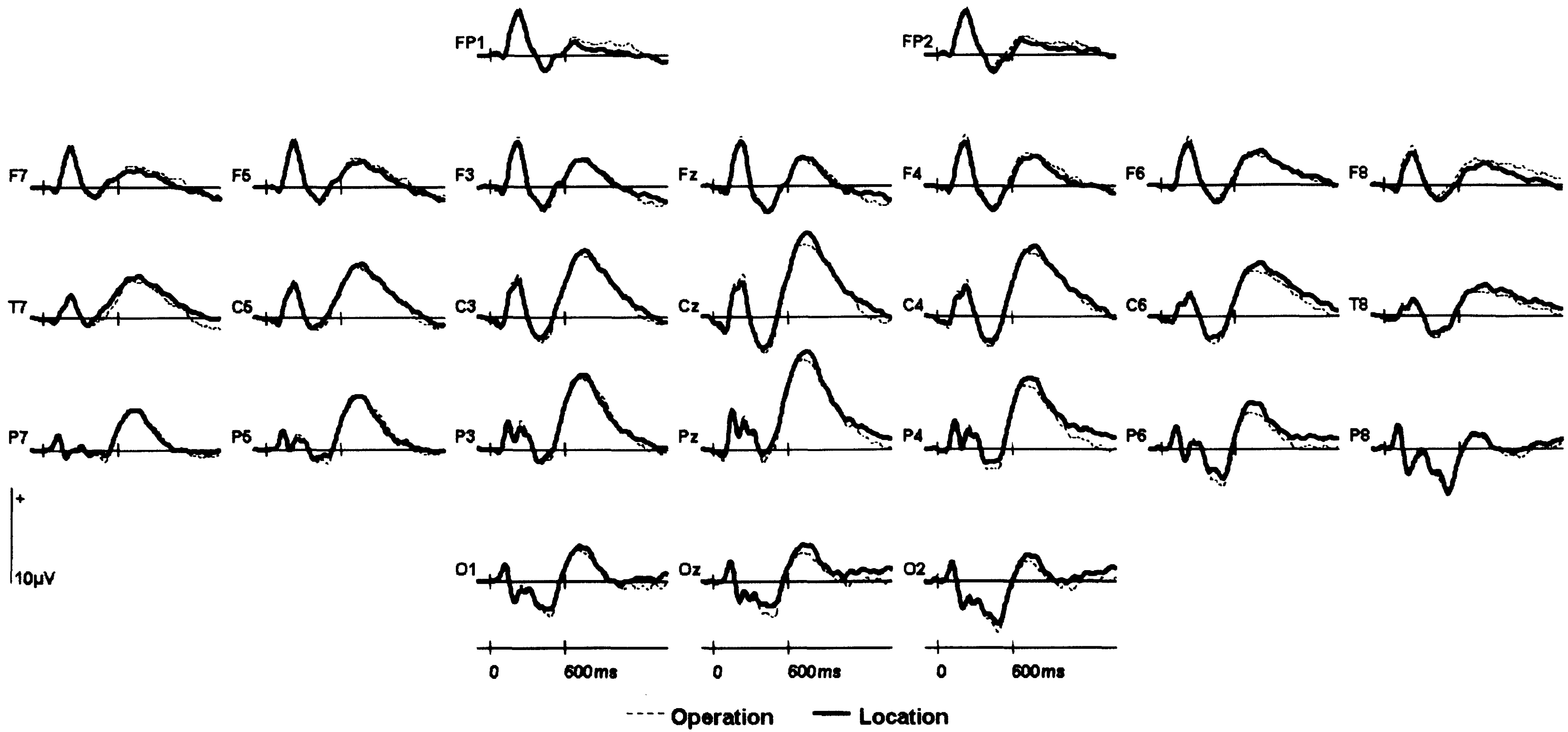

Figure 8.2: Grand average ERPs elicited by correct rejections in the two retrieval tasks for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

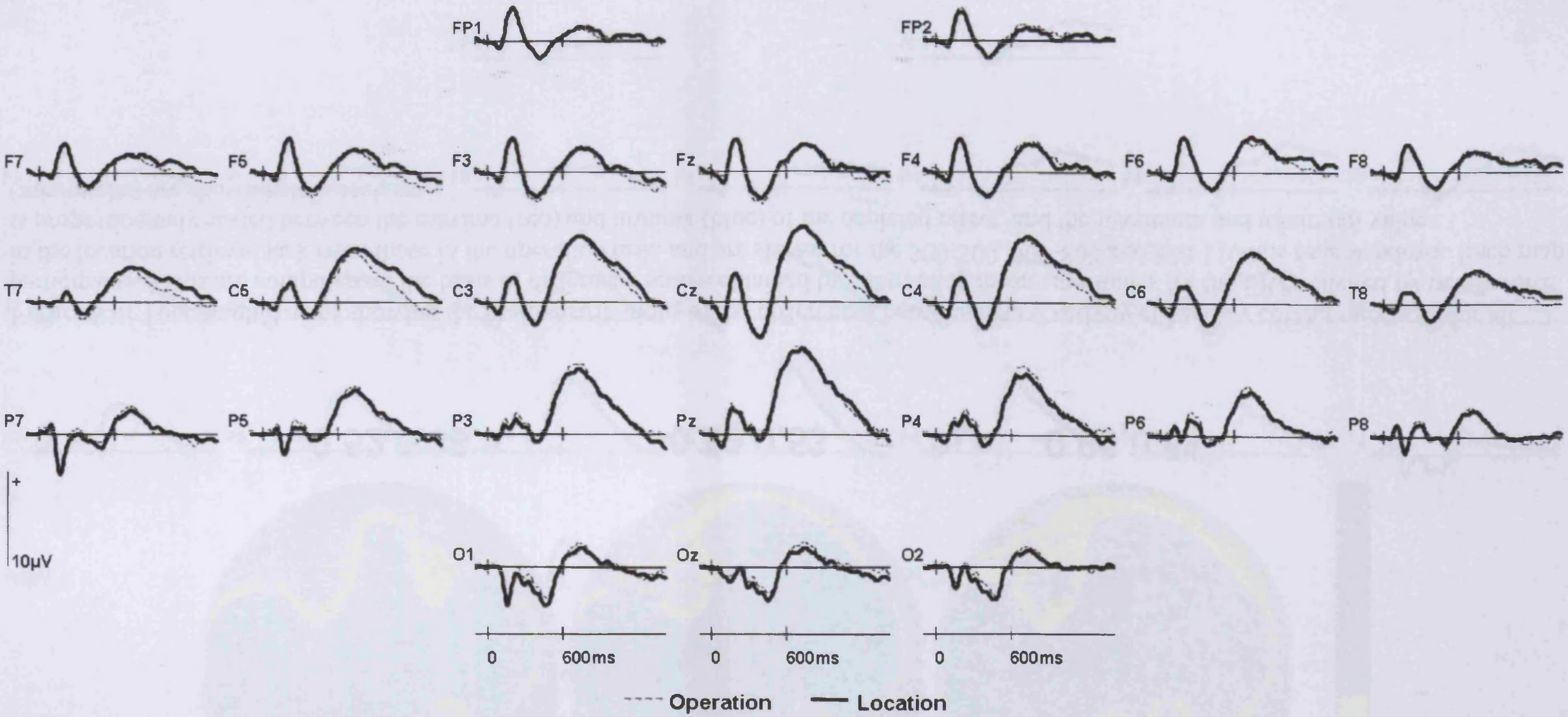

Figure 8.3: Grand average ERPs elicited by correct rejections in the two retrieval tasks for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

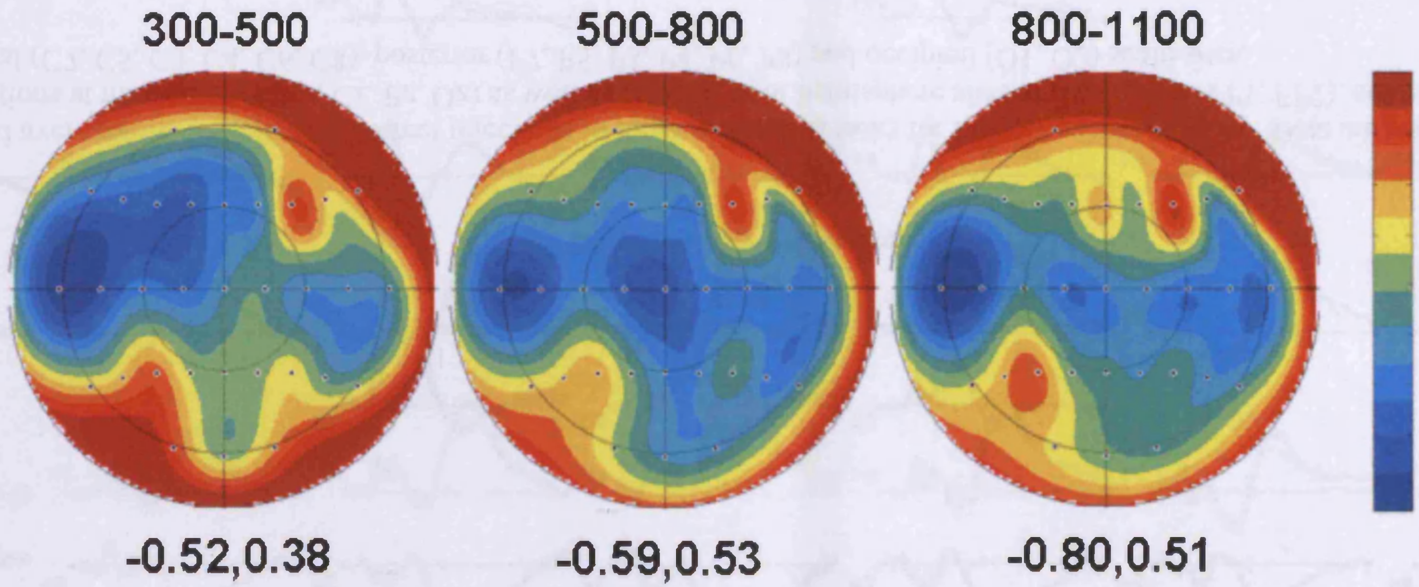

Figure 8.4: Topographic maps showing the scalp distributions of the differences between neural activity elicited by correct rejections for all participants. Maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by items words in the location retrieval task from those in the operation task, and are shown for the 300-500, 500-800 and 800-1100ms time windows. Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

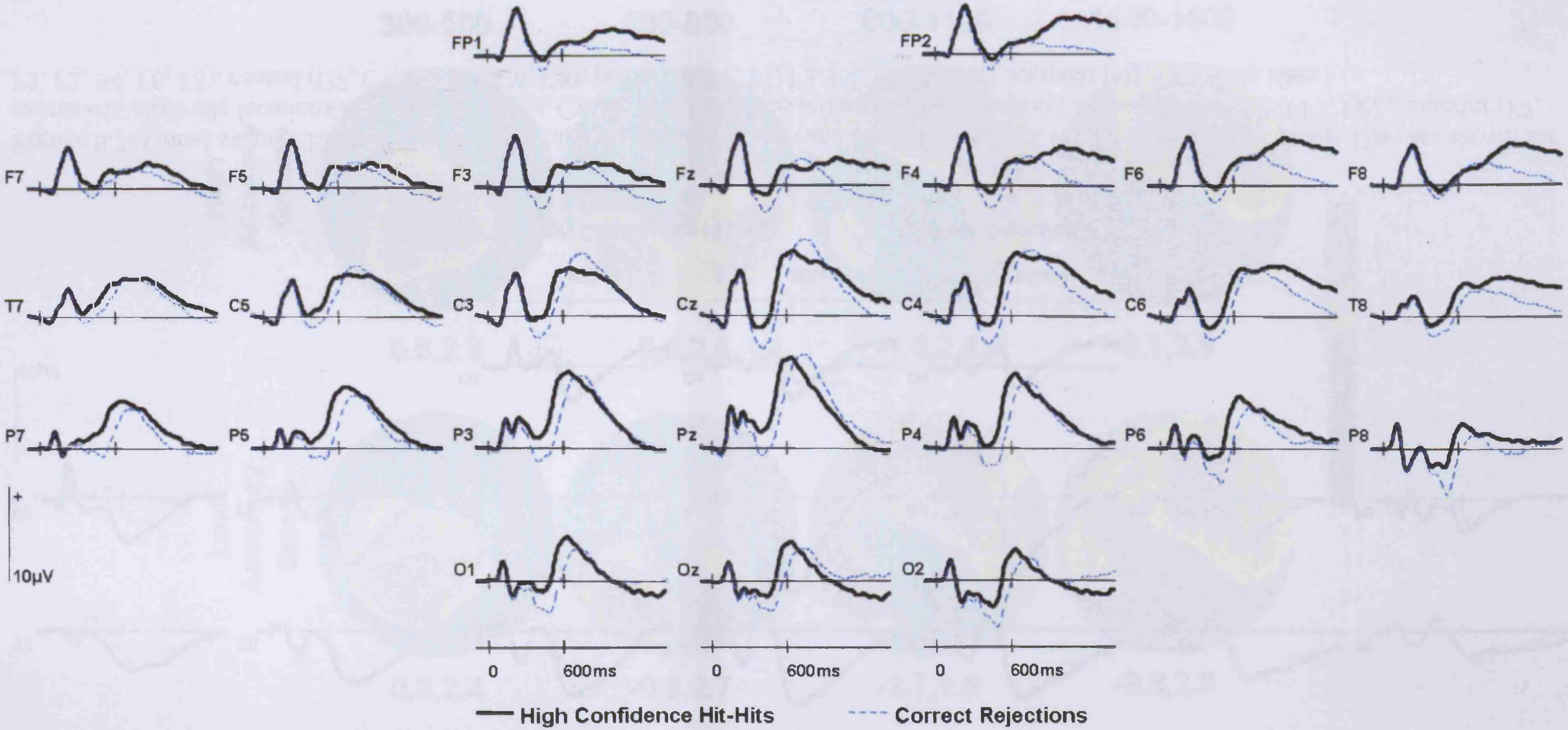

Figure 8.6: Grand average ERPs associated with high confidence hit-hits and correct rejections, for the high accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

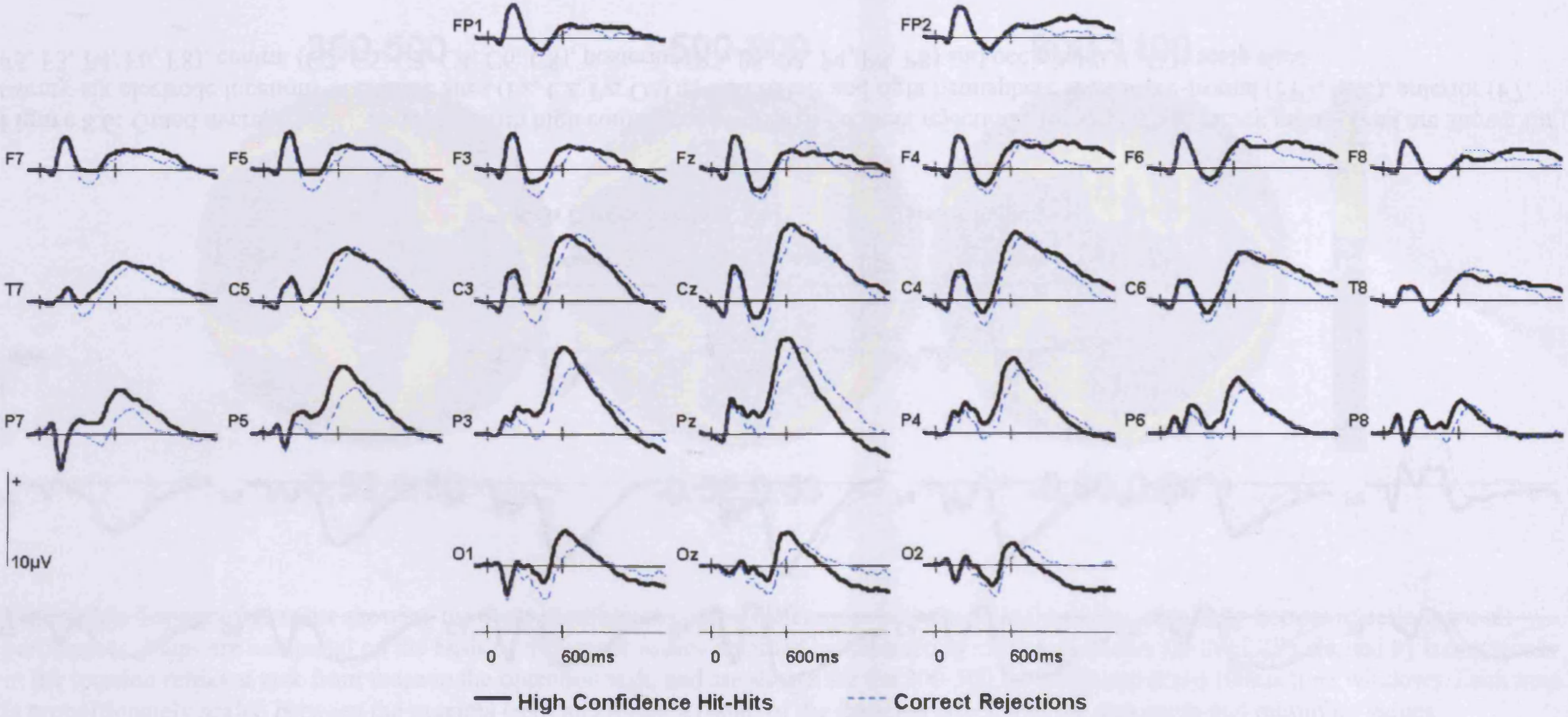

Figure 8.7: Grand average ERPs associated with high confidence hit-hits and correct rejections, for the low accuracy group. Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

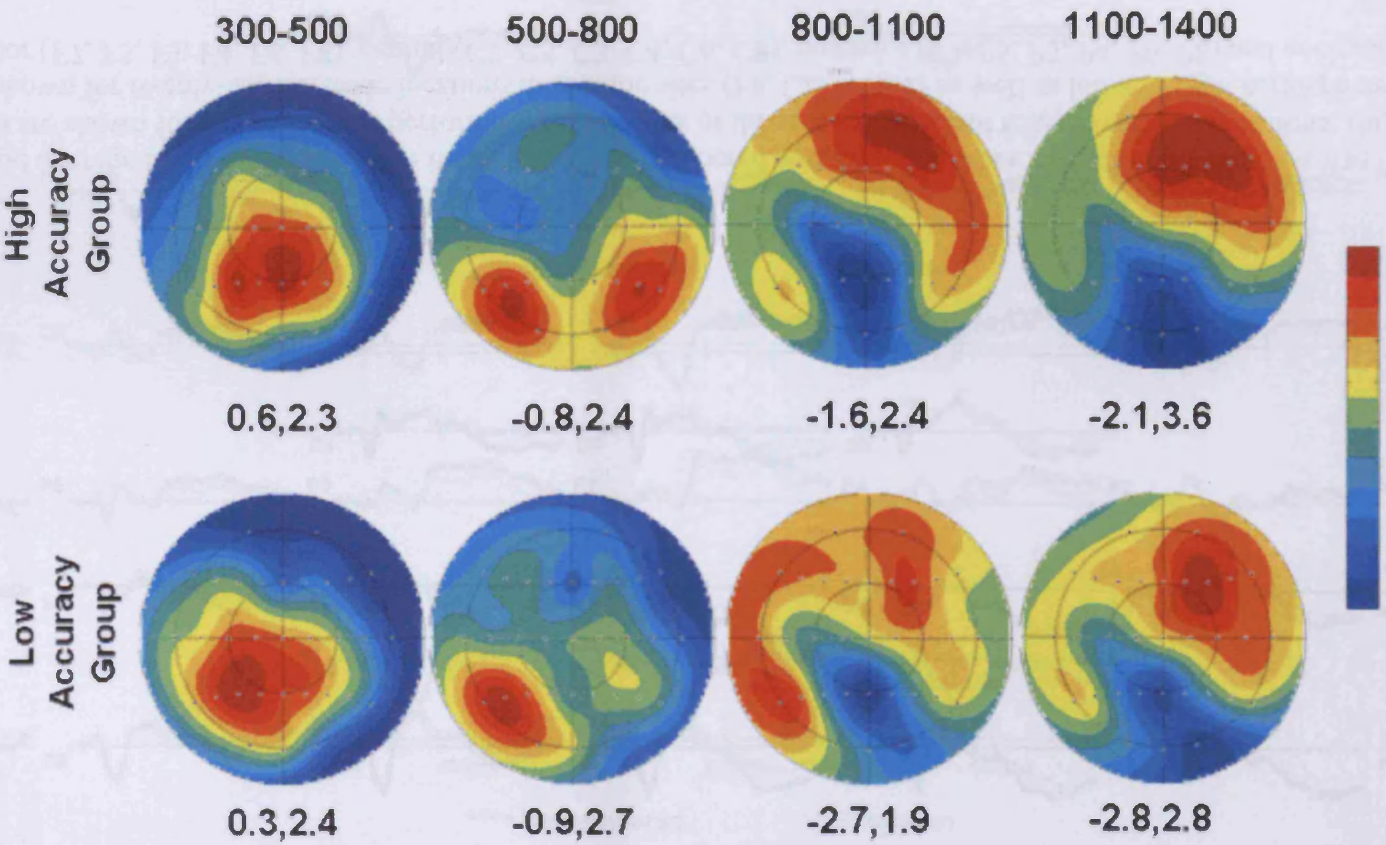

Figure 8.8: Topographic maps showing the scalp distributions of the differences between neural activity elicited by high confidence hit-hits and correct rejections for the high and low accuracy groups. Maps are computed on the basis of difference scores obtained by subtracting mean amplitudes for the ERPs elicited by new items from those elicited by hits, and are shown for four time windows (300-500, 500-800, 800-1100, 1100-1400). Each map is proportionately scaled between the maxima (red) and minima (blue) of the depicted effect, and the maximum and minimum values (microvolts) are shown below each map.

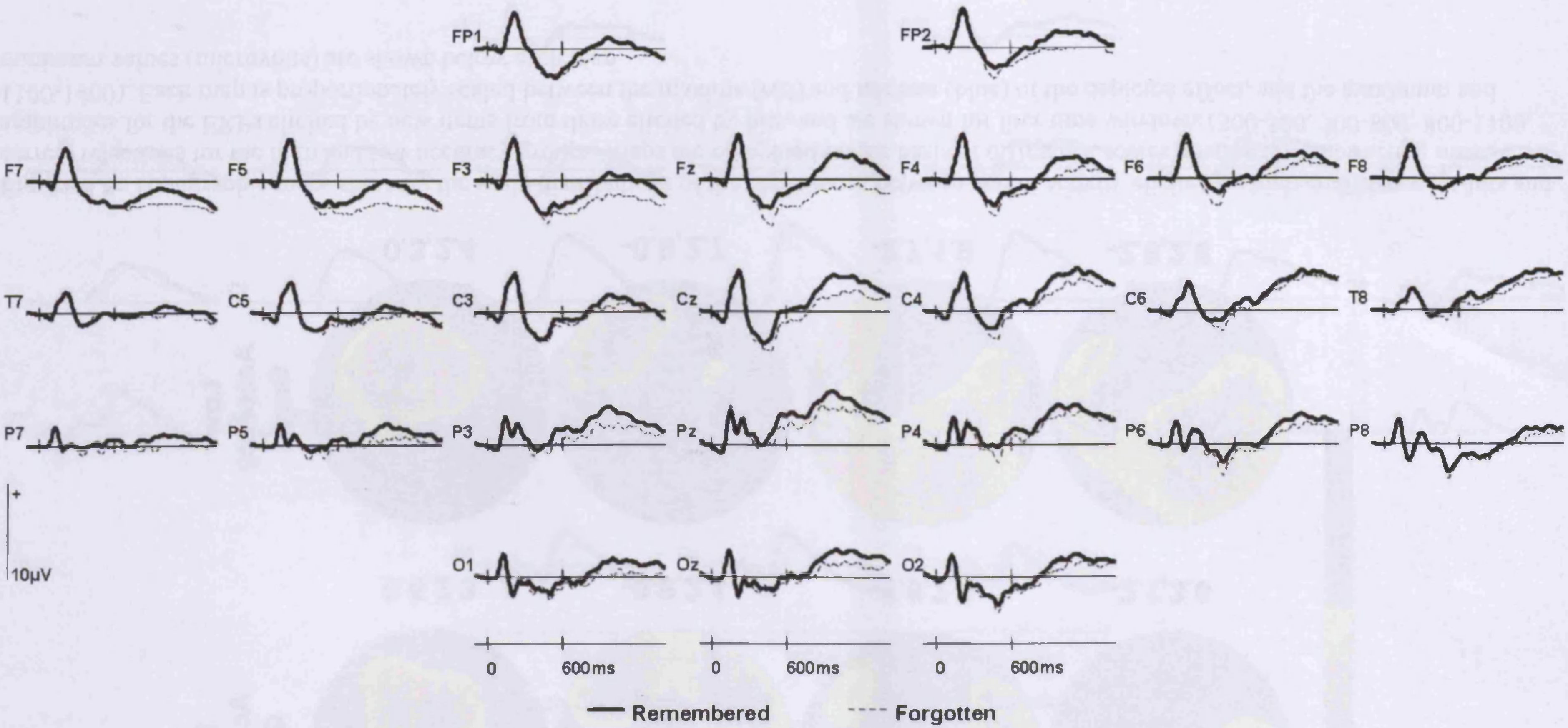

Figure 8.10: Grand average ERPs associated with items that are remembered and forgotten when operation information was required at retrieval. The data are shown for the 14 highest performing participants of those with sufficient trials to make this contrast (high accuracy group). Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

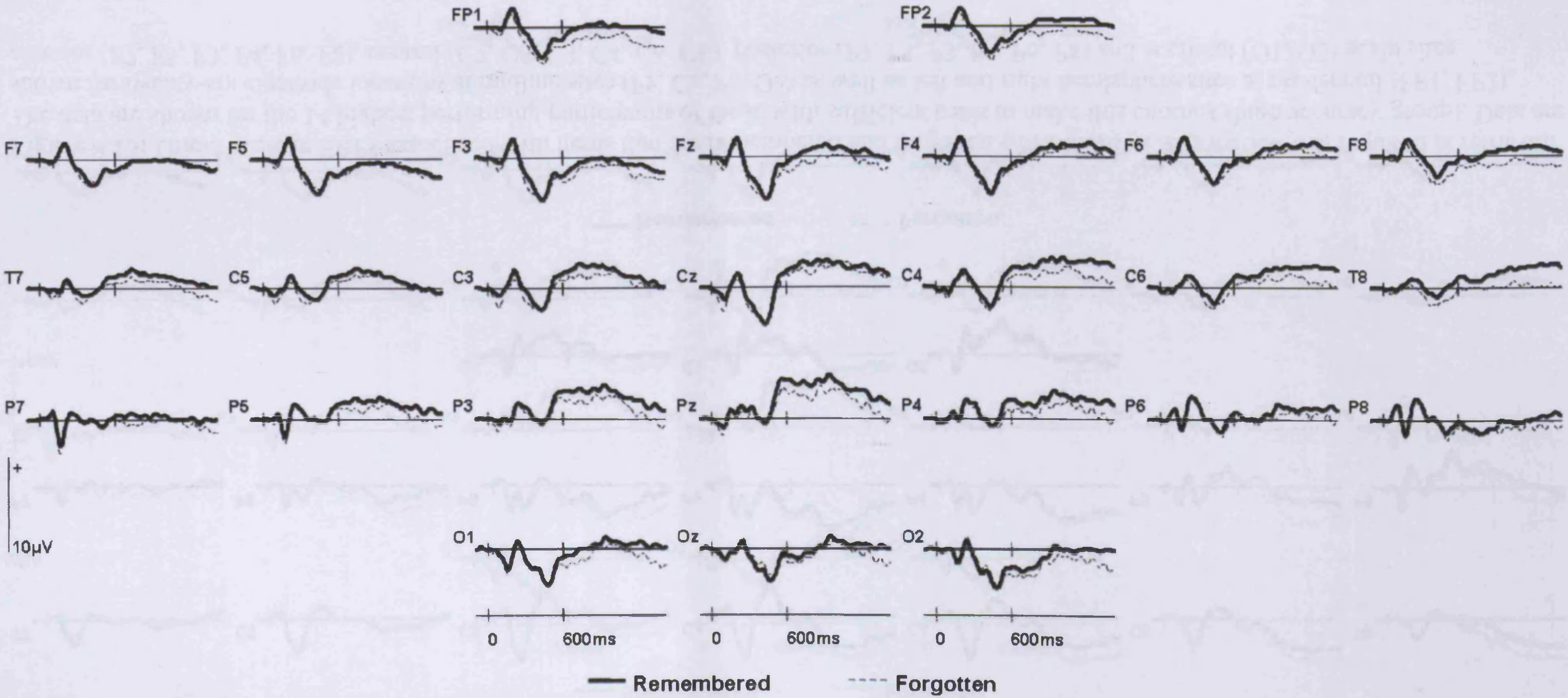

Figure 8.11: Grand average ERPs associated with items that are remembered and forgotten when operation information was required at retrieval. The data are shown for the 14 lowest performing participants of those with sufficient trials to make this contrast (low accuracy group). Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

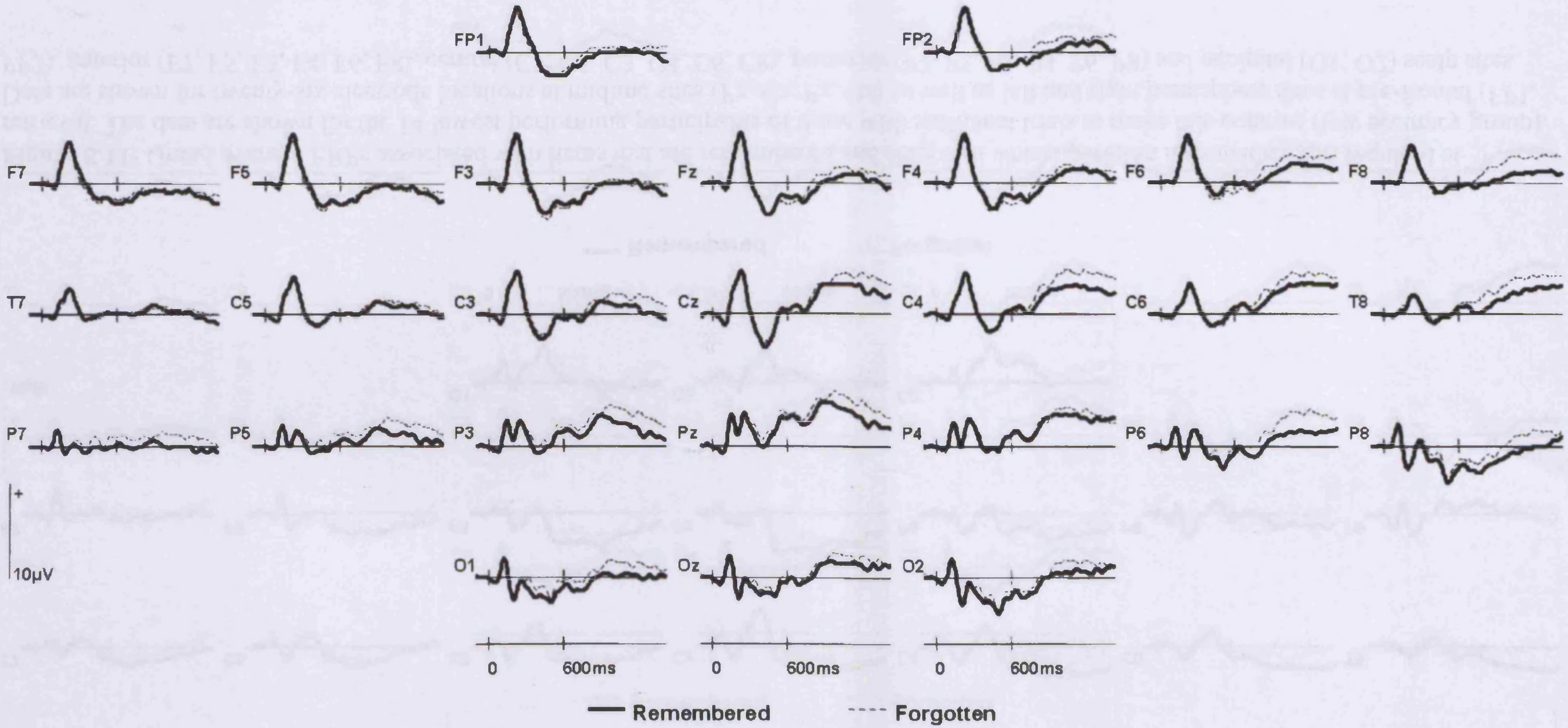

Figure 8.13: Grand average ERPs associated with items that are remembered and forgotten when location information was required at retrieval. The data are shown for the 14 highest performing participants of those with sufficient trials to make this contrast (high accuracy group). Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

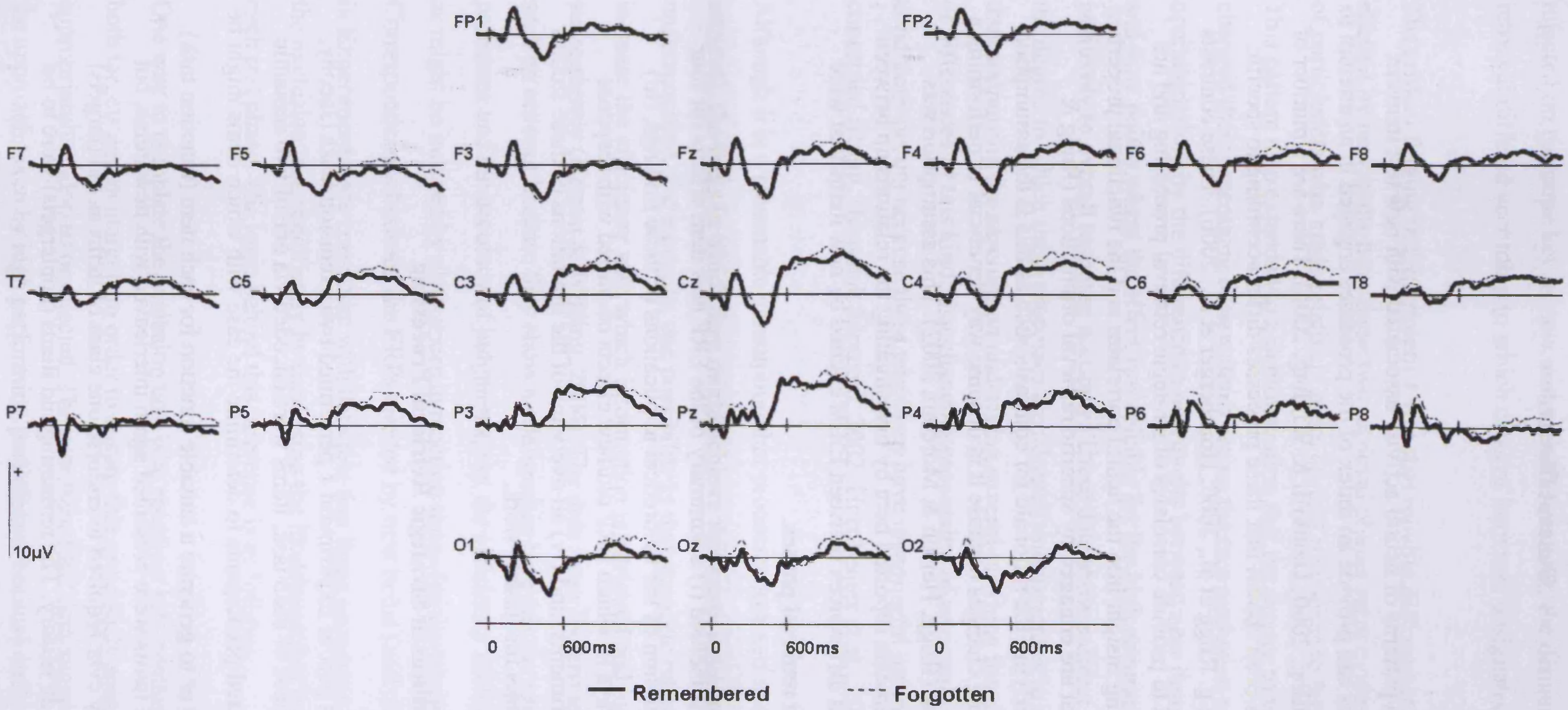

Figure 8.14: Grand average ERPs associated with items that are remembered and forgotten when location information was required at retrieval. The data are shown for the 14 lowest performing participants of those with sufficient trials to make this contrast (low accuracy group). Data are shown for twenty-six electrode locations at midline sites (Fz, Cz, Pz, Oz) as well as left and right hemisphere sites at pre-frontal (FP1, FP2), anterior (F7, F5, F3, F4, F6, F8), central (C7, C5, C3, C4, C6, C8), posterior (P7, P5, P3, P4, P6, P8) and occipital (O1, O2) scalp sites.

General Discussion

Introduction

Comparisons between patterns of neural activity associated with new test items in different retrieval tasks can provide an index of the processes engaged in an attempt to retrieve (Rugg & Wilding, 2000; Dzulkifli & Wilding, 2005). There are a number of reports in which it has been shown that these processes differ according to specific retrieval conditions (e.g. Rugg et al., 2000; Hornberger et al., 2006). These contrasts are widely considered to provide correlates of strategic retrieval processing and are one approach to gaining insight into the neural correlates and the functional properties of the mechanisms that are engaged by specific retrieval orientations (Rugg & Wilding, 2000). Underlying the rationale for contrasts such as this is the assumption that retrieval processing changes because it is in some way beneficial to performing a particular retrieval task (Rugg, Herron & Morcom, 2002). This assumption was explored in the experiments reported here by investigating the relationship between response accuracy and differences between ERPs elicited by new items that were obtained from distinct retrieval phases.

The following sections include (i) a summary of the ERP new item effects for four experiments, (ii) discussion of the theoretical implications of these findings, (iii) comparisons of the ways in which ERP old/new effects co-varied with response accuracy across experiments, and (iv) an overview of the limitations of these studies as well as considerations for further work.

Summary of ERP Indices of Strategic Retrieval Processing

Experiment 1

Participants who took part in Experiment 1 performed two exclusion tasks (Jacoby, 1991). In the study phase of each task, items were encoded via one of two semantic tasks that either required participants to determine the ease with which items might be drawn (drawing task) or to generate a suitable function for each item (function task). In each test phase, all items were presented again interleaved with new items, but participants were only ever required to endorse one class of items as old (targets) according to their study history. The remaining old items (nontargets) were to be rejected on the same key as new items. In this manner, the demands imposed at retrieval differed according to which class of item was designated as the target.

The critical finding in Experiment 1 was that reliable differences between ERPs elicited by new items from these two retrieval phases were evident only in a subgroup of participants who made relatively more correct responses to targets and nontargets. This pattern also extended to a demonstration that the degree to which an individual changed their processing of new items across the two exclusion tasks (as operationalised by the difference in microvolts between new item ERPs at the location and time points where the effect was reliable for the high accuracy group) also related positively to overall response accuracy. These data show a direct relationship between the degree to which these processes are adopted and increases in accurate responding, thus supporting the assumption underlying several previous functional interpretations of differences of this kind; that changing processing of retrieval cues in line with test conditions occurs because these processes have meaningful repercussions for the tasks concerned (Rugg, Herron & Morcom, 2002; Hornberger et al., 2004).

Although it is a reasonable assumption that processes indexed in this manner facilitate retrieval, the ways in which they might achieve this have, until now, been relatively underspecified. For example, one possibility is that strategic retrieval processes might increase the efficiency with which information is retrieved and judgments are made subsequently (Herron & Wilding, 2004). The data from Experiment 1 do not support such an account because they show a relationship between the engagement of these processes and the accuracy of judgments, not the efficiency with which they are made as might be indexed by differences in reaction times for the two groups. Correspondences between the ERPs elicited by new items (and old items; see below) in Experiment 1 are consistent with the view that these processes benefit judgments in the exclusion task specifically by increasing the likelihood that targets are retrieved in each test phase. The logic behind this inference is as follows.

One way to complete the exclusion task is to recollect information associated with both targets and nontargets in order to ensure that previously seen items are appropriately endorsed or rejected. The new item ERP data suggest that this was not the approach taken by high performing participants because such an approach predicts that ERPs elicited by items from tasks with different target designations would remain the same. Instead, the differences between the new item ERPs suggest that participants engaged different processing depending upon the task requirements. The differences between ERPs elicited by old items from the two test phases also support this explanation. Whereas there was little evidence that ERPs to nontargets diverged considerably from one another for either accuracy group, robust differences between ERPs to targets were observed only in the high accuracy group. It was also the case that the degree to which processing of targets differed across the two phases related positively to response accuracy. These data are consistent with the interpretation which states that higher performers prioritised the recovery of details associated with targets rather than nontargets. The operations indexed by new item contrasts may therefore occur because they go towards encouraging the recovery of this information.

In previous reports employing exclusion tasks, the behaviour of the left parietal old/new effect has been used to make similar inferences about how participants complete the exclusion task. This effect consistently acts as a marker of recollection and in some reports is reduced in amplitude for nontargets relative to targets (Herron & Rugg, 2003b; Dzulkifli et al., 2005). This finding has been interpreted as evidence that participants can perform the task by relying predominantly upon the recollection of targets, because when the probability of retrieving this information is sufficiently high, failure to retrieve it can indicate the presence of a nontarget/new item (Herron & Rugg, 2003b). Accordingly, across experiments, Dzulkifli and colleagues (2005; 2006) have shown that greater attenuation of the left parietal old/new effect to nontargets is associated with tasks in which participants were more likely to make accurate target judgments. Moreover, reliable ERP new item effects were present only in the task for which participants made relatively more accurate responses and the parietal old/new effect for nontargets was absent. On the basis of this, Dzulkifli and colleagues inferred that the processes indexed by ERP new item effects are responsible for the ability to selectively recollect information about targets over nontargets as indexed by the left parietal old/new effect.

In Experiment 1, however, there was no evidence of a relationship between response accuracy and the degree to which recollection of nontargets was attenuated relative to targets, suggesting that the processes indexed by new item ERPs are not directly responsible for the relative attenuation of the nontarget effect. The left parietal old/new effect for targets, however, was sensitive to target designation in the high accuracy group: whereas the effect did not differ from that for nontargets in the function designation, it was significantly greater in magnitude for the drawing designation.

A change in the degree to which the amplitude of the target and nontarget effects correspond to one another across exclusion test phases, has been previously reported by Herron & Rugg (2003a). In that design, participants were presented with words and pictures at study but all retrieval cues were words at test. Target designation was manipulated by specifying whether items originally presented as words or pictures were to be responded to as targets. An asymmetry was observed in the pattern of the left parietal old/new effect for nontargets across test phases; the nontarget parietal effect was reliable only in the picture target designation, but was absent when items presented as words acted as targets. The authors suggested that this pattern came about because participants were able to retrieve items in the word target designation with a higher degree of specificity than in the picture designation because of the greater cue-target overlap in the former designation. This enhanced specificity in the word designation may have allowed participants to focus upon word-specific features without attending to semantic features. In the picture designation, however, participants may have been unable to avoid generating representations of cues that correspond with both study formats leading to the recovery of both targets and nontargets.

Similar reasoning can be applied to the pattern of left parietal old/new effects for the high accuracy group in Experiment 1. In the drawing designation, it may have been possible for participants to limit processing principally to the recovery of perceptual or visual features, without recovering associated semantic details to the same extent. By contrast, in the function designation, stressing the recovery of semantic or conceptual attributes may have caused the somewhat automatic generation of corresponding visual/perceptual information for each item, leading to comparable parietal old/new effects for targets and nontargets in this designation.

Regardless of the behaviour of the left parietal old/new effect in this experiment, the outcomes of the paired contrasts, both for new items and targets, provide strong evidence that the degree to which retrieval processing changed across the two test phases was related to increases in overall response accuracy. These data indicate the importance of both pre-retrieval and post-retrieval processing engaged in line with the recovery of targets.

Experiment 2

In line with the reasoning given above, the findings from Experiment 1 indicate that differences between new item ERPs facilitate the recovery of information in line with the target designation in each retrieval task. If such an interpretation is correct, then these ERP effects may provide indices of strategic retrieval processes that can be adopted in order to encourage the recovery of specific mnemonic details. Training individuals to adopt such mechanisms might go someway towards slowing the deterioration in memory performance that occurs with normal aging. Experiment 2 was designed to determine whether participants could be encouraged to adopt this strategy on the basis of instructions alone, and so a second group of participants performed the tasks described in Experiment 1, with the addition that prior to each retrieval phase they were asked to make binary judgments based upon whether they succeeded or failed to recover target information.

The addition of these instructions did not lead to any increase in response accuracy from the average performance reported for participants in Experiment 1. Electrophysiologically, there was no evidence of strategic retrieval processing as indexed by differences between ERPs elicited by new items from the two exclusion tasks. Assuming that the strategy that participants were encouraged to adopt in Experiment 2 is indeed the same as that adopted by high performing participants in Experiment 1, these data indicate that asking participants to use this approach does not lead to changes in the processing of new items across the two retrieval phases.

Although there were no reliable ERP new item effects in Experiment 2, this was not the case for differences between ERPs elicited by targets from the two retrieval tasks. These effects demonstrated a right posterior scalp distribution. This differs from the anterior distribution of the same contrasts reported in Experiment 1 (compare Figure

5.9 with Figure 6.5). The timing of the ERP target effects also differed in the two experiments, becoming reliable 300ms later (around 800ms post-stimulus) in Experiment 2. Although it is necessary to be cautious when interpreting differences between the scalp distributions of effects from different groups of participants, these differences are indicative of the engagement of not entirely the same processes in the two experiments. Despite this, the time course of the differences between ERPs associated with targets from the two retrieval phases (after the time point by which retrieval has been shown to occur), alongside the absence of comparable effects for contrasts between nontargets, is consistent with the interpretation that participants were engaging in post-retrieval processing that changed in line, principally, with targets in each test phase.

Examination of the left parietal old/new effects in this experiment provided no evidence that targets were more likely to be recollected than nontargets. Alongside the failure to observe ERP new item effects in Experiment 2, this suggests that the instructions employed in Experiment 2 did not enable participants to engage in the same strategic processes reflected in Experiment 1. One possibility is that the instructions that were provided to participants, which included the requirement to rehearse the target designation throughout the retrieval phase, may have depleted resources that otherwise would have been used to engage strategic retrieval by some participants. It is because of this possibility that it is not possible to infer on the basis of the ERP data from Experiment 2 whether the changes in ERP processing across test phases reported previously can be engaged on the basis of explicit instructions or not.

The possibility that the ability to engage in strategic retrieval processing is related to the availability of cognitive resources may complicate the prospect of using these mechanisms to facilitate memory in normal aging. This is because there is evidence that the availability of cognitive resources decreases with age (Craik & Byrd, 1982), alongside reports that older adults are less likely to engage in processes of the kind indexed by the ERPs elicited by new items in Experiment 1 (Morcom & Rugg, 2004; Jacoby, Shimizu, Velanova & Rhodes, 2005). It has also been reported, however, that the ability to adopt these processes is not abolished in older adults but, rather, is less readily or automatically adopted (Duverne et al., 2008). The possibility that these age-related differences can be overcome via training remains to be demonstrated.

Experiment 3

The functional account given for the ERP new item effects in Experiment 1 is that they index processes that increase the likelihood that specific details (those associated with targets) will be retrieved. Experiment 3 was designed to determine whether similar processes would be engaged in a recognition memory task in which the requirement to recover contextual details is not explicit to the task but may benefit response accuracy in so far as details of this kind are associated only with old items, whereas both old and new items are associated with varying degrees of familiarity. To this end, participants completed a study phase in which they encoded items in the same function and drawing tasks employed in Experiments 1 and 2. After a 30 minute interval participants completed two distinct retrieval tasks in which new and old items were presented. In each test block, old items were only ever associated with one of the two encoding tasks and participants made a simple old/new judgment to each item.

Reliable ERP new item effects were present from 500-1100ms post-stimulus over left hemisphere sites, but only for the high accuracy group. There was no evidence that this relationship extended to reliable correlations between the amplitude of these effects and response accuracy, and the effects did not demonstrate the marked divergences or the clear left occipital distribution shown for high performing participants in Experiment 1. The marked dissimilarities between the distributions and timings of the effects in Experiments 1 and 3 make it unlikely that the effects in either experiment provide indices of automatic accommodations to the experience of recovering function/drawing information in each retrieval phase. It is reasonable to infer, therefore, in line with the interpretation given for the effects in Experiment 1, that because these differences are reliable only in the group of participants for whom response accuracy was relatively high, changing processing in line with to-be-recovered information is also associated with greater response accuracy in an item recognition task.

A second electrophysiological effect was also related to behaviour in Experiment 3. From 100-800ms post-stimulus, a greater relative positivity for ERPs elicited by new items in the function task occurred over central sites. The size of the difference between new item ERPs at this time point and scalp location was related to the degree to which participants' performance in the two tasks was equivalent. Variability in performance for the two tasks was related primarily to the proportion of correct responses that participants made in the drawing task. Across participants, performance in the function task was consistently high, and so participants who performed well in the drawing task showed comparable performance for the two tasks and thus exhibited superior overall accuracy. In this manner, the early central ERP new item effect was also related to overall response accuracy.

The fact that, for the most part, it was variability in responding in the drawing task that differentiated the high and low relative difficulty groups suggests that the processes indexed by differences between new items from 100-800ms increase the likelihood with which drawing information is recovered. This inference is supported by the behaviour of the left parietal old/new effect across relative difficulty groups. Figures 7.13 and 7.16 demonstrate that, for the high relative difficulty group, the effect was relatively larger in the function task, whereas in the low relative difficulty group, the amplitude of the effect was larger in the drawing task. There exist a number of demonstrations that the size of the left parietal old/new effect is related to the amount of information recollected (e.g. Wilding, 2000). The changes in the amplitude of this effect suggest, therefore, that participants in the low relative difficulty group tended to recollect more drawing relative to function information than did the high relative difficulty group. The differences between new item ERPs from 100-800ms therefore relate to both the greater recollection of drawing details and higher accuracy on this task. These data correspond with the findings from Experiment 1 where it was also shown that for the group of individuals for whom differences between new item ERPs were reliable, there was evidence that recollection for information associated with the drawing task was greater.

Despite these functional correspondences, the time course of differences between the new item ERPs related to increases in accuracy differed considerably in the two experiments. Whereas the effects in Experiment 1 began around 500ms and extended well beyond the point by which retrieval usually occurs (Yonelinas & Jacoby, 1994), in Experiment 3 divergences occurred very early in the epoch only 100ms after the presentation of the stimulus. The reasons for such dramatic differences in the time courses of the two effects are not obvious. They may relate to differences in the average reaction times for the two tasks; although in both tasks correct rejections were made around 1000ms post-stimulus, correct responses to old items were on average nearly 400 milliseconds faster in Experiment 3 (e.g. Exp 1 targets = 1288ms; Exp 3 hits = 908ms), which may necessitate the earlier engagement of strategic retrieval processes in that task. Regardless of the explanation for these differences, variations in time scale imply that there are different time courses over which strategic retrieval processes can be engaged in order to influence retrieval success.

The data from Experiment 3 provide the first demonstration, within a single experiment, that strategic retrieval processing operations are related to increases in the recollection of a particular content type in an item recognition task. As is the case for the contrasts in Experiment 1, the strength of this interpretation is limited, however, because it is based upon paired contrasts that render it impossible to determine the extent to which these processes were engaged in one task over another. Nonetheless, the combined data do indicate that more than one electrophysiological index of strategic retrieval processing can be associated with response accuracy in a recognition task.

Experiment 4

The final experiment in this thesis was designed to investigate whether ERP indices of strategic retrieval processing change with increases in response accuracy in source retrieval paradigms other than the exclusion task. Across a number of study-test blocks, participants encoded two kinds of information for each item; a specific screen location (left/right) and a semantic task (pleasantness/drawing). At test, items were presented again interleaved amongst new items, all of which were presented in the centre of the screen. Participants were required to make old/new judgments, and for those items judged old, to make a subsequent source judgment. In half of the test phases these second judgments related to the item's study location and for the remainder they required the semantic operations engaged during study to be retrieved. Small yet reliable differences between ERPs elicited by new items from these different retrieval tasks occurred from 300-500ms. Differences were also reliable from 800-1100ms post-stimulus, but only in a sub-group of participants who made relatively more correct source judgments. The finding that differences later in the epoch were reliable only in this group suggests that the engagement of strategic retrieval processes over a longer duration is related to an increase in response accuracy. The outcomes of these contrasts indicate that ERP indices of strategic retrieval processes also relate to response accuracy in source retrieval paradigms other than the exclusion task. The assumption is that these processes facilitate the recovery of either location or semantic information in the respective test phases in order to aid source judgments.

The ERP new item effects for high performing participants were larger in Experiment 1 than in Experiment 4. Moreover, the size of these effects was related to response accuracy at the level of the individual only in Experiment 1 (the exclusion task). It is not possible to claim on the basis of this, however, that strategic retrieval processes indexed in this manner play a more influential role in the exclusion task than the source retrieval task. This is because of the particular response requirements that were implemented in Experiment 4, in which participants made old/new judgments prior to the source judgments. If some individuals delayed the recovery of source information until they considered an item to be old, changes in the processing of new items across retrieval tasks are less likely to be detected. In light of this possibility, it will be necessary in future to investigate the relationship between ERP new item effects and accuracy in a source retrieval paradigm in which source/new judgments must be made for all items. Nonetheless, the differences between new item ERPs do indicate that participants did take different retrieval requirements into account when making a retrieval attempt and that the engagement of these processes was related to source accuracy.

Theoretical Implications

Relationships between the engagement of distinct retrieval cue processing operations and response accuracy were shown across Experiments 1, 3 and 4. This pattern demonstrates that retrieval attempts can differ depending upon the task demands, presumably in order to create an emphasis upon the internal representation of the cue that increases the likelihood that specific details are retrieved. This pattern lends support to those models of memory control which include an emphasis on the role of descriptor processes, allowing to-be-retrieved characteristics to be specified prior to retrieval (Norman & Bobrow, 1979; Burgess & Shallice, 1996; Schacter et al., 1998; Moscovitch & Winocur, 2002). These models propose that deficient pre-retrieval specification processes may lead to the retrieval of irrelevant or inappropriate episodic information and in this way may contribute to the phenomenon of confabulation. The results of the current experiments are consistent with these models in so far as they highlight a relationship between pre-retrieval processes and performance on episodic memory tasks. Of additional interest, however, is the implication that the influence of these processes extends to performance in recognition memory as well as free recall tasks, even though the former do not entail an explicit requirement to recall memory contents. This observation further stresses the role of processing engaged at retrieval for accuracy as was first highlighted in the principle of transfer appropriate processing (Morris et al., 1977). Other theoretical implications of these findings are discussed in the following sections, beginning with those insights that the current data points license directly before moving onto considerations that should be addressed in future.

Strategies for Completing Recognition Memory Tasks

Experiments 1, 3 and 4, provide the first reports that the engagement of strategic retrieval processing operations is related to response accuracy. The influence of strategic retrieval processes on behaviour has previously been inferred on the basis of findings in a behavioural paradigm. Jacoby, Shimizu, Daniels and Rhodes (2005) compared the performance on recognition memory tasks of two groups of participants who had initially processed words under deep or shallow conditions. Participants then completed two subsequent recognition memory tasks where the 'new' words in the first were the 'old' words in the second. Old/new discrimination on this final task was superior for the deep encoding group, a finding that was interpreted as a levels of processing effect (Craik & Lockhart, 1972). Specifically, this interpretation was based upon the assumption that both new and old items in the first recognition memory task were subjected to qualitatively distinct retrieval processing in line with the operations that were employed in the initial encoding task. Subjecting new items to deeper processes in one condition led to a subsequent discrimination benefit for those items. These data points indicate that new items are subjected to certain retrieval operations that may have consequences for memorability at a later point. The important addition to this interpretation that the ERP data presented in this thesis allow is that strategic retrieval processing operations can also bestow benefits on response accuracy at the time at which they are engaged.

The data in Experiment 3 (where participants were required to make only old/new judgments) correspond with the findings reported by Jacoby et al. (2005; see also Rugg et al., 2000), by providing electrophysiological evidence that distinct retrieval processing mechanisms are engaged in item recognition test phases. These processes were shown to relate to accuracy in tasks in which there was no explicit requirement to recollect details because, in principle, all responses in an item recognition test can be made on the basis of familiarity. One index of strategic retrieval processing was associated with increases in the amplitude of the left parietal old/new effect for a particular class of item, as well as improved accuracy in the corresponding recognition task.

The behaviour of the left parietal old/new effect in Experiment 3 indicates that recollection has positive benefits for accuracy in an item recognition task. This has implications for one model of recognition memory. In an effort to integrate the existing data on the way in which processes contribute to different types of recognition tasks, Malmberg (2008) has argued that whereas there is consistent evidence that a recall-like (or recollective) process supports associative and plurality-discrimination tasks, numerous factors that dissociate performance in recall and recognition tasks suggest that these processes are unlikely to support memory in single-item recognition tasks. Moreover, Malmberg argues that multiple recognition strategies are available to participants and that *efficient* subjects are those who choose a strategy that enables them to attain an accurate memory response in the shortest amount of time. Familiarity is sufficient to make accurate item recognition judgments and because it is generally held to be a more automatic and earlier occurring phenomenon, reliance upon this form of recognition is assumed to be the most efficient approach to performing item recognition tasks. The ERP data reported in Experiment 3 argue against this position by demonstrating that changes in the ERP index of recollection were related to increases in memory accuracy in an item recognition task without any significant increase in response times. There was no evidence that the ERP old/new effect most likely to reflect familiarity-based processing was related to overall accuracy (although this is of course a null result). Engaging strategic retrieval processes that encourage the recollection of particular details may therefore also represent an efficient recognition strategy when certain details are less likely to be recovered automatically.

Arguably the clearest insight into the strategies that influence responding in recognition tasks is that derived from the findings in the exclusion task employed in Experiment 1. The data indicate that high performing participants did not rely equally on the recovery of both target and nontarget information because such an approach reduces to employing comparable strategic retrieval processes regardless of target designation. This pattern was not found for participants in the high accuracy group, indicating that these participants prioritised source information associated with targets over that related to nontargets. Supporting this claim is the observation that, for this group, reliable differences between ERPs elicited by old items were limited to those associated with targets.

From an alternative viewpoint, it is also the case that the greater the correspondence in the manner with which new items were processed, the lower overall discrimination accuracy was. This line of reasoning suggests that in the case of binary recognition discriminations, attempting to recover multiple elements of information may not be a suitable approach compared to the prioritization of some elements over others. This observation has important repercussions for recognition models such as the source monitoring framework (Johnson et al., 1993) which assumes that source discriminations are based upon the average difference in characteristics of distinct sources. The ERP new item data reported here instead stress that, in some tasks, prioritising the recovery of certain details facilitates judgments about this information and the related possibility that there may be costs associated with attempting to retrieve multiple contents.

Whether this benefit extends to source retrieval paradigms in which judgments do not reduce to a binary discrimination is less clear. In the exclusion task, old items are only ever associated with one of two classes of information, and an appropriate strategy in each retrieval phase appears to be to determine for each item whether a particular class of information is present or not. Strategic retrieval processes may facilitate this strategy by increasing the likelihood that that information is recovered. An additional possibility is that operations such as this may also benefit more specific judgments about this information rather than simply whether it is present or not. Experiment 4 provided an initial examination of this issue, by presenting participants with items that were associated with two orthogonally manipulated classes of contextual information. Contrasts were made between ERPs elicited by new items from separate retrieval tests in which source responses only ever queried one kind of source. Although a new item ERP effect was reliable across all participants in an early time window, this was not the case later in the epoch when the effect was present only for high performing participants. The findings suggest a relationship between response accuracy and the length of time over which strategic retrieval processes are engaged, and that these processes not only benefit binary discriminations such as those that occur in the exclusion task, but are also related to increases in the likelihood of making a correct judgment about the specific contents associated with a memory trace.

Retrieval Effort

According to Rugg and Wilding (2000), retrieval effort is the mobilisation of processing resources in service of a retrieval attempt. This definition is broad, and critically, overlaps to some degree with the interpretation of the strategic retrieval processes related to retrieval orientations that are discussed in this thesis. To advance investigation of this issue, Rugg & Wilding outlined two possible accounts for the relationship between retrieval effort and retrieval orientation. According to one, processes associated with effort may occur as part of a dedicated, task-invariant neural network. The second possibility is that changes in effort are operationalised by increases (or decreases) in the activation of retrieval processes typically engaged in a recognition task.

To date, there are only two published studies in which these accounts have been investigated. Robb & Rugg (2002) reported that within the same paradigm, qualitatively distinct neural correlates were associated with retrieval effort and retrieval orientation. Effects related to retrieval effort were small and restricted to an early time window (0-300ms) whereas those related to retrieval orientations were large and extended from 300-1900ms post-stimulus. Although this indicates that it is possible to neurally and functionally dissociate the two classes of processes, a second study in which effort was investigated using a between-subjects contrast (Dzulkifli et al., 2004) failed to find indices of retrieval effort that were comparable to those reported by Robb & Rugg. The failure to replicate this finding across experiments speaks against a task-invariant index of retrieval effort. Instead, support for the second account posited by Rugg & Wilding (2000) followed the finding that reliable differences between new items were evident only in a group of participants for whom there was behavioural evidence that one task was reliably harder (Dzulkifli et al., 2004).

The unanticipated findings in Experiment 3 provide further insight into the viability of these accounts. It is clear that the latter effect, like that reported by Dzulkifli and colleagues (2004), meets the criteria for an index of retrieval effort in so far as it is sensitive to changes in relative performance in the two tasks (for a critique of the logic surrounding the use of this measure as an indicator of retrieval effort see Mitchell & Hunt, 1989). However, the combined ERP and behavioural data imply that the degree to which this effect was engaged was related to increases in accuracy on one task (the drawing task), whereas participants consistently performed well on the function task. This introduces the possibility that it might be appropriate to engage strategic retrieval processes to recover some types of information rather than others. This might be necessary because some types of encoding operations induce the engagement of semantic processing to a greater degree than others. For example, it is likely that these processes are employed to a greater degree in the function task than the drawing task in which participants might engage predominantly perceptual or visual-based processing. According to the levels of processing framework (Craik & Lockhart, 1972) this would lead to enhanced memory for items processed in the function task in so far as they are processed at a relatively deeper level. One way to overcome the relative processing disadvantage for drawing information therefore might be to engage strategic processes that stress the recovery of these details at retrieval. Speculation along these lines assumes that these retrieval processes have only minor consequences for performance on the function task in Experiment 3.

This pattern suggests that neural correlates that meet the definition of indices of retrieval effort might operate by increasing the likelihood that specific information contents are recovered, rather than simply increasing the relative engagement of retrieval resources. In future, a comprehensive account of strategic retrieval processing may not explicitly delineate retrieval orientations and effort but simply allow for the possibility that the extent to which particular retrieval orientations are adopted is affected by relative difficulty (Dzulkifli et al., 2004).

Mechanisms for Strategic Retrieval

This section outlines the possible mechanisms that might lead to increases in response accuracy by enabling selective retrieval. One way of examining potential mechanisms for selective retrieval is by considering the particular locus at which they are engaged. In the framework set out by Anderson & Bjork (1994) these may occur by influencing the way in which cues are processed (cue bias), by affecting the overall activation of a target (target bias), or by determining the allocation of attention to retrieved products (attention bias; Dywan et al., 1998; Dzulkifli & Wilding, 2005).

In tasks in which the same retrieval requirements are maintained throughout blocks of trials, it seems reasonable to assume that the cognitive processes supporting target-bias operations would be sustained, rather than be re-implemented trial- by-trial (Wilding, Fraser, & Herron, 2005). Consequently, differences between new item ERPs are unable to provide indices of operations that reduce to target-bias. Moreover, the pattern of left parietal old/new effects in Experiment 1 suggests that it is unlikely that the processes indexed by these effects decrease the likelihood of (or inhibit) nontarget recollection, as a result of target bias. This, alongside the relationship between ERP new item effects and response accuracy, points instead to the importance of cue or attention-bias processes in memory retrieval.

Operations indexed by new item contrasts might indicate the role of attention-bias mechanisms that facilitate selective attention to information once successfully retrieved. Alternatively, they might index cue-bias mechanisms that ensure cues are processed in a manner that supports the recovery of particular details. Previous speculations about the role of strategic retrieval processes have suggested that they may facilitate retrieval by increasing the probability that a cue overlaps with a trace, in line with the principle of transfer appropriate processing (Morris et al., 1977). In light of the extended time course of the ERP new item effects reported in one paradigm, Hornberger and colleagues (2004) suggested that those differences indexed the maintenance of internal representations of the cue in order to probe memory. This possibility is supported by the experiments reported here following the relative uniformity of ERP indices of strategic retrieval processing over time, most notably in Experiments 1 and 3. An account of this type therefore implies that the mechanisms by which strategic retrieval processes indexed by new item ERPs operate is by focusing upon the internal representation of the cue itself (cue bias).

This account applies less clearly to the data from Experiment 4 because the effect did not remain significant over successive epochs and changed distribution over time: in the 800-1100 epoch the effect was reliable only for high performers and demonstrated a distribution that was more right lateralised than in the earlier epoch. This indicates that high accuracy participants engaged additional qualitatively distinct strategic retrieval processes later in the epoch. Despite the changes in distribution over time, these data indicate that participants who differentially processed new items over a longer duration made relatively more correct responses overall.

Neural Generators of Strategic Retrieval Processes

The way in which ERP new item effects change across the scalp cannot indicate with any reasonable degree of certainty the likely neuroanatomical generators responsible for strategic retrieval processes. Data from other imaging modalities such as fMRI, however, have been used to identify the regions of the brain that are associated with the engagement of particular retrieval orientations. Studies in which retrieval orientation has been manipulated via the employment of different types of retrieval task (e.g. source recollection versus recency) have revealed that activity in the left anterior prefrontal cortex is greater in tasks that require the explicit recollection of source information (Ranganath et al., 2000; Dobbins et al., 2003). In so far as tasks of this kind have been assumed to require greater control of memory this is consistent with reports of anteriorly distributed ERP new item effects in analogous paradigms (e.g. Johnson et al., 1997; Ranganath & Paller, 2000) and data from clinical and animal lesion studies that stress the role of the prefrontal cortices in controlling episodic retrieval (Simons & Spiers, 2003). Activity in the parietal lobes has also been associated with the engagement of different retrieval orientations (Dobbins et al., 2003; Wagner, Shannon, Kahn & Buckner, 2005; Mecklinger, 2010), and it is likely that both regions are recruited when controlling from memory.

In other studies, specific retrieval orientations have been associated with unique patterns of neural activity incorporating distributed cortical regions (Woodruff, Uncapher & Rugg, 2006; Hornberger, Rugg & Henson, 2006b). Patterns that are unique to a particular contrast are in keeping with the definition provided by Rugg & Wilding (2000), which specifies that the processing bestowed by each retrieval orientation should be dependent upon the particular task demands. This is most clearly demonstrated by reports in which different retrieval orientations are induced by keeping retrieval tasks constant but manipulating the sought-for information. In one study, Hornberger and colleagues (2006b) contrasted the activity elicited by new items across test phases in which retrieval requirements were manipulated in this manner. When participants attempted to retrieve pictures, activity was greater in the fusiform cortex than when attempting to retrieve auditorally-presented words. For the reverse contrast, activity was greater in the auditory cortex. Previous fMRI reports indicate that activity in the fusiform and auditory cortices are associated with visual and auditory imagery, respectively (Ishai, Ungerleider, & Haxby, 2000; Shergill, Bullmore, Brammer, Williams, Murray & McGuire, 2001). These findings were subsequently interpreted in line with the concept of transfer appropriate processing, by which, the engagement of retrieval processes that recapitulate those engaged at encoding increase the likelihood of successful recognition (Morris et al., 1977).

One aspect of the current data that might allow for a similar interpretation relates to the possibility that the posterior/occipital distribution of the ERP new item effects in Experiment 1 might represent the relative engagement of processing supported by the occipital cortex. This would make sense in so far as activity in this region has been associated with visual imagery previously (Ishai et al., 2000), which is likely to be engaged to a greater degree in the drawing task. Engaging in activity that encourages the internal representation of cues to interact with this type of information might lead to an increase in the likelihood with which this information is successfully retrieved. In general, although it is not possible to make strong inferences about the underlying neural generators of any of the ERP effects discussed here, marked divergences in the time courses and distributions of all the ERP new item effects reported in this thesis highlight the variety of distinct strategic retrieval processing operations that can relate to increases in response accuracy across different recognition tasks.

Variability of Processing at Encoding and Retrieval

Across experiments, variability in response accuracy was related to the engagement of strategic retrieval processing. An important question is what enables some individuals

- but not all - to engage processing of this kind. One factor may be the operations that are employed when items are initially encoded. If these processes ensure that memory traces remain distinct from one another this may allow strategic retrieval processes that stress the recovery of one class of information over another to be employed more successfully. The importance of 'distinctiveness' in memory has been stated by a number of theorists (e.g. Nairne, 2002) yet the principle remains relatively poorly defined (Schmidt, 1991) and consequently the ability of neuroimaging measures to index processes that differ in this regard is limited. Nonetheless, the importance of investigating the interplay between various encoding and retrieval strategies remains, and this was one of the issues that Experiment 4 was designed to explore.

Processes elicited during encoding were recorded in Experiment 4 in order to begin to provide some insight into the way in which they relate to response accuracy as well as retrieval processes. Although no reliable interactions between accuracy group and these effects were observed (for a discussion of why the design may not be optimal for detecting such effects see Chapter 8, Discussion), the polarity of subsequent memory effects reversed depending upon retrieval requirements, indicating that participants drew upon qualitatively distinct aspects of the encoding episode to make retrieval judgments. This pattern of data shows that unique processes are associated with the successful encoding of different types of information. Unfortunately, the data from Experiment 4 were unable to provide any insight into the degree to which these processes might vary across individuals.

ERP Measures of Retrieval Orientations

The critical data points in this thesis all comprise contrasts between ERPs elicited by retrieval cues from different test phases to provide correlates of the operations that are engaged following the adoption of retrieval orientations, and the data presented here indicate that these operations are positively related to task performance. A corollary question, therefore, is whether other ERP indices of the engagement of distinct retrieval orientations are also related to response accuracy.

In a number of reports, contrasts have been made between new item ERPs from test phases in which all old items are either copy cues or not (Robb & Rugg, 2002; Herron & Rugg, 2003a; 2003b; Hornberger et al., 2006; Duverne et al., 2008). These contrasts have elicited robust *study material* effects, because differences are sensitive to whether the material in which items are presented (e.g. pictures or words) are consistent across study and test. The mechanisms indexed by contrasts of this kind are assumed to emphasize the properties of retrieval cues to different degrees in line with the targeted material (Hornberger et al., 2004). For example, stressing visual or pictorial concepts may be useful when attempting to recover items that were previously presented as pictures and thus engaging these processes to a greater degree might be related to increases in accurate responses. Although the pattern of ERP new item effects reported here provides support for this prediction, unlike paradigms designed to elicit study material effects, copy cues were used throughout this thesis. It may be the case that copy cues allow for variable strategic processes to be engaged during retrieval. By this logic, when copy cues are not used it may be essential to engage specific retrieval cue processing in order to encourage the recovery of information associated at some level with the presented cue. As a consequence, the engagement of these processes indexed by study material ERP effects may be less open to variability and show a weaker relationship with response accuracy, although this has not been investigated directly.

Correlates of retrieval orientations have also been observed by contrasting ERPs elicited by task cues that differ according to the type of retrieval task they specify (e.g. Herron & Wilding, 2004; Morcom & Rugg, 2004). These are referred to as task cue-elicited effects. It was not possible to use contrasts such as this in the paradigms reported in this thesis because task cue effects require designs in which the test phase comprises interleaved episodic retrieval tasks, and all the designs employed here were made between test blocks in which task demands remained constant. This is because blocked retrieval tasks are more likely to elicit ERP measures of retrieval orientation (Johnson & Rugg, 2006). It may the case, however, that, in paradigms better suited to elicit switches between retrieval orientations, the amplitudes of task cue-elicited effects are related to the proportion of correct responses that participants make. This prediction is in line with the finding that task cue-elicited correlates of retrieval sets (mode or orientation) are related to increases in source accuracy (Herron & Wilding, 2006b) and, if supported, would provide evidence that the degree to which certain operations are engaged before a retrieval cue is presented also have consequences for response accuracy.

ERP Old/New Effects and Response Accuracy

Experiments 1, 3 and 4 provided an opportunity to describe the ways in which ERP old/new effects vary with response accuracy in an exclusion task, an item recognition task and a source retrieval task, respectively. The ways in which the amplitudes of old/new effects vary with accuracy offer insights into the relationship between memory processes and task performance as well as into the functional characterisations associated with each old/new effect. Relationships of this type, along with correspondences across experiments, are addressed in turn below.

The Left Parietal Old/New Effect

Reliable left parietal old/new effects in the 500-800ms window were observed in all four experiments. The behaviour of this effect and the way in which it relates to the functional interpretations of differences between new item ERPs has been discussed in preceding sections of this chapter. There was also a relationship between the amplitude of the left parietal old/new effect and accuracy in Experiment 4. The size of the effect in this time window was greater for those individuals who performed relatively poorly on the source memory task. Previous reports indicate that the effect provides a useful marker of the amount of recollected information (Vilberg & Rugg, 2009) indicating that these participants recollected more information overall. This is surprising if one assumes that recollecting more details concerning an item's source should facilitate responding correctly to questions about source and implies that increases in recollection do not necessarily map onto increases in response accuracy in a source memory task. One possible reason is that participants in the low accuracy group may have recollected information about each item that was not relevant to the current retrieval demands (non-criterial recollection). This might occur if participants failed to engage strategic pre-retrieval processes that stress the recovery of particular details that are necessary for the task in hand. ERP new item effects that were less extended over time for the low accuracy group support this account. Combined, this pattern suggests that increases in the amounts of recollected information alone are insufficient to ensure high accuracy in a source retrieval paradigm, but that processes engaged before and after recollection are also important. Discussion of the importance of post-retrieval operations is included below, in light of the behaviour of the late right frontal old/new effect in Experiment 4.

The Mid Frontal Old/New Effect

An early mid frontal old/new effect was greater in magnitude for ERPs elicited by targets in the exclusion task employed in Experiment 1 but only for participants who were less likely to make a correct response. Previously associated with familiarity-based recognition processes (Curran, 2000), this effect has been shown to be sensitive to changes in criterion (Azimian-Faridani & Wilding, 2006). One possibility is that changes in the amplitude of the effect reduce to changes in criterion for targets and nontargets in this group. This would come about if, for the low accuracy group, the criterion by which target judgments were made was relatively more conservative, causing only targets with relatively greater familiarity to be responded to as 'targets', and thereby increasing the amplitude of the effect for these items. It is not clear why some participants might adopt this bias but it is the case that attending to the relative familiarity of items is an inappropriate strategy for completing the exclusion task effectively because only recollection can ensure that items are responded to correctly (Jacoby, 1991).

The effect in this time window was not sensitive to changes in response accuracy in an item recognition (Experiment 3) or source retrieval task (Experiment 4). It is tempting to infer that variations in familiarity may make only minimal contributions to overall accuracy, especially in view of the changes in the later-occurring ERP old/new effects that do vary with response accuracy, as are discussed below. It is necessary to be mindful, however, of the restricted conclusions that can be made on the basis of null findings.

The Late Posterior Negativity

In Experiments 1, 2 and 4, ERPs elicited by new items demonstrated a greater relative positivity in comparison to ERPs elicited by correctly responded to old items from approximately 600-700ms onwards over midline posterior and occipital sites. This effect, the late posterior negativity (LPN), has been related to the formation of integrated representations of recognised items complete with bound contextual attributes, a process thought to be engaged most often in source retrieval tasks (Johansson & Mecklinger, 2003). In line with this, the relative negativity for old items was reliable only in those paradigms in which participants were required to retrieve source details and was not evident in the item recognition task employed in Experiment 3. It is interesting to note that in the experiments in which it was possible to make a contrast across accuracy groups (Experiments 1 and 4), the effect was largest for the sub-group of participants who made fewer correct responses overall. Following the failure to observe reliable ERP new item effects for these participants in Experiments 1 and 4, one possibility is that the failure to engage pre-retrieval processes that stress the recovery of particular details may lead to the requirement to employ compensatory post-retrieval mechanisms. In line with this, the processes posited by the LPN are thought to allow the recovery of item-context associations, including task-relevant source-specifying information, when this is not automatically recovered (Mecklinger, 2010). If the LPN indexes post-retrieval source integrating operations that provide a greater level of specification about each item's source, then one might expect that the engagement of such processes would lead to high accuracy in source retrieval tasks. This licenses one of two possibilities; (i) the enhanced LPNs across these experiments are not related to the re-integration of task-relevant source details, or (ii) that re-integration of source-specifying information does not provide source discrimination advantages over and above those endowed by the engagement of strategic pre-retrieval processes.

In favour of the former of these two possibilities is evidence that links the LPN with error monitoring processes following response conflict (Johansson & Mecklinger, 2003). This account might also explain the larger LPN for lower performers if a tendency to make relatively more incorrect responses leads to the experience of response conflict more generally. This explanation applies most obviously to the enhanced LPN to nontargets for low performers in Experiment 1, if individuals experienced conflict when effectively responding 'new' to 'old' items (Herron, 2007). It is less likely to apply, however, to the enhanced LPN in Experiment 4 for low performers because that effect was elicited by high confidence correct source responses, which are unlikely to be associated with response conflict. Combined with the specificity of the effect to source retrieval paradigms, this suggests that the effects are more likely to be related to the re-integration of source details supporting the second of the alternative accounts for this effect.

The Right Frontal Old/New Effect

In all four experiments, late right frontal old/new effects were revealed from around 800ms, remaining until the end of the recording epoch. In Experiments 3 and 4, these effects varied with accuracy group.

Figures 7.5, 7.6 and 7.7 show that in Experiment 3, the right frontal old/new effect in the final (1100-1400ms) time window was greater in amplitude and demonstrated a more superior distribution in the high than the low accuracy group. Although there are some reports of right frontal old/new effects that occur in simple recognition tasks (e.g. Rugg, Allan & Birch, 2000), these effects occur predominantly in source memory tasks and thus have been associated with the requirement to monitor the products of successful retrieval (Wilding & Rugg, 1996). If this interpretation of the effect is correct, then the findings from Experiment 3 suggest that those who engage in these monitoring processes to a greater degree are more likely to make a correct response even in simple-item recognition tasks in which correct responses can be made upon the basis of familiarity as well as recollection.

Problematic for this interpretation, however, is the observation that the frontal effect that was sensitive to accuracy from 1100-1400ms occurred after the point at which participants had made their responses (mean reaction times; hits = 944ms, correct rejections = 1026ms). It is not clear how processes that are engaged after responses have been made might contribute to increases in accuracy. It may be that continuing to monitor the products of retrieval may facilitate the engagement of a retrieval orientation that stresses the recovery of that information throughout a retrieval task leading to boosts in overall response accuracy.

An earlier (800-1100ms) right frontal old/new effect was sensitive to accuracy in Experiment 4. Old/new effects in this epoch were both larger in amplitude and exhibited a more anterior distribution for the high accuracy group (see Figure 8.5). As was the case in the preceding experiment, these data indicate that engaging in post-retrieval monitoring processes to a greater degree is associated with higher response accuracy in a source retrieval task. Differences in the timing of the late frontal effects that were sensitive to accuracy in Experiments 3 and 4 raise questions about why changing the requirements to include the recovery of source would cause accuracy-related monitoring processes to be engaged earlier. One possibility is that the requirement to make a subsequent source judgment increased the need to immediately monitor recovered mnemonic outputs. Further insight into the possible role of this effect comes from considering the relationship between the amplitude of the right frontal effect and the earlier left parietal old/new effect.

In Experiment 4, the left parietal old/new effect and the right frontal effect demonstrated a double dissociation; whereas the earlier parietal effect was largest in the low accuracy group, the later frontal effect was largest in the high accuracy group. This dissociation between the two effects provides a degree of insight into the functional significance of the latter effect. It is unlikely that processes indexed by the right frontal effect in Experiment 4 are related to the inhibition of unrelated or untargeted recollected information because the effect was engaged to a greater degree in the group for whom relatively less information was recollected. If the effect was related to processes of this kind it should occur for those individuals for whom the amplitude of the left parietal old/new effect was greater. Instead the effect is likely to reflect processes that continue to monitor the products of retrieval for task-relevant source details leading to increases in accurate responding. It is important to recognise that late right frontal old/new effects are likely to index a variety of post-retrieval mechanisms, some of which may not be specific to episodic retrieval tasks (Hayama et al., 2008). Thus it is possible, especially in view of the changes in the timing of the frontal effects that varied across the two tasks, that different post-retrieval mechanisms were related to accuracy across Experiments 3 and 4.

It is interesting to note that, across experiments, the amplitude of late right frontal old/new effects was consistently related to increases in response accuracy whereas the amplitude of the late posterior negativity was related to reduced response accuracy. Although functional accounts of these old/new effects are still incomplete, this distinction does suggest that some post-retrieval processes exert more influence over the accuracy of recognition judgments than others.

Assorted Caveats and Outstanding Issues

Although in a number of instances median split analyses indicated a relationship between the amplitude of ERP old/new effects and response accuracy, these observations did not extend to reliable correlations. One reason for this might be that processing indexed by ERP old/new effects is not open to the degree of variability that processing reflected by paired contrasts allows for. For the sake of brevity, the majority of contrasts between old/new effects have been collapsed across retrieval task, although where old/new effects have interacted with retrieval requirements and response accuracy these are reported (see Appendices A and E). The outcomes of paired contrasts and the way in which they have been used to constrain alternative functional accounts illustrate the importance of employing paired contrasts across tasks with distinct retrieval demands.

In order to control for the effect of inter-subject variability on electrical morphology it has been essential to make simple paired contrasts across retrieval phases in all the experiments reported here. An important caveat for contrasts of this kind is that they can only indicate relative changes in the processing engaged across tasks. It is not possible, therefore, to determine the extent to which increases in these operations might be engaged principally in one task, or whether these effects index qualitatively distinct operations in each task. One avenue to overcoming this problem might be to employ designs containing three retrieval phases, one of which is designed to be relatively neutral with regard to the engagement of strategic retrieval processes. One way to do this would be to adapt the design reported in Experiment 1 to include a 'baseline' inclusion task (Jacoby, 1991) in which participants must respond 'old' to items from both the function and drawing task regardless of study history, thus limiting the need to engage strategic retrieval operations. It should then be possible to contrast ERPs elicited by new items from the three test phases to determine the extent to which processing might change qualitatively or quantitatively with retrieval demands.

The paradigm in Experiment 4 was adapted to begin investigating the interplay between various encoding and retrieval processes. Specifically, it was designed so that ERP indices of encoding-related processes, subsequent memory effects (Paller et al., 1987; Friedman & Johnson, 2000), could be compared with overall response accuracy and the adoption of strategic retrieval processes. There was no evidence of a reliable relationship between the amplitude of these effects and the level of accuracy with which participants made source judgments. Although there are strong theoretical reasons for exploring this avenue, the outcomes of Experiment 4 serve as a cautionary reminder of the problems that arise from attempts to index both encoding and retrieval operations within the same design. Designs that are optimal for recording separate contrasts at encoding and retrieval are not necessarily compatible and so, at this stage of enquiry, it may be more appropriate to undertake experiments that address variability at each stage separately before attempting to combine them.

As is the case with all empirical investigation, the findings presented in this thesis require additional validation via replication. Crucially, however, the broad pattern concerning the critical findings - that the engagement of ERP indices of strategic retrieval processes is related positively to accurate responding in recognition tasks - has been replicated across the experiments reported here.

General Conclusions

Control mechanisms operate throughout retrieval to ensure relevant information is selected rapidly and successfully (Burgess & Shallice, 1996; Schacter, Koutstaal, & Norman, 1998). The work in this thesis supports those models that include an emphasis on processes engaged prior to retrieval by highlighting the importance of operations engaged during a retrieval attempt and the relationship these have with response accuracy in memory recognition tasks. This assertion follows from the outcomes of contrasts between ERPs elicited by new items from test phases with diverging retrieval demands. In so far as contrasts of this kind provide item-related indices of the strategic retrieval processes bestowed following the adoption of a retrieval orientation (Rugg & Wilding, 2000) they indicate, for the first time, that the degree to which participants adopt strategic retrieval processes has consequences for accurate responding. Evidence of a relationship between these processes and response accuracy was found across recognition memory tasks with different retrieval requirements, including those that do and those that do not require the explicit recovery of contextual information. The scalp distributions and time courses of these processes differed across the different recognition paradigms emphasizing the various specific retrieval processes that can relate to increases in response accuracy. A necessary development in future work will be a careful analysis of interactions between encoding and retrieval and the influence these have on individual differences in response accuracy.

References

Aggleton, J. P., Vann, S. D., Denby, C., Dix, S., Mayes, A. R., Roberts, N., et al. (2005). Sparing of the familiarity component of recognition memory in a patient with hippocampal pathology. *Neuropsychologia, 43*, 1810-1823.

Allan, K., Wilding, E. L., & Rugg, M. D. (1998). Electrophysiological evidence for dissociable processes contributing to recollection. *Acta Psychologica, 98,* 231-252.

Allison, T. (1984). Recording and interpreting event-related potentials. In E. Donchin (Ed.), *Cognitive psychophysiology: Event-related potentials and the study of cognition* (pp. 1-36). New Jersey: Hillsdale.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychonomic Bulletin & Review, 7,* 522-530.

Anderson, M. C., & Bjork, R. A. (1994). Mechanisms of inhibition in long term memory. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory Processes in Attention, Memory, and Language* (pp. 265-325). San Diego, California: Academic Press.

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. *Nature, 410,* 366-369.

Azimian-Faridani, N., & Wilding, E. L. (2006). The influence of criterion shifts on electrophysiological correlates of recognition memory. *Journal of Cognitive Neuroscience, 18,* 1075-1086.

Benoit, R. G., Werkle-Bergner, M., Mecklinger, A., & Kray, J. (2009). Adapting to changing memory retrieval demands: Evidence from event-related potentials. *Brain and Cognition, 70,* 123-135.

Binnie, C. D. (1987). Recording techniques: Montages, electrodes, amplifiers, and filters. In A. M. Halliday, S. R. Butler & R. Paul (Eds.), *A Textbook of Clinical Neurophysiology* (pp. 3-22). New York: Wiley.

Bridger, E. K., Herron, J. E., Elward, R. L., & Wilding, E. (2009). Neural correlates of individual differences in strategic retrieval processing. *Journal of Experimental Psychology: Learning, Memory and Cognition, 35,* 1175-1186.

Bridson, N. C., Fraser, C. S., Herron, J. E., & Wilding, E. L. (2006). Electrophysiological correlates of familiarity in recognition memory and exclusion tasks. *Brain Research, 1114,* 149-160.

Bureš, J. (1967). Electrophysiology of the Cerebral Cortex. In J. Bureš, M. Petráň & J. Zachar (Eds.), *Electrophysiological Methods in Biological Research* (pp. 507-585). New York: Academic Press.

Burke, D. M., & Light, L. L. (1981). Memory and aging: The role of retrieval-processes. *Psychological Bulletin, 90*, 513-546.

Burgess, P. W., & Shallice, T. (1996). Confabulation and the control of recollection. *Memory, 4,* 359-411.

Camp, C. J., Markley, R. P., & Kramer, J. J. (1983). Naive mnemonics: What the "do-nothing" control group does. *American Journal of Psychology, 96,* 503-511.

Coles, M. G. H., & Rugg, M. D. (1995). Event-related brain potentials: An introduction. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind. Event-related brain potentials and cognition.* (pp. 1-26). New York: Oxford University Press.

Coltheart, M. (1981). The MRC Psycholinguistic Database. *Quarterly Journal of Experimental Psychology: A, 33*, 497-505.

Cooper, R., Osselton, J. W., & Shaw, J. C. (1980). *EEG Technology.* London: Butterworths.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 191-211). New York: Plenum.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behaviour, 11,* 671-684.

Craik, F. I. M. & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 13*, 474-479.

Cruse, D., & Wilding, E. L. (2009). Prefrontal cortex contributions to episodic retrieval monitoring and evaluation. *Neuropsychologia, 47,* 2779-2789.

Curran, T. (1999). The electrophysiology of incidental and intentional retrieval: ERP old/new effects in lexical decision and recognition memory. *Neuropsychologia, 37,* 771-785.

Curran, T. (2000). Brain potentials of recollection and familiarity. *Memory and Cognition, 28,* 923-938.

Curran, T. (2004). Effects of attention and confidence on the hypothesized ERP correlates of recollection and familiarity. *Neuropsychologia, 42,* 1088-1106.

Curran, T., & Cleary, A. M. (2003). Using ERPs to dissociate familiarity from recollection in picture recognition. *Cognitive Brain Research, 15,* 191-205.

Curran, T., & Dien, J. (2003). Differentiating amodal familiarity from modality-specific memory processes: An ERP study. *Psychophysiology, 40,* 979-988.

Curran, T., & Hancock, J. (2007). The FN400 indexes familiarity-based recognition of faces. *NeuroImage, 36,* 464-471.

Cycowicz, Y. M., Friedman, D., & Snodgrass, J. G. (2001). Remembering the colour of objects: An ERP investigation of source memory. *Cerebral Cortex, 11,* 322-334.

Dab, S., Claes, T., Morais, J., & Shallice, T. (1999). Confabulation with a selective descriptor process impairment. *Cognitive Neuropsychology, 16,* 215-242.

De Chastelaine, M., Friedman, D., Cycowicz, Y. M., & Horton, C. (2009). Effects of multiple study-test repetition on the neural correlates of recognition memory: ERPs dissociate remembering and knowing. *Psychophysiology, 46,* 86-99.

Démonet, J. F., Chollet, F., Ramsay, S., Cardebat, D., Nespoulous, J. L., Wise, R., et al. (1992). The anatomy of phonological and semantic processing in normal subjects. *Brain, 115,* 1753-1768.

Diana, R. A., Reder, L. M., Arndt, J., & Park, H. (2006). Models of recognition: A review of arguments in favor of a dual-process account. *Psychonomic Bulletin & Review, 13,* 1-21.

Dewhurst, S. A., & Hitch, G. J. (1999). Cognitive effort and recollective experience in recognition memory. *Memory, 7,* 129-146.

Dobbins, I., & Han, H. (2006). Isolating rule- versus evidence-based prefrontal activity during episodic and lexical discrimination: A functional magnetic resonance imaging investigation of detection theory distinctions. *Cerebral Cortex, 16,* 1614-1622.

Dobbins, I. G., Rice, H. J., Wagner, A. D., & Schacter, D. L. (2003). Memory orientation and success: Separable neurocognitive components underlying episodic recognition. *Neuropsychologia, 41,* 318-333.

Donaldson, D. I., Peterson, S. E., Ollinger, J. M., & Bucker, R. L. (2001). Dissociating state and item components of recognition memory using fMRI. *NeuroImage, 13,* 129-142.

Donaldson, D. I., & Rugg, M. D. (1998). Recognition memory for new associations: Electrophysiological evidence for the role of recollection. *Neuropsychologia, 36,* 377-395.

Donaldson, D. I., & Rugg, M. D. (1999). An event-related study comparing associative recognition and associative recall. *Cognitive Brain Research, 8,* 1-16.

Donchin, E. (1981). Surprise!...Surprise? *Psychophysiology, 18,* 493-513.

Duarte, A., Ranganath, C., Winward, L., Hayward, D., & Knight, R. T. (2004). Dissociable neural correlates for familiarity and recollection during the encoding and retrieval of pictures. *Cognitive Brain Research, 18,* 255-272.

Duncan, J., & Owen, A. M. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences, 23,* 475-483.

Dunn, J. C. (2004). Remember-know: A matter of confidence. *Psychological Review, 111,* 524-542.

Duverne, S., Motamedinia, S., & Rugg, M. D. (2008). Effects of age on the neural correlates of retrieval cue processing are modulated by task demands. *Journal of Cognitive Neuroscience, 21,* 1-17.

Düzel, E., Cabeza, R., Picton, T. W., Yonelinas, A. P., Scheich, H., Heinze, H. J., et al. (1999). Task-related and item-related brain processes of memory retrieval. *Proceedings of the National Academy of Sciences: USA, 96,* 1794-1799.

Düzel, E., Neufang, M., & Heinze, H. (2005). The oscillatory dynamics of recognition memory and its relationship to event-related responses. *Cerebral Cortex, 15,* 1992-2002.

Düzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H. J., & Tulving, E. (1997). Event-related brain potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Sciences: USA, 94,* 5973-5978.

Dywan, J., Segalowitz, S. J., & Webster, L. (1998). Source monitoring: ERP evidence for greater reactivity to non-target information in older adults. *Brain and Cognition, 36,* 390-430.

Dzulkifli, M. A., Herron, J. E., & Wilding, E. L. (2006). Memory retrieval processing: Neural indices of processes supporting episodic retrieval. *Neuropsychologia, 44,* 1120-1130.

Dzulkifli, M. A., Sharpe, H. L., & Wilding, E. L. (2004). Separating item-related electrophysiological indices of retrieval effort and retrieval orientation. *Brain and Cognition, 55,* 433-443.

Dzulkifli, M. A., & Wilding, E. L. (2005). Electrophysiological indices of strategic episodic retrieval processing. *Neuropsychologia, 43,* 1152-1162.

Ecker, U. K. H., & Zimmer, H. D. (2009). ERP evidence for flexible adjustment of retrieval orientation and its influence on familiarity. *Journal of Cognitive Neuroscience, 21,* 1907-1919.

Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007). Color and context: An ERP study on intrinsic and extrinsic feature binding in episodic memory. *Memory and Cognition, 35,* 1483-1501.

Elward, R. L., & Wilding, E. L. (in submission). Working memory capacity predicts the magnitude of an electrophysiological marker of recollection and the engagement of cognitive control processes. *Brain Research.*

Fletcher, P. C., & Henson, R. N. A. (2001). Frontal lobes and human memory: Insights from functional neuroimaging. *Brain, 124,* 849-881.

Friedman, D., Cycowicz, Y. M., & Bersick, M. (2005). The late negative episodic memory effect: The effect of recapitulating study details at test. *Cognitive Brain Research, 23,* 185-198.

Friedman, D., & Johnson, R. (2000). Event-related potential (ERP) studies of memory encoding and retrieval: A selective review. *Microscopy Research and Techniques, 51,* 6-28.

Friston, K. J., Price, C. J., Fletcher, P. C., Moore, C., Frackowiack, R. S. J., & Dolan, R. J. (1996). The trouble with cognitive subtraction. *NeuroImage, 4,* 97-104.

Garavan, H., Ross, T. J., & Stein, E. A. (1999). Right hemispheric dominance of inhibitory control: An event-related functional MRI study. *Proceedings of the National Academy of Sciences: USA, 96,* 8301-8306.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory and Cognition, 16,* 309-313.

Gardiner, J. M., & Java, R. I. (1990). Recollective experience in word and non-word recognition. *Memory and Cognition, 18,* 23-30.

Geiselman, R. E., Woodward, J. A., & Beatty, J. (1982). Individual differences in verbal memory performance: A test of alternative information-processing models. *Journal of Experimental Psychology: General, 111,* 109-134.

Gillund, G., & Shiffrin, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review, 91,* 1-67.

Glanzer, M., Kim, K., Hilford, A., & Adams, J. K. (1999). Slope of the receiver-operating characteristic in recognition memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 25*, 500-513.

Greenhouse, G. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 49,* 95-112.

Groh-Bordin, C., Zimmer, H. D., & Ecker, U. K. H. (2006). Has the butcher on the bus dyed his hair? When color changes modulate ERP correlates of familiarity and recollection. *NeuroImage, 32,* 1879-1890.

Haig, A. R., Gordon, E., & Hook, S. (1997). To scale or not to scale: McCarthy and Wood revisited. *Electroencephalography and Clinical Neurophysiology, 103,* 323-325.

Hanslmayr, S., Klimesch, W., Sauseng, P., Gruber, W. R., Doppelmayr, M., Freunberger, R., et al. (2007). Alpha phase reset contributes to the generation of ERPs. *Cerebral Cortex, 17,* 1-8.

Hayama, H. R., Johnson, J. D., & Rugg, M. D. (2008). The relationship between the right frontal old/new ERP effect and post-retrieval monitoring: Specific or non-specific? *Neuropsychologia, 46,* 1211-1223.

Herron, J. E. (2007). Decomposition of the late posterior negativity: Effects of retrieval and response fluency. *Psychophysiology, 44,* 233-244.

Herron, J. E., & Rugg, M. D. (2003a). Retrieval orientation and the control of recollection. *Journal of Cognitive Neuroscience, 15,* 843-854.

Herron, J. E., & Rugg, M. D. (2003b). Strategic influences on recollection in the exclusion task: Electrophysiological evidence. *Psychonomic Bulletin & Review, 10,* 703-710.

Herron, J. E., & Wilding, E. L. (2004). An electrophysiological dissociation of retrieval orientation and retrieval mode. *NeuroImage, 22,* 1554-1562.

Herron, J. E., & Wilding, E. L. (2006a). Brain and behavioral indices of retrieval mode. *NeuroImage, 32,* 863-870.

Herron, J. E., & Wilding, E. L. (2006b). Neural correlates of control processes engaged before and during recovery of information from episodic memory. *NeuroImage, 30,* 634-644.

Hillyard, S. A., & Münte, T. F. (1984). Selective attention to color and locational cues: An analysis with event-related potentials. *Perception and Psychophysics, 36,* 185-198.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review, 109,* 679-709.

Hornberger, M., Morcom, A. M., & Rugg, M. D. (2004). Neural correlates of retrieval orientation: Effects of study-test similarity. *Journal of Cognitive Neuroscience, 16,* 1196-1210.

Hornberger, M., Rugg, M. D., & Henson, R. N. (2006a). ERP correlates of retrieval orientation: Direct versus indirect memory tasks. *Brain Research, 1071,* 124-136.

Hornberger, M., Rugg, M. D., & Henson, R. N. (2006b). fMRI correlates of retrieval orientation. *Neuropsychologia, 44,* 1425-1436.

Ishai, A., Ungerleider, L. G., & Haxby, J. V. (2000). Distributed neural systems for the generation of visual images. *Neuron, 28*, 979-990.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30,* 513-541.

Jacoby, L. L., Shimizu, Y., Daniels, K. A., & Rhodes, M. G. (2005). Modes of cognitive control in recognition and source memory: Depth of retrieval. *Psychonomic Bulletin & Review, 12,* 852-857.

Jacoby, L. L., Shimizu, Y., Velanova, K., & Rhodes, M. G. (2005). Age differences in depth of retrieval: Memory for foils. *Journal of Memory and Language, 52,* 493-504.

Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairments in patients with frontal lobe lesions. *Neuropsychologia, 27,* 1043-1056.

Jasper, H. A. (1958). The Ten-Twenty system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10,* 371-375.

Johansson, M., & Mecklinger, A. (2003). The late posterior negativity in ERP studies of episodic memory: Action monitoring and retrieval of attribute conjunctions. *Biological Psychology, 64,* 91-117.

Johansson, M., Stenberg, G., Lindberg, M., & Rosen, I. (2002). Memory for perceived and imagined pictures: An event-related potential study. *Neuropsychologia, 40,* 986-1002.

Johnson, J. D., Minton, B. R., & Rugg, M. D. (2008). Content dependence of the electrophysiological correlates of recollection. *NeuroImage, 39,* 406-416.

Johnson, J. D., & Rugg, M. D. (2006). Electrophysiological correlates of retrieval processing: Effects of consistent versus inconsistent retrieval demands. *Journal of Cognitive Neuroscience, 18,* 1531-1544.

Johnson, J. D., & Rugg, M. D. (2007). Recollection and the reinstatement of encoding-related cortical activity. *Cerebral Cortex, 17,* 2507-2515.

Johnson, M. K., Foley, M. A., Suengas, A. G., & Raye, C. L. (1988). Phenomenal characteristics of memories for perceived and imagined autobiographical events. *Journal of Experimental Psychology: General, 117,* 371-376.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). A source monitoring framework. *Psychological Bulletin, 114,* 3-28.

Johnson, M. K., Kounios, J., & Nolde, S. F. (1997). Electrophysiological brain activity and memory source monitoring. *NeuroReport, 7,* 2929-2932.

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review, 88,* 67-85.

Jones, G. V. (1987). Independence and exclusivity among psychological processes: Implications for the structure of recall. *Psychological Review, 94,* 229-235.

Kapur, S., Craik, F. I. M., Jones, C., Brown, G. M., Houle, S., & Tulving, E. (1995). Functional role of the prefrontal cortex in retrieval of memories: A PET study. *NeuroReport, 6,* 1880-1884.

Kent, C., & Lamberts, K. (2008). The encoding-retrieval relationship: Retrieval as mental stimulation. *Trends in Cognitive Sciences, 12,* 92-98.

Kirchhoff, B. A., & Buckner, R. L. (2006). Functional-anatomic correlates of individual differences in memory. *Neuron, 51,* 263-274.

Klimesch, W., Doppelmayr, M., Schwaiger, J., Winkler, T., & Gruber, W. R. (2000). Theta oscillations and the ERP old/new effect: Independent phenomena? *Clinical Neurophysiology, 111,* 781-793.

Kutas, M., & Dale, A. M. (1997). Electrical and magnetic readings of mental functions. In M. D. Rugg (Ed.), *Cognitive Neuroscience* (pp. 197-242). Cambridge, MA: MIT Press.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203-205.

Lepage, M., Ghaffar, O., Nyberg, L., & Tulving, E. (2000). Prefrontal cortex and episodic memory retrieval mode. *Proceedings of the National Academy of Sciences: USA, 97,* 506-511.

Levy, B. J., & Anderson, M. C. (2002). Inhibitory processes and the control of memory retrieval. *Trends in Cognitive Sciences, 6,* 299-305.

Levy, B. J., & Anderson, M. C. (2008). Individual differences in the suppression of unwanted memories: The executive deficit hypothesis. *Acta Psychologica, 127,* 623-635.

Leynes, P. A., & Bink, M. L. (2002). Did I do that? An ERP study of memory for performed and planned actions. *International Journal of Psychophysiology, 45,* 197-210.

Leynes, P. A., & Phillips, M. C. (2008). Event-related potential (ERP) evidence for varied recollection during source monitoring. *Journal of Experimental Psychology: Learning, Memory and Cognition, 34,* 741-751.

Loftus, E. F. (1993). The reality of repressed memories. *American Psychologist, 48,* 518-537.

Lorento de Nó, R. (1947). Analysis of the distribution of action currents of nerve in volume conductors. *Studies from the Rockefeller Institute for Medical Research, 132,* 384-477.

MacCallum, R. C., Zhang, S., Preacher, K. J., & Rucker, D. D. (2002). On the practice of dichotomization of quantitative variables. *Psychological Methods, 7,* 19-40.

MacKenzie, G., & Donaldson, D. (2007). Dissociating recollection from familiarity: Electrophysiological evidence that familiarity for faces is associated with a posterior old/new effect. *NeuroImage, 36,* 454-463.

Makeig, S., Debener, S., Onton, J., & Delorme, A. (2004). Mining event-related brain dynamics. *Trends in Cognitive Sciences, 8,* 204-210.

Malmberg, K. J. (2008). Recognition memory: A review of the critical findings and an integrated theory for relating them. *Cognitive Psychology, 57,* 335-384.

Mandler, G. (1980). Recognising: The judgment of previous occurrence. *Psychological Review, 87,* 252-271.

Marsh, R. L., & Hicks, J. L. (1998). Test-format changes source-monitoring decision processes. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24,* 1137-1151.

McCarthy, G., & Wood, C. C. (1985). Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalography and Clinical Neurophysiology, 62,* 203-208.

McDaniel, M. A., & Kearney, E. M. (1984). Optimal learning strategies and their spontaneous use: The importance of task-appropriate processing. *Memory and Cognition, 12,* 361-373.

Mecklinger, A. (2000). Interfacing mind and brain: A neurocognitive model of recognition memory. *Psychophysiology, 37,* 565-582.

Mecklinger, A. (2010). The control of long-term memory: Brain systems and cognitive processes. *Neuroscience and Biobehavioral Reviews, 34,* 1055-1065.

Mecklinger, A., Johansson, M., Parra, M., & Hanslmayr, S. (2007). Source-retrieval requirements influence late ERP and EEG memory effects. *Brain Research, 1172,* 110-123.

Mehler, J., Morton, J., & Jusczyk, P. W. (1984). On reducing language to biology. *Cognitive Neuropsychology, 1,* 83-116.

Mesulam, M. M. (1990). Large-scale neurocognitive networks and distributed processing for attention, language and memory. *Annals of Neurology, 28,* 597-613.

Metcalf, K., Langdon, R., & Coltheart, M. (2007). Models of confabulation: A critical review and a new framework. *Cognitive Neuropsychology, 24,* 23-47.

Miltner, W., Braun, C., Johnson, J. R., Simpson, G. V., & Ruchkin, D. S. (1994). A test of brain electrical source analysis (BESA): A simulation study. *Electroencephalography and Clinical Neurophysiology, 91,* 295-310.

Min, B. K., Busch, N. A., Debener, S., Kranczioch, C., Hanslmayr, S., Engel, A. K., et al. (2007). The best of both worlds: Phase-reset of human EEG alpha activity and additive power contribute to ERP generation. *International Journal of Psychophysiology, 65,* 58-68.

Mitchell, D. B., & Hunt, R. R. (1989). How much "effort" should be devoted to memory? *Memory and Cognition, 17,* 337-348.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7,* 134-140.

Morcom, A. M., & Rugg, M. D. (2002). Getting ready to remember: The neural correlates of task set during recognition memory. *NeuroReport, 13,* 149-152.

Morcom, A. M., & Rugg, M. D. (2004). Effects of age on retrieval cue processing as revealed by ERPs. *Neuropsychologia, 42,* 1525-1542.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behaviour, 16,* 519-533.

Moscovitch, M. (1989). Confabulation and the frontal systems: Strategic versus associative retrieval in neuropsychological theories of memory. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of Memory and Consciousness: Essays in Honour of Endel Tulving* (pp. 133-160). Hillsdale, N.J.: Erlbaum.

Moscovitch, M. (1992). Memory and working-with-memory: A component process model based on modules and central systems. *Journal of Cognitive Neuroscience, 4,* 257-267.

Moscovitch, M., & Melo, B. (1997). Strategic retrieval and the frontal lobes: Evidence from confabulation and amnesia. *Neuropsychologia, 35,* 1017-1034.

Moscovitch, M., & Winocur, G. (2002). The frontal cortex and working with memory. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 188-209). London: Oxford University Press.

Nairne, J. S. (2002). The myth of the encoding-retrieval match. *Memory, 10,* 389-395.

Nessler, D., & Mecklinger, A. (2003). ERP correlates of true and false recognition after different retention delays: Stimulus- and response-related processes. *Psychophysiology, 40,* 146-159.

Nessler, D., Mecklinger, A., & Penney, T. B. (2001). Event related brain potentials and illusory memories: The effects of differential encoding. *Cognitive Brain Research, 10,* 283-301.

Norman, D. A., & Bobrow, D. G. (1979). Descriptions: An intermediate stage in memory retrieval. *Cognitive Psychology, 11,* 107-123.

Nyberg, L., Cabeza, R., & Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin and Review, 3,* 135-148.

O'Reilly, R. C., & McClelland, J. L. (1994). Hippocampal conjunctive encoding, storage, and recall: Avoiding a tradeoff. *Hippocampus, 4,* 661-682.

Osterhout, L., & Holcomb, P. J. (1995). Event-related potentials and language comprehension. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of Mind:*

Event-Related Potentials and Cognition (pp. 171-215). Oxford: Oxford University Press.

Otten, L. J., & Rugg, M. D. (2001). Electrophysiological correlates of memory encoding are task-dependent. *Cognitive Brain Research, 12,* 11-18.

Paller, K. A., Kutas, M., & Mayes, A. R. (1987). Neural correlates of encoding in an incidental learning paradigm. *Electroencephalography and Clinical Neurophysiology, 67,* 360-371.

Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. *Trends in Cognitive Sciences, 11,* 243-250.

Picton, T. W. (1987). The recording and measurement of evoked potentials. In A. M. Halliday, S. R. Butler & R. Paul (Eds.), *A Textbook of Clinical Neurophysiology* (pp. 23-40). New York: Wiley.

Picton, T. W., Bentin, S., Berg, P., Donchin, E., Hillyard, S. A., Johnson, S. A., et al. (2000). Guidelines for using human event-related potentials to study cognition: Recording standards and publication criteria. *Psychophysiology, 37,* 127-152.

Picton, T. W., Lins, O. G., & Scherg, M. (1994). The recording and analysis of event-related potentials. In F. Boller & J. Grafman (Eds.), *Handbook of Neuropsychology* (pp. 3-73). New York: Elsevier.

Rajaram, S. (1993). Remembering and knowing: Two means of access to the personal past. *Memory and Cognition, 21,* 89-102.

Ranganath, C., Johnson, M. K., & D'Esposito, M. (2000). Left anterior prefrontal activation increases with demands to recall specific perceptual information. *The Journal of Neurosciences, 20,* RC108.

Ranganath, C., & Paller, K. A. (1999). Frontal brain potentials during recognition are modulated by requirements to retrieve perceptual details. *Neuron, 22,* 605-613.

Ranganath, C., & Paller, K. A. (2000). Neural correlates of memory retrieval and evaluation. *Cognitive Brain Research, 9,* 209-222.

Richardson, J. T. E. (1998). The availability and effectiveness of reported mediators in associative learning: A historical review and an experimental investigation. *Psychonomic Bulletin & Review, 5,* 597-614.

Ritter, P., & Villringer, A. (2006). Simultaneous EEG-fMRI. *Neuroscience and Biobehavioral Reviews, 30,* 823-838.

Robb, W. G. K., & Rugg, M. D. (2002). Electrophysiological dissociation of retrieval orientation and retrieval effort. *Psychonomic Bulletin and Review, 9,* 583-589.

Roediger, H. L., & Gallo, D. A. (2002). Levels of processing: Some unanswered questions. In M. Naveh-Benjamin, M. Moscovitch & H. L. Roediger (Eds.), *Perspectives on human memory and cognitive aging: Essays in honour of Fergus Craik* (pp. 28-47). New York: Psychology Press.

Roediger, H. L., Gallo, D. A., & Geraci, L. (2002). Processing approaches to cognition: The impetus from the levels-of-processing framework. *Memory, 10,* 319-332.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124,* 207-231.

Rugg, M. D., Allan, K., & Birch, C. S. (2000). Electrophysiological evidence for the modulation of retrieval orientation by depth of study processing. *Journal of Cognitive Neuroscience, 12,* 664-678.

Rugg, M. D., & Coles, M. G. H. (1995). The ERP and cognitive psychology: Conceptual issues. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of Mind: Event-Related Brain Potentials and Cognition* (pp. 27-39). Oxford: Oxford University Press.

Rugg, M. D., Cox, C. J. C., Doyle, M. C., & Wells, T. (1995). Event-related potentials and the recollection of low and high frequency words. *Neuropsychologia, 33,* 471-484.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11,* 251-257.

Rugg, M. D., Fletcher, P. C., Allan, K., Frith, C. D., Frackowiak, R. S. J., & Dolan, R. J. (1998). Neural correlates of memory retrieval during recognition memory and cued recall. *NeuroImage, 8,* 262-273.

Rugg, M. D., Fletcher, P. C., Frith, C. D., Frackowiak, R. S. J., & Dolan, R. J. (1996). Differential activation of the prefrontal cortex in successful and unsuccessful memory retrieval. *Brain, 119,* 2073-2083.

Rugg, M. D., & Henson, R. N. (2002). Episodic memory retrieval: An (event-related) functional neuroimaging perspective. In A. E. Parker, E. L. Wilding & T. J. Bussey (Eds.), *The Cognitive Neuroscience of Memory Encoding and Retrieval* (pp. 3-37). Hove, UK: Psychology Press.

Rugg, M. D., Herron, J. E., & Morcom, A. (2002). Electrophysiological studies of retrieval processing. In L. R. Squire & D. L. Schacter (Eds.), *Neuropsychology of Memory* (pp. 154-165). New York: Guilford Publications.

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the neural correlates of implicit and explicit memory. *Nature, 392,* 595-598.

Rugg, M. D., Schloerscheidt, A. M., Doyle, M. C., Cox, C. J. C., & Patching, G. R. (1996). Event-related potentials and the recollection of associative information. *Cognitive Brain Research, 4,* 297-304.

Rugg, M. D., & Wilding, E. L. (2000). Retrieval processing and episodic memory. *Trends in Cognitive Sciences, 4,* 108-115.

Rugg, M. D., & Yonelinas, A. P. (2003). Human recognition memory: A cognitive neuroscience perspective. *Trends in Cognitive Sciences, 7,* 313-319.

Sauseng, P., & Klimesch, W. (2008). What does phase information of oscillatory brain activity tell us about cognitive processes? *Neuroscience and Biobehavioral Reviews, 32,* 1001-1013.

Sauseng, P., Klimesch, W., Gruber, W. R., Hanslmayr, S., Freunberger, R., & Doppelmayr, M. (2007). Are event-related potential components generated by phase resetting of brain oscillations? A critical discussion. *Neuroscience, 146,* 1435-1444.

Schacter, D. L., Chiu, C. Y. P., & Ochsner, K. N. (1993). Implicit memory: A selective review. *Annual Review of Neuroscience, 16,* 159-182.

Schacter, D. L., Koutstaal, W., & Norman, K. A. (1996). Can cognitive neuroscience illuminate the nature of traumatic childhood memories? *Current Opinion in Neurobiology, 6,* 207-214.

Schacter, D. L., Norman, K. A., & Koutstaal, W. (1998). The cognitive neuroscience of constructive memory. *Annual Review of Psychology, 49,* 289-318.

Scherg, M. (1990). Fundamentals of dipole source potential analysis. In F. Grandori, G. L. Romani & M. Hoke (Eds.), *Auditory evoked electric and magnetic fields. Topographic mapping and functional localization. Advances in Audiology* (pp. 40-69). Karger: Basel.

Schloerscheidt, A. M., & Rugg, M. D. (2004). The impact of change in stimulus format on the electrophysiological indices of recognition. *Neuropsychologia, 42,* 451-466.

Schmidt, S. R. (1991). Can we have a distinctive theory of memory? *Memory and Cognition, 19,* 523-542.

Schnider, A. (2003). Spontaneous confabulations and the adaptation of thought to ongoing reality. *Nature Reviews Neuroscience, 4,* 662-671.

Semlitsch, H., Anderer, P., Schuster, P., & Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology, 23,* 695-703.

Semon, R. S. (1921). *The Mneme*. London: George Allen & Unwin.

Senkfor, A. J., & Van Petten, C. (1998). Who said what? An event-related potential investigation of source and item memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24,* 1005-1025.

Shallice, T., & Evans, M. E. (1978). The involvement of the frontal lobes in cognitive estimation. *Cortex, 14,* 294-303.

Shaughnessy, J. J. (1981). Memory monitoring accuracy and modification of rehearsal strategies. *Journal of Verbal Learning and Verbal Behavior, 20,* 216-230.

Shergill, S. S., Bullmore, E. T., Brammer, M. J., Williams, S. C. R., Murray, R. M., & McGuire, P. K. (2001). A functional study of auditory verbal imagery. *Psychological Medicine, 31,* 241-253.

Simons, J. S., & Spiers, H. J. (2003). Prefrontal and medial temporal lobe interactions in long-term memory. *Nature Reviews Neuroscience, 4,* 637-648.

Smith, M. E. (1993). Neurophysiological manifestations of recollective experience during recognition memory judgments. *Journal of Cognitive Neuroscience, 5,* 1-13.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117,* 34-50.

Spencer, K. M., Vila Abad, E., & Donchin, E. (2000). On the search for the neurophysiological manifestation of recollective experience. *Psychophysiology, 37,* 494-506.

Squire, L. R., & Zola, S. M. (1998). Episodic memory, semantic memory and amnesia. *Hippocampus, 8,* 205-211.

Stenberg, G., Johansson, M., & Rosen, I. (2006). Conceptual and perceptual memory: Retrieval orientations reflected in event-related potentials. *Acta Psychologica, 122,* 174-205.

Swick, D., Senkfor, A. J., & Van Petten, C. (2006). Source memory retrieval is affected by aging and prefrontal lesions: Behavioral and ERP evidence. *Brain Research, 30,* 161-176.

Talsma, D., & Kok, A. (2001). Nonspatial intermodal selective attention is mediated by sensory brain areas: Evidence from event-related potentials. *Psychophysiology, 38,* 736-751.

Temple, C. M., & Richardson, P. (2004). Developmental amnesia: A new pattern of dissociation with intact episodic memory. *Neuropsychologia, 42,* 764-781.

Tendolkar, I., Schoenfeld, A., Golz, G., Fernandez, G., Kuhl, K., Ferszt, R., et al. (1999). Neural correlates of recognition memory with and without recollection in patients with Alzheimer's disease and healthy controls. *Neuroscience Letters, 263,* 45-48.

Tulving, E. (1983a). Ecphoric processes in episodic memory. *Philosophical Transactions of the Royal Society of London: B, 302,* 361-371.

Tulving, E. (1983b). *Elements of Episodic Memory.* Oxford: Oxford Psychology.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352-373.

Urbach, T. P., & Kutas, M. (2002). The intractability of scaling scalp distributions to infer neuroelectric sources. *Psychophysiology, 39,* 791-808.

Vargha-Khadem, F., Gadian, D. G., Watkins, K. E., Connelly, A., Van Paesschen, W., & Mishkin, M. (1997). Differential effects of early hippocampal pathology on episodic and semantic memory. *Science, 277,* 376-380.

Verfaellie, M., & Treadwell, J. R. (1993). Status of recognition memory in amnesia. *Neuropsychology, 7,* 5-13.

Vilberg, K. L., Moosavi, R. F., & Rugg, M. D. (2006). The relationship between electrophysiological correlates of recollection and amount of information retrieved. *Brain Research, 1122,* 161-170.

Vilberg, K. L., & Rugg, M. D. (2009). Functional significance of retrieval-related activity in lateral parietal cortex: Evidence from fMRI and ERPs. *Human Brain Mapping, 30,* 1490-1501.

Voss, J. L., Lucas, H. D., & Paller, K. A. (in press). Conceptual priming and familiarity: Different expressions of memory during recognition testing with distinct neurophysiological correlates. *Journal of Cognitive Neuroscience.*

Voss, J. L., & Paller, K. A. (2007). Neural correlates of conceptual implicit memory and their contamination of putative neural correlates of explicit memory. *Learning and Memory, 14,* 259-267.

Voss, J. L., & Paller, K. A. (2009). An electrophysiological signature of unconscious recognition memory. *Nature Neuroscience, 12,* 349-355.

Wagner, A. D., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1998). Prefrontal cortex and recognition memory: functional MRI evidence for context-dependent retrieval processes. *Brain, 121,* 1985-2002.

Wagner, A. D., Shannon, B. J., Kahn, I., & Buckner, R. L. (2005). Parietal lobe contributions to episodic memory retrieval. *Trends in Cognitive Sciences, 9,* 445-453.

Wais, P. E., Mickes, L., & Wixted, J. T. (2008). Remember/Know judgments probe degrees of memory strength. *Journal of Cognitive Neuroscience, 20,* 400-405.

Werkle-Bergner, M., Mecklinger, A., Kray, J., Meyer, P., & Düzel, E. (2005). The control of memory retrieval: Insights from event-related potentials. *Cognitive Brain Research, 24,* 599-614.

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The frontal lobes and autonoetic consciousness. *Psychological Bulletin, 121,* 331-354.

Wilding, E. L. (1999). Separating retrieval strategies from retrieval success: An event-related potential study of source memory. *Neuropsychologia, 37,* 441-454.

Wilding, E. L. (2000). In what way does the parietal ERP old/new effect index recollection? *International Journal of Psychophysiology, 35,* 81-87.

Wilding, E. L. (2001). Event-related functional imaging and episodic memory. *Neuroscience and Biobehavioral Reviews, 25,* 545-554.

Wilding, E. L. (2006). The practice of rescaling scalp-recorded event-related potentials. *Biological Psychology, 72,* 325-332.

Wilding, E. L., Doyle, M. C., & Rugg, M. D. (1995). Recognition memory with and without retrieval of context: An event-related potential study. *Neuropsychologia, 33,* 743-767.

Wilding, E. L., Fraser, C. S., & Herron, J. E. (2005). Indexing strategic retrieval of colour information with event-related potentials. *Cognitive Brain Research, 25,* 19-32.

Wilding, E. L., & Herron, J. E. (2006). Electrophysiological measures of episodic memory control and memory retrieval. *Clinical EEG and Neuroscience, 37,* 315-321.

Wilding, E. L., & Nobre, A. C. (2001). Task-switching and memory retrieval processing: Electrophysiological evidence. *NeuroReport, 12,* 3613-3637.

Wilding, E. L., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of source. *Brain, 119,* 889-905.

Wilding, E. L., & Sharpe, H. (2003). Episodic memory encoding and retrieval: Recent insights from event-related potentials. In A. Zani & A. Mado-Proverbio (Eds.), *The Cognitive Electrophysiology of Mind and Brain* (pp. 169-196). San Diego: Academic Press.

Wilson, F. N., & Bayley, R. H. (1950). The electrical field of an eccentric dipole in a homogenous spherical conducting medium. *Circulation, 1,* 84-92.

Wixted, J. T., & Stretch, V. (2004). In defense of the signal-detection interpretation of remember/know judgments. *Psychonomic Bulletin & Review, 11,* 616-641.

Wood, C. C. (1987). Generators of event-related potentials. In A. M. Halliday, B. S. R. & R. Paul (Eds.), *A textbook of clinical neurophysiology* (pp. 535-567). New York: Wiley.

Woodruff, C. C., Hayama, H. R., & Rugg, M. D. (2006). Electrophysiological dissociation of the neural correlates of recollection and familiarity. *Brain Research, 1100,* 125-135.

Woodruff, C. C., Uncapher, M. R., & Rugg, M. D. (2006). Neural correlates of differential retrieval orientation: Sustained and item-related components. *Neuropsychologia, 44,* 3000-3010.

Yick, Y. Y. & Wilding, E. L. (2008). Material-specific neural correlates of memory retrieval. *NeuroReport, 19,* 1463-1467.

Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory and Cognition, 20,* 1341-1354.

Yonelinas, A. P. (1997). Recognition memory ROCs for item and associative information: The contribution of recollection and familiarity. *Memory and Cognition, 25,* 747-763.

Yonelinas, A. P. (2001). Consciousness, control and confidence: The 3 Cs of recognition memory. *Journal of Experimental Psychology: General, 130,* 361-379.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years research. *Journal of Memory and Language, 46,* 441-517.

Yonelinas, A. P., & Jacoby, L. L. (1994). Dissociations of processes in recognition memory: Effects of interference and of response speed. *Canadian Journal of Experimental Psychology, 48*, 516-535.

Yonelinas, A. P., & Jacoby, L. L. (1995). The relation between remembering and knowing as bases for recognition: Effects of size congruency. *Journal of Memory and Language, 34,* 622-643.

Yonelinas, A. P., Kroll, N. E., Quamme, J. R., Lazzara, M., & Knight, R. (2002). Effects of extensive temporal lobe damage or mild hypoxia on recollection and familiarity. *Nature Neuroscience, 5,* 1236-1241.

Yonelinas, A. P., Otten, L. J., Shaw, K. N., & Rugg, M. D. (2005). Separating the brain regions involved in recollection and familiarity in recognition memory. *Journal of Neuroscience, 25,* 3002-3008.

Yovel, G., & Paller, K. A. (2004). The neural basis of the butcher-on-the-bus phenomenon: When a face seems familiar but is not remembered. *NeuroImage, 21,* 789-800.

Appendix A

Experiment 1: Analyses of ERP old/new effects separated according to target designation

Analyses of the ERP old/new effects in Experiment 1 were also conducted on ERPs separated for the two target designations. Figures A1 and A2 show the ERP waveforms to targets, nontargets and new items in the two target designations for the high and low accuracy group respectively.

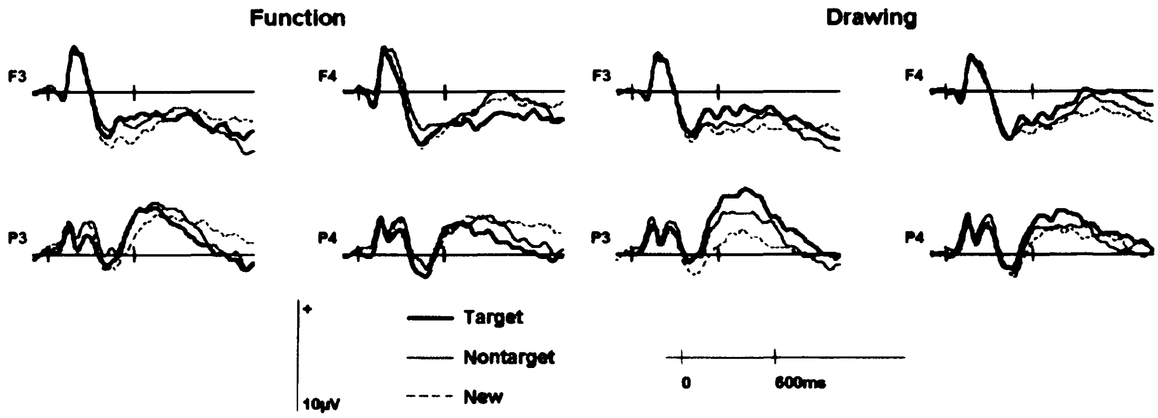

Figure A1: Grand average ERPs elicited by targets, nontargets and new items separated for the two target designations in the high accuracy group. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

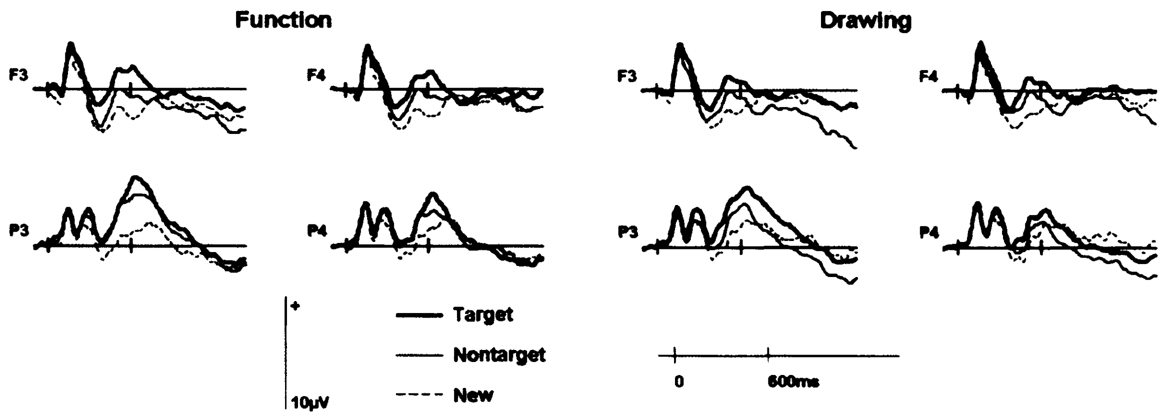

Figure A2: Grand average ERPs elicited by targets, nontargets and new items separated for the two target designations in the low accuracy group. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

Initial ANOVAs were conducted across the four time windows used in all other analyses (300-500, 500-800, 800-1100 and 1100-1400ms) and included factors of accuracy group (high/low), response category (target/nontarget/new), target designation (function/drawing), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior). The outputs of these ANOVAs are presented in Table A1 which shows interactions including factors of group, response category and target designation occurred in the final three time windows. In these epochs, follow-up paired comparisons (target vs. new, nontarget vs. new and target vs. nontarget) were conducted separately for the high and low accuracy groups. Consistent with the outcomes of the paired contrasts reported for this experiment, interactions including the factors of response category and target designation occurred in the high group only. These are shown in Table A2.

For the high group, these interactions map onto the pattern reported for the paired contrasts for Experiment 1. From 500-800ms, old/new effects for targets were larger in the drawing than the function target designation, at multiple sites extending over left posterior scalp. At left hemisphere sites, targets were greater than nontargets in the drawing target designation only. From 800-1100ms old/new effects were greater in the drawing task and greatest at left posterior sites. In the final 1100-1400ms time window, ERPs to new items were more positive than targets in the function designation particularly over the left hemisphere. In the drawing designation, targets were more positive than new items over the right hemisphere. Targets were more positive than nontargets in the drawing designation only, over right hemisphere sites.

Table A1: Outcomes of global ANOVAs for old/new effects in each time window. Key: GP = accuracy group, TD = target designation, RC = response category, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$. Degrees of freedom are shown in brackets.

	300-500	500-800	800-1100	1100-1400
RC	$F(1.8,62.4) = 12.84$ ***	$F(1.9,65.3) = 17.10$ ***	-	$F(2,67.9) = 4.91$ *
GP x RC	$F(1.8,62.4) = 4.81$ *	-	-	-
RC x HM	$F(2,67.2) = 3.60$ *	$F(1.8,60.7) = 13.79$ ***	$F(1.9,65.7) = 3.51$ *	-
RC x ST	$F(3.6,123) = 6.21$ ***	$F(3.7,127.1) = 5.39$ **	-	$F(4.7,159.9) = 4.89$ ***
GP x TD x RC	-	-	$F(2,66.8) = 3.46$ *	-
GP x RC x ST	$F(3.6,123) = 3.56$*	-	-	-
RC x AP x HM	-	$F(1.9,65.9) = 11.66$ ***	$F(1.8,59.7) = 8.05$ **	$F(1.9,63.6) = 21.07$ ***
RC x AP x ST	-	$F(4.2,142.7) = 5.36$ ***	$F(3.8,127.8) = 9.00$ ***	$F(4.4,150.2) = 4.65$ **
RC x HM x ST	$F(5.7,194.9) = 2.62$ *	$F(6.1,206.5) = 4.95$ ***	$F(5.5,187.6) = 2.78$ *	-
RC x AP x HM x ST	-	$F(5.6,189.7) = 3.92$ **	$F(5.6,189.6) =3.50$ **	$F(5.7,195.2) = 3.49$ **
GP x TD x RC x AP x HM	-	$F(2,67.7) = 3.46$ *	$F(2,66.5) = 3.57$ *	-
GP x TD x RC x AP x ST	-	$F(5.8,195.9) = 2.23$ *	-	$F(5.6,190.2) = 2.85$ *

Table A2: Outputs from paired comparisons for the high accuracy group in the final three time windows. Key: TD = target designation, RC = response category, AP = anterior-posterior dimension, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom are shown in brackets.

		500-800	800-1100	1100-1400
Target vs. New	TD x RC	-	F(1,17) = 6.41 *	-
	TD x RC x HM	-	-	F(1,17) = 4.96 *
	TD x RC x AP x HM	F(1,17) = 8.59 **	F(1,17) = 10.07 **	-
Target vs. Nontarget	TD x RC x HM	-	-	F(1,17) = 5.90 *
	TD x RC x AP x ST	F(3.4,57.7) = 3.05 *	-	-

Appendix B

Experiment 1: Complete Outputs for ERP Old/New Effects Analyses

Table B1 shows the complete outputs of the paired comparisons (targets vs. new, nontargets vs. new and targets vs. nontargets) for the four time windows (300-500, 500-800, 800-1100 and 1100-1400ms) for the high accuracy group. The same outputs for the low accuracy group are shown in Table B2. For all analyses, ANOVAs included factors of response category, hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior).

Table B1: Outputs from paired comparisons in each time window for the high accuracy group. Key: RC = response category, AP = anterior-posterior dimension, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom are shown in brackets.

		300-500	500-800	800-1100	1100-1400
Target vs. New	RC	F(1,17) = 4.90 *	F(1,17) = 9.04 **	-	-
	RC x HM	-	F(1,17) = 10.46 **	-	-
	RC x AP x HM	-	-	-	F(1,17) = 7.78 *
	RC x AP x ST	-	F(1.9,32.5) = 3.36 *	F(1.8,30.5) = 5.04 *	-
	RC x HM x ST	F(3.3,55.7) = 2.78 *	F(2.8,47.2) = 5.63 **	-	-
Nontarget vs. New	RC	F(1,17) = 8.08 *	-	-	F(1,17) = 4.57 *
	RC x HM	-	F(1,17) = 6.34 *	-	-
	RC x ST	F(1.9,31.7) = 4.05 *	F(2.5,42.1) = 4.08 *	-	-
	RC x AP x HM	-	-	F(1,17) = 6.25 *	F(1,17) = 23.48 ***
	RC x HM x ST	F(3.2,54.9) = 3.06 *	F(3,51.8) = 4.28 **	-	-
	RC x AP x HM x ST	-	F(2.9,49) = 3.38 *	F(3,51.5) = 2.81 *	F(3,50.2) = 3.16 *

Table B2: Outputs from paired comparisons in each time window for the low accuracy group. Key: RC = response category, AP = anterior-posterior dimension, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom are shown in brackets.

		300-500	500-800	800-1100	1100-1400
Target vs. New	RC	F(1,17) = 16.79 **	F(1,17) = 21.70 ***	-	-
	RC x AP	F(1,17) = 4.77 *	-	-	F(1,17) = 4.65 *
	RC x HM	-	F(1,17) = 12.80 **	-	-
	RC x ST	F(1.5,24.7) = 15.19 ***	F(1.9,32) = 6.07 **	-	F(2.1,36.1) = 5.50 **
	RC x AP x HM	-	F(1,17) = 16.31 **	F(1,17) = 7.89 *	F(1,17) = 14.40 **
	RC x AP x ST	-	F(2.9,49.7) = 7.87 ***	F(2.6,43.8) = 9.15 ***	F(3.1,53.2) = 7.82***
	RC x AP x HM x ST	-	F(2.8,47.2) = 4.09 *	F(2.6,44.8) = 3.25 *	F(2.6,44.5) = 3.26 *
Nontarget vs.	RC	F(1,17) = 7.34 *	F(1,17) = 5.47 *	-	-
New	RC x HM	-	F(1,17) = 10.09 **	-	-
	RC x ST	F(2.1,36.5) = 9.15 ***	-	F(1.8,31.3) = 8.92 **	F(2.5,42.9)=13.88***
	RC x AP x HM	-	F(1,17) = 11.31 **	F(1,17) = 9.87 **	F(1,17) = 18.42 ***
	RC x AP x ST	-	F(2.3,39.1) = 5.82 **	F(2.2,37.8) = 7.67 **	F(2.9,48.9) = 4.54 **
	RC x HM x ST	-	F(2.8,47.7) = 3.27 *	-	-
	RC x AP x HM x ST	-	F(3.2,547.7) = 4.18 **	F(2.9,48.5) = 4.09 *	F(2.8,47.2) = 3.41 *
Target vs.	RC	F(1,17) = 5.82 *	F(1,17) = 10.51 *	-	-
Nontarget	RC x HM	F(1,17) = 6.26 *	-	-	-
	RC x ST	F(2.3,39.8) = 5.62 **	F(2.7,45.3) = 5.66 **	-	-

Appendix C

Experiment 2: Analyses of ERP old/new effects separated according to target designation

Analyses of the ERP old/new effects in Experiment 2 were also conducted on ERPs separated for the two target designations. Figure C1 shows the ERP waveforms to targets, nontargets and new items in the two target designations.

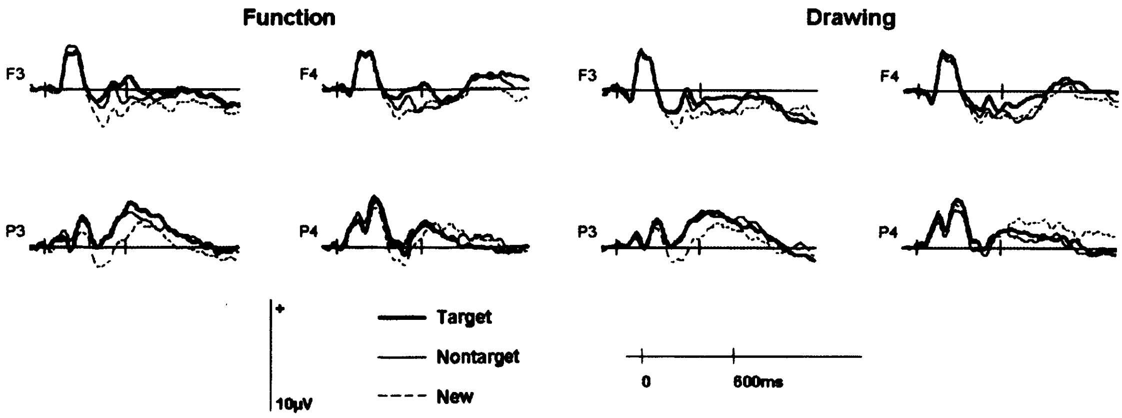

Figure C1: Grand average ERPs elicited by targets, nontargets and new items separated for the two target designations. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

Initial ANOVAs were conducted across the four time windows used in all other analyses (300-500, 500-800, 800-1100 and 1100-1400ms) and included factors of response category (target/nontarget/new), target designation (function/drawing), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior). The outputs of these ANOVAs are shown in Table C1, which shows that interactions including the factors of response category and target designation occurred in the 500-800 and 800-1100ms time windows. In these epochs, follow-up paired comparisons (target vs. new, nontarget vs. new and target vs. nontarget) were conducted. Interactions with the factor of target designation occurred only for the target/nontarget item contrast in each time window. From 500-800ms, an interaction between target designation, response category, anterior-posterior and hemisphere ($F(1,17) = 5.82$, $p<0.05$) occurred because targets were greater than nontargets over anterior sites but at these sites demonstrated a degree of right lateralisation in the function task only. In the 800-1100ms epoch, target designation interacted with response category and hemisphere ($F(1,17) = 6.56$,

$p<0.05$) because whereas targets were relatively more positive-going over the left hemisphere in the function designation, they were more positive over the right hemisphere in the drawing designation.

Table C1: Outcomes of global ANOVAs for old/new effects in each time window. Key: RC = TD = target designation, response category, AP = anterior-posterior dimension, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom are shown in brackets.

	300-500	500-800	800-1100	1100-1400
RC	F(1.6,27) = 7.45 **	-	-	-
RC x HM	F(1.8,29.9) = 5.00 *	F(1.4,24.4) = 16.17 ***	F(1.6,26.4) = 12.16 ***	-
TD x RC x HM	-	-	F(1.9,32.9) = 3.73 *	-
RC x AP x HM	-	F(1.8,31.2) = 4.97 *	-	F(1.8,30.1) = 8.70 **
RC x AP x ST	-	F(3.2,55.2) = 4.70 **	F(3.5,58.8) = 6.38 ***	F(4.4,74.8) = 5.07 **
RC x HM x ST	-	F(5,84.6) = 4.39 **	F(4.6,77.9) = 3.36 *	-
TD x RC x AP x HM	-	F(1.9,33.1) = 3.41 *	-	-

Appendix D

Experiment 3: Mean numbers of trials per category

Table D1: Mean numbers of trials per participant and response category separated according to accuracy group. Ranges in parentheses.

Response		Accuracy Group	
Category	Task	High	Low
Correct Rejections	Function	34 (20-47)	29 (19-45)
	Drawing	34 (19-50)	33 (20-48)
Hits	Function	63 (33-85)	59 (32-91)
	Drawing	63 (32-98)	57 (34-81)

Table D2: Mean numbers of trials per participant and response category separated according to relative difficulty group. Ranges in parentheses.

Response		Relative Difficulty Group	
Category	Task	High	Low
Correct Rejections	Function	33 (19-47)	30 (19-45)
	Drawing	34 (20-50)	34 (19-47)
Hits	Function	64 (38-91)	58 (32-84)
	Drawing	59 (35-90)	61 (32-98)

Appendix E

Experiment 3: Analyses of ERP old/new effects separated according to retrieval task and accuracy group

Analyses of the ERP old/new effects in Experiment 3 were also conducted on ERPs separated for the two retrieval phases. Figure E1 shows the ERP waveforms to hits and correct rejections in the two retrieval tasks for the high and low accuracy group respectively.

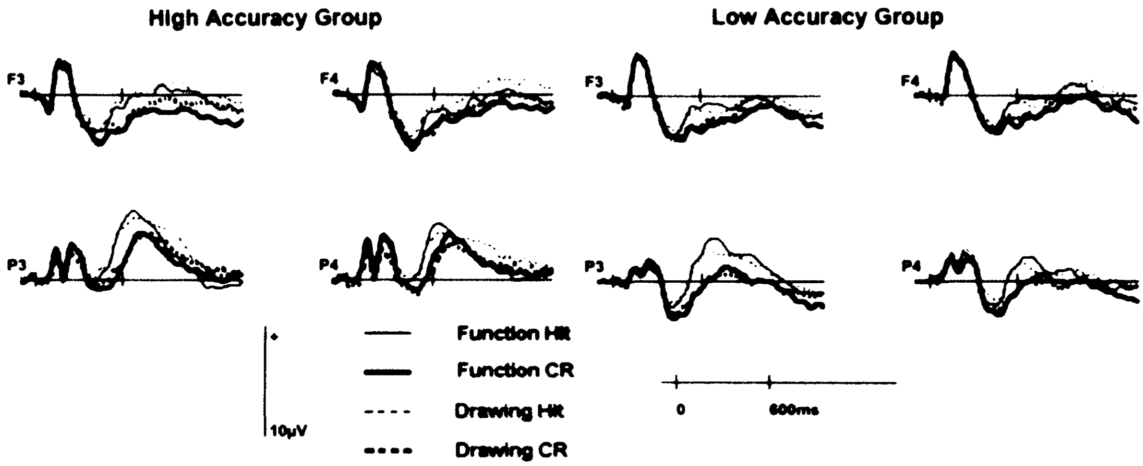

Figure E1: Grand average ERPs elicited by hits and correct rejections (CR) separated for the two retrieval tasks in the high accuracy group. Data are shown for four superior electrodes at left and right, frontal and parietal locations.

Initial ANOVAs were conducted across the four time windows used in all other analyses (300-500, 500-800, 800-1100, 1100-1400) and included factors of accuracy group (high/low), response category (hits/correct rejections), retrieval task (operation/location), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior). The outputs of these ANOVAs are shown in Table E1 which shows interactions including the factors of retrieval task, response category and hemisphere from 500ms onwards. Old/new effects in the function task were left lateralised from 500-1100ms but were lateralised in the final time window. Old/new effects in the drawing task became right lateralised in the final (1100-1400ms) window. An interaction including the factors of group and retrieval task occurred in the 800-1100ms epoch because the left lateralised aspect of the function old/new effect was larger in the high accuracy group.

Table E1: Outcomes of global ANOVAs for old/new effects in each time window. Key: GP = accuracy group, TS = retrieval task, RC = response category, AP = anterior-posterior, HM = left/right hemisphere, ST = site, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$. Degrees of freedom are shown in brackets.

	300-500	500-800	800-1100	1100-1400
RC	$F(1,34) = 16.87$ ***	$F(1,34) = 27.29$ ***	$F(1,34) = 10.14$ **	-
RC x AP	-	$F(1,34) = 7.68$ **	-	-
RC x HM	-	$F(1,34) = 7.43$ *	-	-
RC x ST	-	$F(2.1,70.6) = 8.49$ ***	-	-
RC x AP x ST	-	-	$F(2.7,93.) = 2.86$ *	$F(2.6,89.3) = 3.58$ *
RC x AP x HM	-	-	-	$F(1,34) = 6.31$ *
TS x RC x HM	-	$F(1,34) = 8.86$ **	$F(1,34) = 5.72$ *	$F(1,34) = 5.22$ *
GP x TS x RC x HM	-	-	$F(1,34) = 4.24$ *	-

Appendix F

Experiment 3: Analysis of the relationship between the amplitude of ERP new item effects and response accuracy

To determine whether the relationship between new item ERP differences and response accuracy extended to the level of the individual, the amplitude difference in microvolts between the two classes of new item (function minus drawing) was plotted against the collapsed Pr value for each individual. These data were extracted from the time windows (500-800 and 800-1100ms) and electrode sites (left frontal, FP1, F1, F3, F5, F7; left posterior, O1, P1, P3, P5, P7) where the effects were reliable in the high accuracy group. There were no significant correlations at any site or timepoint.

Appendix G

Experiment 3: Analyses of ERP new item effects on the standard montage (Relative difficulty analysis)

Analyses of the ERP new item effects for the high and low relative difficulty group were also conducted upon the standard montage. This montage covered four regions of interest each comprising five electrode sites selected equally from both hemispheres and from anterior-posterior positions: FP1/FP2, F7/F8, F5/F6, F3/F4, F1/F2, P7/P8, P5/P6, P3/P4, P1/P2 and O1/O2. Five analysis epochs were used for these analyses (100-300, 300-500, 500-800, 800-1100, 1100-1400ms) and analyses included the between-subjects factor of relative difficulty group (high/low) and within-subjects factors of task (function/drawing), hemisphere (left/right), anterior-posterior and site (inferior/mid-lateral/superior/midline/pre-superior).

Effects again were reliable only in the first three time windows (100-300, 300-500 and 500-800ms) and included factors of relative difficulty group and target designation. Separate within-group ANOVAs again revealed reliable effects of target designation in the low relative difficulty group only. The outputs of both the initial and follow-up ANOVAs are shown in Table G1.

Table G1: Outcomes of ANOVAs for relative difficulty contrasts for ERP new item effects in the first three time windows. Key: GP = relative difficulty group, TS = task, AP = anterior-posterior dimension, HM = left/right hemisphere, ST = site, * = p<0.05, ** = p<0.01, *** = p<0.001. Degrees of freedom in brackets.

		100-300	300-500	500-800
N =36	GP x TS	F(1,34) = 4.97 *	-	-
	GP x TS x ST	F(2,68.9) = 4.64 *	-	-
	GP x TS x AP x HM	-	-	F(1,34) = 8.84 **
	TS x AP x HM x ST	-	F(3.1,104.7) = 2.89 *	-
Low Rel Diff	TS	F(1,17) = 4.48 *	-	-
	TS x ST	F(1.9,32.1) = 4.26 *	-	-
	TS x AP x HM	-	-	F(1,17) = 10.07 **

Appendix H

Experiment 4: Analysis of behaviour for 28 participants who contributed sufficient trials for the subsequent memory contrasts

The following analyses were conducted upon the data for the 28 participants who contributed sufficient trials for subsequent memory analyses. Table H1 shows the mean proportions of correct rejections as well as the proportions of source/confidence responses for all old items correctly termed old (hits) separated for the two retrieval tasks. Table H2 shows the proportions of correct responses to these five response categories, collapsed across retrieval task but separated for the high and low accuracy groups.

Table H1: Mean proportions of correct rejections, hit-hits and hit-misses separated according to high and low confidence and retrieval task for the 28 participants with sufficient trial numbers for subsequent memory contrasts. Standard deviations in parentheses.

	Retrieval Task	
	Operation	Location
P(CR)	0.93 (0.07)	0.94 (0.07)
P(Hit-hit: high)	0.70 (0.13)	0.50 (0.17)
P(Hit-hit: low)	0.17 (0.12)	0.33 (0.15)
P(Hit-miss: high)	0.07 (0.10)	0.05 (0.07)
P(Hit-miss: low)	0.05 (0.04)	0.12 (0.07)

An initial ANOVA on Pr values (p[hit] – p[FA]) with factors of group (high/low), and retrieval task (operation/location) showed that correct responding was greater in the high group ($F(1,26) = 8.72$, $p<0.01$) but did not differ for the two tasks. Mean Br values in the high accuracy group were 0.38 and 0.47 for the operation and location tasks respectively. The comparable Br scores were 0.49 and 0.60 for the low accuracy group and these scores did not differ across group or retrieval task.

Hits were submitted to a mixed ANOVA with factors of group (high/low), retrieval task (operation/location), source accuracy (hit-hit/hit-miss) and response confidence (high/low). High confidence responses were more likely than low confidence responses (F(1,26) = 29.95, p<0.001) and hit-hits more likely than hit-misses (F(1,26) = 1288.23 ,p<0.001). The latter effect was moderated by an interaction between source accuracy and group (F(1,26) = 30.68, p<0.001), because the likelihood of making a correct source judgment was superior in the high accuracy group. There were also further interactions between retrieval task and response confidence (F(1,26) = 103.55, p<0.001), source accuracy and response confidence (F(1,26) = 106.87, p<0.001) as well as a three way interaction between retrieval task, source accuracy and response confidence (F(1,26) = 27.67, p<0.001).

Table H2: Mean proportions of correct rejections, hit-hits and hit-misses separated according to high and low confidence and accuracy group for the 28 participants with sufficient trial numbers for subsequent memory contrasts. Standard deviations in parentheses.

	Accuracy Group	
	High	Low
P(CR)	0.97 (0.02)	0.90 (0.08)
P(Hit-hit: high)	0.63 (0.11)	0.58 (0.14)
P(Hit-hit: low)	0.28 (0.11)	0.22 (0.14)
P(Hit-miss: high)	0.02 (0.03)	0.10 (0.06)
P(Hit-miss: low)	0.07 (0.02)	0.10 (0.04)

Bonferroni-corrected t-tests (corrected alpha level p<0.003) were conducted within and across tasks in order to break this interaction down. All contrasts were significant (minimum t(27) = 2.89, p<0.008) except for the following: high confidence hit-misses did not differ across the two tasks, and hit-misses in the operation task did not differ with response confidence. These analyses confirm that participants used the confidence scale differently for the two tasks, making reliably more high confidence hit-hits in the operation task as is shown in Table H1. This replicates the pattern of data reported for all 36 participants in Experiment 3.

Table H3 shows the reaction times associated with correct responses for the categories presented in Table H1. Analyses of reaction times also comprised two ANOVAs. An initial ANOVA conducted upon correctly responded to old and new items with factors of group (high/low), retrieval task (operation/location) and response category (hits/correct rejections), revealed no reliable effects. The second ANOVA on hits, with factors of group (high/low), retrieval task (operation/location), response accuracy (hit-hit/hit-miss) and response confidence (high/low) revealed a main effect of response confidence ($F(1,26) = 28.63$, $p<0.001$) because initial old/new judgments to items attracting high confidence source judgments were quicker (993 vs. 1195). There was also a main effect of task ($F(1,26) = 4.84$, $p<0.05$) because responses were faster in the location task (1048 vs. 1140). There were no reliable effects involving group.

Table H3: Mean response times for correct rejections, hit-hits and hit-misses separated to according to retrieval task and high and low confidence for the 28 participants with sufficient trial numbers for subsequent memory contrasts. Standard deviations are shown in parentheses.

	Retrieval Task	
	Operation	Location
CR	1033 (277)	981 (234)
Hit-hit: high	1035 (257)	945 (238)
Hit-hit: low	1251 (299)	1136 (361)
Hit-miss: high	977 (284)	1014 (302)
Hit-miss: low	1297 (525)	1095 (356)

To summarise the behavioural data, correct source judgments were more likely in the high than the low accuracy group. Although participants used the confidence scales differently in the two retrieval tasks, source accuracy was not affected by retrieval tasks. Responses were quicker for responses later given with high rather than low confidence and for judgments made in the location task.

Appendix I

Experiment 4: Analysis of the relationship between the amplitude of ERP effects and response accuracy

A number of additional correlational analyses were conducted to determine whether the amplitude of ERP new item effects, ERP old/new effects and ERP subsequent memory effects were related to response accuracy in Experiment 4.

ERPs elicited by New Items

For each participant, the degree to which new item ERPs differed across retrieval tasks was operationalised by subtracting the mean amplitude of new item ERPs in the location retrieval task from new item ERPs in the operation retrieval task. This was calculated at all electrode sites used in the original analysis but restricted to the epochs in which a reliable interaction with the factor of retrieval task had previously occurred, 300-500 and 800-1100ms post-stimulus. For each epoch, these measures were plotted against participants' conditional probability of a correct source judgment, collapsed across retrieval task and response confidence. There were no reliable correlations at any electrode locations.

These same indices of each individual's engagement of strategic retrieval processing were also plotted against an index of retrieval task difficulty. This index consisted of subtracting each individual's proportion of hit-hits in the location task from hit-hits in the operation task. There were no significant relationships between this index and differences between new item ERPs at any electrode or time point.

ERP Old/New Effect

For each participant, the amplitudes of new item ERPs were subtracted from high confidence hit-hit ERPs to determine the sizes of the old/new effects. This was calculated at all electrode sites used in the original analysis but restricted to the epochs in which a reliable interaction with the factor of accuracy group occurred; 500-800 and 800-1100ms. For each epoch, these measures were plotted against participants' conditional probability of a correct source judgment, collapsed across retrieval task and response confidence. There were no reliable correlations at any electrode locations in either epoch.

Subsequent Memory Effects

Although there was no statistical evidence of a relationship between the amplitude of the subsequent memory effects and accuracy group, correlational analyses can provide greater power than median-split analyses in some circumstances (MacCallum, Zhang, Preacher & Rucker, 2002), and in accordance with this, the amplitudes of SM effects were calculated for each individual and plotted against the index of source accuracy used previously. For each participant and for each retrieval task, the amplitudes of forgotten ERPs were subtracted from remembered ERPs to determine the sizes of the subsequent memory effects. This was calculated at all electrode sites used in the original analysis but restricted to the epochs in which a reliable interaction with the factor of retrieval task had previously occurred; 800-1100 and 1100-1400ms. For each epoch, these measures were plotted against participants' conditional probability of a correct source judgment, collapsed across retrieval task and response confidence. There were no reliable correlations at any electrode locations in either retrieval task.