EVENT RELATED BRAIN POTENTIAL STUDIES OF STRATEGIC RETRIEVAL PROCESSING IN EPISODIC MEMORY

MARIAM ADAWIAH DZULKIFLI
2005

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

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

ABSTRACT

The relationship between three classes of retrieval processes – orientation, effort and success – was investigated using ERPs and behavioural measures. Participants studied words in two different contexts in five experiments. In subsequent test phases they responded positively to old words from one study context (targets), and negatively to old words from the alternate context (non-targets) as well as to new words. In experiment One-Four participants completed different study-test cycles across which target designation was varied. The contrasts between the ERPs evoked by new test words separated according to target designation in Experiment One revealed correlates of processes that form part of a retrieval attempt, but in that experiment effort and orientation were confounded. In Experiment Two, effort and orientation were systematically manipulated. The key finding was that the degree of engagement in an orientation varies with task difficulty. In Experiment Three differences between the ERPs evoked by classes of new test words were different to those in Experiments One and Two, providing support for the concept of orientation as different encoding tasks were employed in Experiment Three. These correlates of retrieval orientation were proposed to influence selective recollection as the left-parietal old new effect – the ERP signature of recollection - was evident for targets and not for non-targets in Experiment Three. This hypothesis was supported by findings in Experiment Four where left-parietal old/new effects were evident for both targets and non-targets, while of indices of orientation were less evident than in Experiment Three. Behavioural data collected in Experiment Five provided some evidence to suggest that selective recovery of some information held in memory is achieved because of processes that influence the accessibility of memory representations. In combination

these findings contribute to current understanding of human episodic retrieval processing.

ACKNOWLEDGEMENTS

My sincere gratitude to my supervisor, Dr. Ed Wilding, for his constructive guidance, encouragement and patience throughout the period of my study. My gratitude is also extended to Dr Helen Sharpe, Dr. Jane Herron, Dr Carina Fraser and Miss Nazanin Azamian-Faridani who always had the time to discuss my research as well as my problems.

Thanks to my family in Malaysia for the understanding and emotional support. A special thanks to my husband Juhari Haji Zakaria and my two twinkle little stars, Husna and Harith, who have been constant inspirations.

5. CHAPTER 5: EXPERIMENT TWO

6. CHAPTER 6: EXPERIMENT THREE

7. **CHAPTER 7: EXPERIMENT FOUR**

8. **CHAPTER 8: EXPERIMENT FIVE**

9. **CHAPTER 9: GENERAL DISCUSSION**

Chapter 1

1.1. Introduction

Human memory is commonly separated into short-term and long-term memory, a dichotomy associated for the most part with the work of Atkinson and Shiffrin (1968), but also assumed in similar forms and models by many other researchers (e.g. Shallice and Warrington, 1970; Baddeley and Hitch, 1974). Short-term memory is typically assumed to have limited capacity and is regarded as a form of memory within which information is stored temporarily. Long-term memory, by contrast, is assumed to have limitless capacity and information can be stored for long durations.

Long-term memory has also been separated into different memory forms, which have been referred to as declarative and non-declarative memory (Squire and Knowlton, 1995) as well as explicit and implicit memory (Graf and Schacter, 1985; Schacter, 1987). Declarative or explicit memory is characterised as a conscious form of memory for facts and events. Non-declarative memory was described initially by Squire and Zola-Morgan (1991) as procedural memory, but later they adopted the term non-declarative memory (Zola-Morgan and Squire, 1993) in recognition of the fact that there may be different kinds of 'non-declarative' memory, which include conditioning and priming, as well as the acquisition of procedural skills and habits. Non-declarative or implicit memory is defined as a form of memory which can influence behaviour in the absence of awareness of the relevant learning episode.

Declarative memory has also been fractionated, and the division between semantic and episodic memory is associated primarily with the work of Tulving (1972; 1983). Semantic memory consists of information or knowledge about the world. Episodic memory is memory for specific prior events and occurrences (Tulving, 1972). The relationship between episodic and semantic memory remains controversial (e.g. Squire, 1992; Tulving, 1972; 1983; 1986; 1993b), but the focus here is on episodic memory and the ways in which control of episodic retrieval can be exerted.

A central memory process in this thesis is recollection. This process is defined as the recovery of qualitative information about a prior event (Yonelinas, 2002), such as when or where an event occurred, or from which source (e.g. modality) information was acquired. Recollection is therefore a form of declarative memory, and is typically assumed to involve recovery of information from episodic memory.

Recollection is one of two processes that form part of a dual-process model of recognition memory (Jacoby, 1981; Yonelinas, 2002; for an important precursor, see Mandler, 1980). The other process is familiarity, which is a strength based signal that provides information relevant to whether or not an item or event has occurred previously. The distinction between recollection and familiarity is supported by behavioural findings in control participants (Jacoby and Dallas, 1981; Gardiner, 1988; Jacoby, 1991, Verfaelli and Treadwell, 1993; Rajaram, 1993; Yonelinas, 1994; 1997; Yonelinas and Jacoby, 1995) as well as studies of individuals with selective brain damage (for examples, see Vargha-Khadem, Gadian, Watkins, Connely, Van Paesschen and Mishkin, 1997; Yonelinas, 1998; Duzel, Picton, Cabeza, Yonelinas, Scheich, Heinze and Tulving, 2001; Brown and Aggleton, 2001). The most widely assumed relationship between recollection and familiarity is one of independence, although this relationship may not always hold (Curran and Hintzman, 1995), and there are at least two other alternative models (Jones, 1987), although neither has the weight of empirical support that the independence account has. Tulving (1985) suggested a link between semantic memory and familiarity, although this is not widely accepted (Yonelinas, 2002). Familiarity is by definition a form of declarative memory, but whether some processes that are also classified as 'non-declarative' contribute to familiarity remains a possibility (Jacoby and Dallas, 1981; Whittlesea, 1993).

The operational means of distinguishing recollection from familiarity involves designing tasks either that require recovery of qualitative (source or context) information about a prior episode, or asking participants to report on their experience at the time of making memory judgments (Tulving, 1985; Gardiner, 1993). Presumably, correct source or context judgments, or experiential reports of remembering, provide indices of recollection, whereas the ability only to make judgments of prior occurrence that are not associated with accurate source judgments or experiences of remembering is based upon familiarity. The first approach is taken in Experiments 1-4 of this thesis, while the second approach is adopted in Experiment 5, and the Remember/Know procedure (Tulving, 1985) employed in that study is described in more detail there, along with some other aspects of dual-process theories of memory that are relevant to the issues Experiment 5 was designed to address (see Chapter 8, in particular page 200 onwards). Despite the use of different approaches, all of the work in this thesis is concerned with processes that are responsible for or related to recollection, also referred to below as selective remembering.

One of the most challenging questions in contemporary memory research is how selective remembering occurs. The fact that specific events can be recovered from a system containing very many events and often many similar events suggests that selective remembering is likely to involve control operations that operate prior to retrieval as well as after retrieval. This assumption is encapsulated in computational models of episodic retrieval (Metcalfe, 1993; McClelland, McNaughton and O'Reilly, 1995), and support for the importance of the engagement of control operations comes from studies of individuals for whom brain damage has resulted in selective memory impairments (Stuss, Eskes and Foster, 1994).

The work in this thesis is concerned with how selective retrieval occurs, with one important focus being on the way in which strategic retrieval processing promotes selective recovery of information from memory. The theoretical starting point for this work is a recent proposal concerning retrieval processing by Rugg and Wilding (2000). This proposal, however, borrows heavily from and overlaps with earlier proposals concerning how selective retrieval is enabled, and the most important of these are reviewed below.

1.2. Models of retrieval processing

The General Abstract Processing System (GAPS)

This framework for episodic memory retrieval was discussed in detail by Tulving (1983) in his influential book on episodic retrieval. The core of the GAPS is the thirteen elements that are held to constitute the episodic memory system. These elements include encoding operations as well as the relationship between encoding and retrieval, and the precise details of the GAPs framework are not important here. There are, however, some key concepts that are critical to note. One concept that is contained in the GAPS, and which is central to all models of memory retrieval, is the concept of a memory trace or engram (Semon, 1904; Semon, 1921; Schacter, 1987). The engram results from memory encoding, and it is the interaction between a trace or engram and a retrieval cue that is a key process in episodic retrieval. The trace/cue interaction has been termed ecphory (Semon, 1904), and *ecphoric information* is one term that has been used to describe the outcome of ecphory.

For present purposes, perhaps the most important concept that was introduced by Tulving (1983) is *retrieval mode*, even though it was not included in the GAPS framework. According to Tulving (1983), this is a cognitive state or set that is adopted and maintained when there is a need to engage in episodic retrieval. Retrieval mode is assumed to be maintained tonically and biases individuals to process stimulus events as retrieval cues rather than as plain inputs from the environment (for a recent review, see Wheeler, Stuss and Tulving, 1997). It has also been claimed that entry into retrieval mode is necessary in order for episodic retrieval to occur, but this claim seems somewhat incompatible with the widely accepted view that spontaneous or unintentional recollection can occur. While it is in principle possible to argue that mode can in some circumstances be adopted automatically, this claim is not supported by the findings of empirical studies of retrieval mode (see below). A more parsimonious perspective is that adopting retrieval mode may have positive benefits for episodic retrieval, but that there are conditions under which retrieval from episodic memory can occur in the absence of mode, for example when a particularly vivid memory is activated by an appropriate retrieval cue.

Despite the fact that the concept of retrieval mode was introduced more than 20 years ago, strong empirical support for this construct has emerged only in the last 10 years, and has come almost wholly from studies in which brain activity was recorded while participants completed memory retrieval tasks. On the basis of findings in a series of positron emission tomography (PET) studies, Tulving and colleagues (1994) proposed that retrieval mode was supported by activity in right-prefrontal cortex. This claim was based on findings that activity in this region was greater during tasks that required episodic retrieval than during tasks that did not, and that the activity in this region did not differentiate between different classes of test items – for example, old (previously studied) and new (unstudied) words. Lepage and colleagues (2000) conducted a multi-study analysis of PET data gathered from experiments in which participants completed either an episodic (most commonly old/new recognition memory) or a semantic retrieval task (Kapur, Craik, Jones, Brown, Houle and Tulving, 1995; Nyberg, Tulving, Habib, Nilsson, Kapur, Houle, Cabeza and McIntosh, 1995). They identified the right prefrontal cortex as the region that supports retrieval mode.

The presence of brain activity that differentiates episodic from non-episodic tasks, but which does not differentiate between stimulus-types, can be interpreted as providing support for the concept of retrieval mode, but the fact that the majority of the data discussed here was obtained in PET studies of episodic retrieval is important, because using this imaging technique it is not possible to separate activity that is initiated by the presentation of individual items from activity that is initiated at the start of a task and which is maintained for the duration of a task (Rugg, 1998; Donaldson, Allan and Wilding, 2002). The findings in these PET studies provide conceptual support for retrieval mode only if the pattern of activity that is responsible for the results is maintained throughout the episodic task.

Arguably stronger evidence in support of the concept of mode comes from studies where event-related potentials (ERPs) were recorded during tasks designed to index retrieval mode (Duzel, Cabeza, Picton, Yonelinas, Scheich, Heinze and Tulving, 1999; Duzel, Picton, Cabeza, Yonelinas, Scheich, Heinze and Tulving, 2001[1]; Morcom and Rugg, 2001). In the studies of Duzel and colleagues (1999; 2001), participants studied a series of words. At test, they were presented with blocks of four-item lists. They were cued to engage in either an episodic retrieval (old/new recognition) or a semantic retrieval task (animacy judgements) at the start of each block. Compared to cues signalling the requirement to complete the semantic task, the cues signalling the episodic retrieval task evoked ERPs which were more positive-going. The relative positivity onset prior to the first test word in each block and was maintained for the duration of the block. The fact that the effect was maximal over right anterior sites is consistent with the findings from PET studies (Lepage, Ghaffar, Nyberg and Tulving, 2000) and supports the claim that retrieval mode is supported by this region of the brain. Duzel et al. (2001) also showed that the activity that distinguished between the episodic and semantic retrieval conditions could be modelled by a generator located in right-prefrontal cortex.

Morcom and Rugg (2001) employed the same retrieval task as Duzel et al. (1999), but participants in their studies were cued on each trial to complete either an episodic or a semantic retrieval task. ERPs were recorded during the 1.5 second interval between

---

[1] The 2001 paper due to Duzel et al. contains an extended analysis of the electrophysiological data they presented in their earlier report (Duzel et al., 1999).

the cue and the onset of the subsequent test item to which the episodic or semantic retrieval judgement was required. Consistent with the finding of Duzel et al. (1999), Morcom and Rugg (2001) observed that the activity evoked by the episodic retrieval cues was relatively more positive-going at right fronto-central scalp sites than the activity evoked by the semantic retrieval cues.

In keeping with the conclusion of Duzel et al. (2001), Morcom and Rugg (2001) proposed that the differences between the cue-related activity indicate the adoption and/or the maintenance of a retrieval mode. This claim is also supported by the findings of Herron and Wilding (2004), who demonstrated that preparatory activity at right frontal electrodes was more positive-going in two different episodic retrieval tasks than in a semantic retrieval task (for further discussion of other findings in this paper, see section 1.3).

Burgess and Shallice (1996)

Tulving (1983) did not discuss in detail processes that operate after retrieval. The importance of post-retrieval processing, however, is emphasised in a number of conceptions of how memory retrieval operates. On the basis of a detailed analysis of memory protocol studies and considerations of how memories are distorted in individuals who confabulate, Burgess and Shallice (1996) put forward a model of memory control. According to the model, confabulations occur due to the failure of memory control processes, which are governed by the frontal cortex. These control processes are the key aspects of the model, which constitutes a stage where retrieval cues are specified (descriptor processes) and stages following retrieval where the information retrieved via those cues is monitored and verified (editor processes) and integrated with other cognitive demands (mediator processes: for a related view, see Koriat and Goldsmith, 1996). These processes are assumed to be under a degree of strategic control during autobiographical retrieval and to operate iteratively: if the monitoring processes reveal that the information retrieved is inappropriate or not sufficiently relevant, further retrieval cues are specified and the processes are reiterated.

Burgess and Shallice's (1996) conception of these control processes is based on the concept of a supervisory system proposed by Norman and Shallice (1980; 1986). They also argued that descriptor processes and editing processes are specific to memory retrieval and controlled by the frontal cortex – claims that are supported by work with neuropsychological patients (for review, see Stuss et al., 1994) as well as numerous recent findings in PET and functional magnetic resonance imaging (fMRI) studies (Tulving et al., 1994; Nyberg et al., 1995). The precise functional roles that are played by sub-regions of frontal cortex are, however, a matter of considerable debate (for recent reviews, see Fletcher and Henson, 2001; Wood and Grafman, 2003).

The Source Monitoring and Constructive Memory Frameworks (SMF, CMF).

The constructive memory framework (CMF) (Schacter, Norman and Koutstall, 1998) was developed from work in which the emphasis is on the constructive nature of the memory system (Johnson, Hashtroudi and Lindsay, 1993; McClelland et al., 1995). A precursor to the CMF is the source monitoring framework (SMF) of Johnson and colleagues (Johnson, Hashtroudi and Lindsay, 1993). In the SMF memory is not viewed as a literal reproduction of the past. Rather, memory is the result of various perceptual and reflective processes that form memory records. According to Johnson et al. (1993), memory records have different characteristics that include details of perceptual, contextual, semantic and affective information, as well as cognitive operations that were engaged at the time of encoding.

The amounts of these different characteristics are assumed to vary with the origin of the memory records, as memories acquired from different origins have different patterns of the distributions of these characteristics. For example, an activated memory record for a perceived event is likely to have more perceptual details than an imagined event. Johnson and colleagues propose that source judgements can be made by assessing the distribution of different memory characteristics for memories of different origins. So when distinguishing between stimuli that might have been perceived or imagined (Johnson and Raye, 1981) one strategy would be to use the amount of perceptual detail that is recovered, as this should be greater for real than imagined events and therefore a good indicator of the source of a memory. The SMF thus involves attribution and decision processes that evaluate characteristics of a memory record, and the central concepts in the SMF are supported by the findings in numerous experiments. For example, in the studies of Dodson and Johnson (1993) participants were able to retrieve the details of an episode better when the test questions presented all possible sources to consider than when a yes-no binary question specific to one particular source was asked. Dodson and Johnson (1993) argued that the simultaneous presentation of all sources oriented participants to consider all dimensions of the memory record's characteristics at the same time and encouraged them to put more weight on characteristics that are diagnostic for the demands of the task. The claim that source discriminations are often made on the basis of an assessment of the presence or absence of particular characteristics is also supported by the verbal reports of participants in source monitoring studies (Johnson, Foley, Suengas and Raye, 1988).

On the basis of the above, Schacter and colleagues (1998) proposed the CMF in which retrieval processing involves focusing, pattern completion and criterion setting. According to Schacter et al. (1998), the critical process, and the principal addition to SMF, is focusing, a process which involves refining a description of the characteristics of episodes that are to be retrieved. A good retrieval focus can lead not only to recollection of information relevant to target information but also the details of the target information. The description of the information to be retrieved is then matched with the stored memory representations (McClelland et al., 1995). When this pattern completion process produces a match, this will lead to a decision stage, where recovered information is evaluated according to task-dependent criteria, in much the same way as in the SMF.

Rugg and Wilding (2000)

While doing so in different ways, and to different extents, the frameworks outlined above (see also Koriat and Goldsmith, 1996) emphasise the importance for retrieval of processes that operate after ecphory or pattern matching, as well as processes (e.g. focusing) that operate prior to the interaction between a retrieval cue and a memory record or trace. It is now widely accepted that the strategic control of retrieval involves processing at both of these loci, and this assumption is also made by Rugg and Wilding (2000), who provided a description of processes that operate before and after ecphory, as well as a discussion of how these processes could be isolated in appropriately designed brain imaging experiments.

Rugg and Wilding (2000) distinguished four classes of retrieval process. The three that may form part of a retrieval attempt are retrieval mode, retrieval orientation and retrieval effort. Similar to retrieval mode, which has already been discussed, retrieval orientation is a cognitive set that is maintained tonically. Retrieval orientation determines the specific form of retrieval operations that will be engaged when a retrieval cue is encountered. Thus, orientation but not mode should vary according to the specific episodic demands of a retrieval task. The working definition, therefore, of retrieval mode is that it is a process engaged when episodic retrieval is needed, and which is maintained for the duration of the requirement for episodic retrieval. Neural activity associated with retrieval mode can thus be identified by contrasting sustained or low frequency changes in neural activity that are obtained in episodic versus non-episodic retrieval tasks. The working definition of retrieval orientation is that it is a retrieval task-dependent cognitive set. Neural activity indexing retrieval orientations (or differences between orientations) can be identified by contrasting sustained or low frequency changes in neural activity while participants are completing episodic tasks that have qualitatively different retrieval demands.

There is, however, a second means of obtaining neural indices of retrieval orientations. This is achieved by contrasting the neural activity elicited by new items in episodic retrieval tasks having different demands. The logic underlying this contrast is described in more detail in section 1.3, but the important point here is that, other factors being equal, differences between ERPs evoked by new test items can be regarded as item-related indices of retrieval orientations, and such differences are assumed to emerge because of the adoption of distinct retrieval orientations.

Another class of retrieval process that may form part of a retrieval attempt is retrieval effort. This class of process is defined as the differential engagement of processing resources during a retrieval attempt. From the perspective of a working definition, differences in retrieval effort may be manifest when retrieval tasks vary in their difficulty, as may be indicated by differences in the accuracy of responding and/or the reaction times that are associated with memory judgments. Neural activity indexing changes in effort, therefore, can be elicited by contrasting tasks that vary in their level of difficulty while requiring retrieval of qualitatively similar kinds of information. This description also emphasises how, at least in principle, neural activity associated with retrieval orientation and retrieval effort can be separated, since orientation should vary according to what is to be retrieved, while effort should vary according to how difficult that information is to retrieve or process (for extended comments concerning issues related to the means of inferring differences in retrieval effort, see pages 212-213 of the General Discussion).

The fourth class of retrieval process referred to by Rugg and Wilding (2000) is retrieval success. They described this class of retrieval process only briefly, and in their article they focused primarily on the relationships between mode, orientation and effort. Processes associated with successful retrieval and the ways in which retrieved information is processed are, however, central to this thesis. Retrieval success is defined as any process associated with, or contingent upon, ecphory. Thus successful retrieval can be inferred from task performance in so far as recovery of information from memory is necessary in order to complete retrieval tasks at levels above chance. The neural correlates of retrieval success can be revealed by contrasting the activity elicited by retrieval cues eliciting veridical mnemonic information (hits) and those that either cannot (new items) or those that fail to do so (misses). The contrast that is most commonly employed in order to elicit neural correlates of retrieval success, or processes contingent upon successful retrieval, is the contrast between hits and correct rejections. In the ERP literature, differences between the neural activity associated with hits and with correct rejections are referred to as old/new effects, and further discussion of the relevant literature is contained in section 1.4 of this thesis.

The work in this thesis is concerned with strategic retrieval processing in episodic memory, focusing on three of the above classes of retrieval process; those that are engaged prior to retrieval (orientation and effort) and those that are engaged during and after retrieval is successful. The dependent variables employed are behavioural measures of memory performance as well as scalp-recorded event-related potentials (ERPs). The remainder of this chapter reviews the relevant electrophysiological literature. The aims of the thesis are then stated and discussed in the context of the existing literature. Chapter Two provides details about the methodology used in this thesis. Chapter Three describes the general methods common to all experiments that are reported in Chapters Four to Eight. Chapter Nine – the concluding chapter – contains a summary and a general discussion.

1.3. Retrieval Attempts

Significant progress towards understanding the relationship between the processes which might form part of a retrieval attempt (mode, orientation and effort) has been aided by the opportunity to acquire neural activity associated with each of these putative processes. This is due to the fact that it is difficult to make inferences about cognitive processes related to retrieval cue processing from behavioural data alone (Rugg and Wilding, 2000; Wilding, 2001). One focus in the experiments in this thesis is on two classes of processes that form part of a retrieval attempt: retrieval orientation and retrieval effort. To date, the relationship between these two classes of process is not well determined. In this regard, Rugg and Wilding (2000) provided two potential accounts of the relationship between retrieval effort and retrieval orientation. The first is that effort is associated with changes in the levels of activity in a dedicated and presumably task invariant neural circuit. Another possibility is that changes in effort will be reflected in the level of activity in those regions that are typically engaged during a retrieval task. To investigate these possibilities, it is necessary to ensure that experiments are designed in a way such that the two classes of process are controlled systematically, and this has been accomplished in only some ERP studies to date.

Two approaches have been adopted to provide electrophysiological evidence for the concept of retrieval orientation. The first is to record the activity of the brain in periods prior to presentation of retrieval cues, and separate this preparatory activity according to the kinds of episodic information that participants are preparing to retrieve. Herron and Wilding (2004) recorded ERPs in the period during which participants were preparing to retrieve semantic information (making animacy or pleasantness judgements) or different kinds of episodic task (remembering spatial/location or remembering encoding task). Similar to the study of Morcom and Rugg (2001), participants were cued on a trial-by trial basis to complete one of the three retrieval tasks. Herron and Wilding (2004) reported that the ERPs evoked by both episodic cues were more positive-going than those evoked by the semantic cues at right anterior sites, a finding that is in line with previous studies (Morcom and Rugg, 2001; Duzel et al., 1999; 2001) and fulfils the criteria for being a neural correlate of retrieval mode. They also reported a relatively greater positivity at left anterior scalp sites that was evoked by the cues directing participants to retrieve encoding task compared to cues directing participants to retrieve spatial information. This finding provides support for the concept of retrieval orientation, as the activity indicates that participants engaged different processes according to what episodic information they were preparing to retrieve (Rugg and Wilding, 2000).

The second approach to investigating correlates of retrieval orientations is to restrict contrasts to items presented for the first time at test and separated according to one or more aspects of task demands (Johnson, Kounios and Nolde, 1996; Wilding, 1999; Ranganath and Paller, 1999; Rugg, Allan and Birch, 2000; Wilding and Nobre, 2001; Robb and Rugg, 2002; Herron and Rugg, 2003a). These contrasts enable investigation of processes related to retrieval attempts independently from processes that are contingent on retrieval success. The logic is that any differences between the ERPs that are evoked by new items will reflect processes that are engaged in pursuit of memory retrieval. New items will not index successful memory retrieval because these items were not presented in prior study phases and hence no corresponding memory trace for the items is available (Donaldson et al., 2002).

The following section contains a review of ERP studies that have been conducted to investigate processes associated with retrieval attempts. In all of these studies, contrasts have been restricted to classes of new test items. Generally these studies have either required participants to complete a single encoding task followed by two or more retrieval tasks, each having different test instructions (see for example Ranganath and Paller, 1999; Wilding, 1999), or required participants to complete two encoding tasks prior to completing a single retrieval task (see for example Rugg, Allan and Birch, 2000). For the former, the assumption is that the way the participants interrogate their memory in search of relevant information will vary according to test instructions. For the latter approach, the assumption is that the memory retrieval operations engaged at test are determined by what the participants experienced at encoding.

The outcome of a contrast between ERPs evoked by new test items was initially reported by Johnson, Kounios and Nolde (1996). Study materials were words and pictures and participants were divided into two groups. Each had to perform different encoding tasks prior to completing the same retrieval task. One group (function group) was asked to rate the number of functions that could be generated for each object designated by each word or picture. The other group (artist group) had to rate how difficult the object denoted by the word or picture would be to draw. In the test phase, participants engaged in either a recognition memory task (discriminating between old and new test items) or a source memory task (distinguishing old from new test items, and for words judged old indicating whether the object had been encountered as a word or a picture at study). Johnson and colleagues reported that the ERPs elicited by both new and old test words in the source memory test differed markedly according to group over frontal and posterior sites. This finding is important because it demonstrated that the neural activity elicited by physically identical cues (new items) can vary according to the specific demands of retrieval tasks.

Johnson et al. proposed that the differences were a result of the different tasks performed by the two groups of participants at study (Johnson et al., 1996). They suggested that in keeping with the SMF (see section 1.2) participants in the two groups relied on different characteristics of memory traces in order to make test judgements. They suggested that the differences between the ERPs elicited by new items reflected the emphasis on perceptual details of a memory trace for participants from the drawing group, and on conceptual details for participants from the function group.

In the study of Wilding (1999), all participants engaged in one encoding task and at test they were required to retrieve different aspects of information that had been encoded at study. They listened to words spoken in either a male or a female voice and were to make an active/passive judgement (action encoding task) or a pleasant/unpleasant judgement (liking encoding task) depending on the cue that preceded each spoken word. Two different retrieval tasks followed. In one retrieval condition (voice task), participants distinguished new words from old words spoken at study by either the male voice or the female voice. In the other condition (operations task), participants distinguished new words from old words to which either an active/passive or a pleasant/unpleasant judgement had been made at study.

The ERPs elicited by new items in the two retrieval tasks were distinguished by a polarity reversal over the frontal sites of both hemispheres, with the differences extending to central midline sites. In the voice retrieval task new items evoked more positive going ERPs at left-frontal sites, whereas the ERPs evoked by the same category of items in the operations retrieval task were more positive going at right-frontal electrode sites. This pattern of differences was relatively consistent from approximately 300-1400 ms post-stimulus. There was no marked difference in the reaction times for correct judgements to new items in the two retrieval tasks (1123 vs. 1129 ms) and the discrimination values representing the probabilities of distinguishing old from new items were also similar (0.81 for voice; 0.82 for task), leading Wilding (1999) to suggest that the differences in the ERP modulations evoked by new items in the two retrieval tasks were not linked to task difficulty. Rather, the differences were due to the different retrieval orientations adopted by participants in the voice and operations retrieval tasks (although see Wilding and Sharpe, 2003; Dzulkifli, Sharpe and Wilding, 2004).

Retrieval related ERP modulations over left-frontal scalp sites were also reported by Ranganath and Paller (1999). In that study, each participant completed a picture encoding task, followed by two different retrieval tasks; a general retrieval task and a specific retrieval task. At test, stimuli consisted of pictures which took one of three forms: old, new or new pictures that were perceptually similar to old pictures. These ‘similar’ pictures had been re-scaled, resulting in small changes to their height and width. In the general retrieval task, participants were asked to make old/new recognition judgements, responding old to studied as well as to perceptually similar pictures. In the specific retrieval task, participants were asked to make the same old/new recognition judgements, but to respond old only to previously studied pictures. The two conditions were designed to differ in the degree to which participants were required to process perceptual details of the test items.

The ERPs evoked by new items in the specific retrieval condition were significantly more positive going than the ERPs evoked by new items in the general retrieval condition. The effect was reliable from approximately 400 to 1200 ms post-stimulus and was evident primarily over the left-frontal scalp. Ranganath and Paller (1999) proposed that the ERP effects that differentiated the specific and the general retrieval tasks were due to the different retrieval demands associated with each task. They suggested that in comparison to the general retrieval task, the specific retrieval task demanded more attention to perceptual details of the items and participants needed to engage in more evaluative operations before making old/new judgements (see also Ranganath and Paller, 2000; Ranganath, Johnson and D'Esposito, 2000).

Rugg, Allan and Birch (2000) also reported activity over the left-frontal scalp that differentiated between classes of new test items. In their study, all participants engaged in deep (generating meaningful sentences from the words presented) and shallow encoding tasks (performing an alphabetic judgement task). At test, participants were to make old/new judgements to words presented in two separate test blocks. Each test block contained old words that had been processed in only one of the two encoding tasks, along with words that were new.

The ERPs evoked by new test words were more positive-going at left frontal locations when they were intermixed with shallowly encoded old words than with deeply encoded old words. Rugg, Allan and Birch (2000) argued that the shallowly encoded old words were more difficult to remember than the deeply encoded old words (which was supported by the behavioural data). They argued that retrieval effort was therefore engaged to a greater extent in the block containing shallowly encoded words, and that this was reflected in the greater positivity shown by the ERPs over the left frontal scalp. They suggested that this 'effort' interpretation could also be applied to the data due to Ranganath and Paller (1999).

In addition to this left-frontal ERP effect, Rugg et al. (2000) reported that the ERPs evoked by new items in the block that contained deeply studied items were more negative going than those in the block which contained the shallowly encoded old items, primarily at midline and right hemisphere centro- parietal scalp locations. Rugg et al. (2000) proposed that this effect likely indexed processes that were distinct from those indexed by the left-frontal effect discussed above. Support for this proposal stems from the fact that the right-centro parietal negativity evoked by new items in the deep retrieval condition resembles the N400 ERP component which was first reported in studies of language processing (Kutas and Hilyard, 1980). The N400 ERP component, which takes the form of a negative-going deflection that peaks around 400 ms post stimulus, is elicited by items that undergo different levels of processing, with the amplitude of the N400 increasing as tasks require semantic rather than non-semantic operations (e.g. Rugg, Furda and Lorist, 1988).

In light of these resemblances, Rugg et al. (2000) proposed that the N400-like modulation in their study indexed processes related to the requirement to search for semantically versus non-semantically encoded words. They suggested that participants adopted different orientations that resulted in processing test items in the blocks with old items subjected to deep encoding with respect to their semantic attributes, and test items in the other blocks with respect to their perceptual features, with little focus on the semantic features. They suggested that these operations were adopted in order to maximise retrieval success in line with the principle of transfer appropriate processing (Morris, Bransford and Franks, 1977), according to which the probability of successful retrieval increases with the increase in the amount of overlap between study and test processing.

Rugg et al. thus suggested that they had identified correlates of orientation as well as effort in the same experiment. The only aspect of the data that supports this view, however, is the fact that the left anterior modulation they reported resembles those reported by Ranganath and colleagues (1999; 2000), while the centro-parietal modulation resembles the N400. Changes in orientation as well as changes in effort are confounded in this study, thus in principle these two modulations may have a common functional correlate, and this could be orientation or effort.

In summary, these ERP studies have all revealed reliable differences between the ERPs evoked by classes of new items. The differences have been interpreted to reflect processes that operate independently of retrieval success because the contrasts have been restricted to different classes of new test items. The data in the studies where behavioural accuracy is equivalent across tasks provide some support for the view that ERPs index processes related to orientation rather than effort (Ranganath and Paller, 2000; Wilding, 1999). The designs of all studies, however, did not allow an independent manipulation of retrieval effort and retrieval orientation. Thus, the data do not speak to the relationship between these two classes of retrieval process.

The only study to date in which task difficulty was manipulated directly is due to Robb and Rugg (2002). In four recognition memory tests, orientation and effort were manipulated orthogonally. Orientation was manipulated by using different study materials (words vs. pictures), whereas effort was manipulated by varying the length of study lists and the study-test intervals (easy vs. hard recognition tasks). They reasoned that by doing so they could isolate ERP effects specific to orientation and effort.

There were two encoding tasks; in a picture encoding task, participants were required to judge whether the size of an object presented in pictorial form was smaller or larger than a newspaper, whereas in a word encoding task, participants were to judge whether the named object would be more likely to be found indoors or outdoors. These two encoding tasks differed in that the picture encoding task was assumed to rely on imagery-based information while the word encoding task relied on a more abstract form of information. Test stimuli were words only. The test phase following the picture encoding task involved making judgements about whether or not each word was the name of a studied picture. In the test phase for the word encoding task, participants were asked to judge whether each test word had been shown at study or not. The study-test interval was 30 seconds for the easy conditions, while for the hard conditions the interval was 5 minutes. The length of study-test lists in the hard conditions was longer compared to the easy conditions and this was achieved by including additional filler items in the lists.

Robb and Rugg (2002) reported that the ERPs elicited by new items were different for the easy and the hard conditions. The size of the effects was small, restricted to the frontal, central and parietal midline sites and only evident in the initial 300 ms of the recording epoch. The effects for the study materials were more obvious. The ERPs evoked by new items in the picture blocks were more negative going than those evoked by new items in the word blocks from around 300 ms post stimulus and extended until the end of recording epoch. The effects were widely distributed over the scalp. Robb and Rugg (2002) proposed that the effects cannot be attributed to differences in difficulty between the two kinds of retrieval tasks because there was no interaction involving difficulty and study material. The effects were interpreted as reflecting the use of different retrieval orientations by participants when attempting to retrieve pictures as opposed to words. The authors were of the opinion that the correlate of effort required replication, and that there could be other ways to manipulate difficulty so as to elicit more pronounced ERP effects than were observed for these study materials. This possibility, and the more general question of the correspondence between retrieval effort and retrieval orientation is a central theme in this thesis, and particularly in the first two experiments (Chapters 4 and 5).

Complementary findings to those of Robb and Rugg (2002) have been reported by Herron and Rugg (2003a). In their experiment, an equal number of pictures and words were presented in the encoding phase. At test, all stimuli were words, which were either old or new. The old words were either re-presentations of words, or of words corresponding to the objects denoted by the pictures. The retrieval tasks comprised an exclusion procedure (Jacoby, 1991), in which an ‘old’ response is to be made to one class of old items (targets) and a ‘new’ response is to be made to the other class of old items (non-targets) as well as to genuinely new items. In separate retrieval phases, targets were designated as old words that had been encountered either as words or as pictures (see section 1.4.1 for further details of the exclusion task).

The ERPs evoked by new words in the study of Herron and Rugg (2003a) varied according to the sought-for information in a way that was very similar to the divergences reported by Robb and Rugg (2002). Because no differences were found with respect to the new item RTs or accuracy, Herron and Rugg (2003a) suggested that the differences between the ERPs evoked by new words were not likely to reflect retrieval effort. Instead, the effect was proposed to index retrieval processing resulting from the adoption of different retrieval orientations. These findings extend those of Robb and Rugg (2002) because the effects were obtained in a task in which encoding tasks were intermixed rather than blocked, and in which the retrieval tasks required source rather than recognition judgements.

The findings thus add weight to the view that this effect is related to task-specific retrieval operations. This argument has been developed further in recent publications (Hornberger, Morcom and Rugg, 2004; Herron and Rugg, 2003b), in which putative indices of orientation have been linked to the likelihood of successful retrieval by observing the conditions under which indices of orientations occur alongside changes in ERP indices of successful retrieval. The relationship between orientation and retrieval success is a focus in the second half of this thesis, in which changes in indices of orientation are correlated with changes in ERP old/new effects – electrophysiological indices of retrieval success. For this reason a review of ERP old/new effects is provided here.

1.4. Retrieval Success: Evidence from ERP Old/New Effects

Cognitive operations associated with successful episodic retrieval are reflected by a class of ERP modulations called 'old/new effects'. The effects are typically revealed by contrasting ERPs evoked in conditions where retrieval is successful against those evoked in baseline conditions where retrieval does not or cannot occur. For example, by comparing the differences between the waveforms evoked by correctly recognised old words (hits) and correctly rejected new words (correct rejections) in recognition memory tasks. A robust finding is that ERPs differentiate items correctly recognised as old from correctly rejected new items (Wilding and Sharpe, 2004; Donaldson et al., 2002). There is a number of old/new effects, three of which are directly relevant to the work in this thesis and which will be reviewed in the following section.

1.4.1. Left-parietal old/new effect

The ERP old/new effect to which probably the most attention has been paid to is the left-parietal old/new effect (Rugg and Allan, 2000). This effect differentiates correctly recognised old items from correctly rejected new items, in that the ERPs evoked by the former are more positive going compared to the ERPs evoked by the latter class of items. The effect onsets approximately 500 ms post-stimulus, lasts for several hundred milliseconds and is evident maximally at left parietal scalp sites.

The first report of what is likely to be this effect is due to Sanquist, Rohrbaugh, Syndulko and Lindsley (1980), and for the most part discussions of the likely functional significance of this effect have been focused on dual-process theories of recognition memory (e.g. Mandler, 1980; Jacoby, 1991). The dual-process framework due to Jacoby and colleagues (Jacoby and Dallas, 1981; Jacoby and Kelley, 1992;

Jacoby, Kelley and Dywan, 1989) is the one that is referred to most frequently now, and in that framework two processes – recollection and familiarity – are deemed to be able to support recognition memory judgements. Recollection is successful retrieval of information from episodic memory and entails recovery of contextual details about a prior event, such as where or when it occurred. Familiarity is an acontextual strength-based signal that provides information solely about prior occurrence.

The claim that recollection and familiarity are distinct processes is supported by evidence that the two can be manipulated independently in control populations (for a detailed review, see Yonelinas, 2002), and that selective deficits in recollection can occur following brain damage (Aggleton and Shaw, 1996; Vargha-Khadem, Gadian, Watkins, Connely, Van Paesschen and Mishkin, 1997). For present purposes, the important point is that the left-parietal old/new effect likely indexes recollection rather than familiarity[2].

In the period between 1980 and 1995 proposals that the left-parietal old/new effect indexed either recollection or familiarity were advanced (for recollection accounts, see Paller and Kutas, 1992; Paller, Kutas and McIsaac, 1995; Smith, 1993; Smith and Halgren, 1989; Van Petten, Kutas, Kluender, Mitchiner and McIsaac, 1991; for familiarity accounts, see Friedman, 1990; Johnson, Pfefferbaum and Kopell, 1985; Rugg, Brovedani and Doyle, 1992; Rugg and Doyle, 1992).

---

[2] There are recent suggestions that a different old/new effect – the mid-frontal old/new effect – indexes familiarity, although this claim is disputed (cf Curran, 2000; Mecklinger, 2000; Tsivilis, Otten and Rugg, 2001; Yovel and Paller, 2004).

The findings in some of these studies also established that the effect was not simply a consequence of stimulus repetition (Neville, Kutas, Chesney and Schmist, 1986; Smith, 1993; Wilding and Rugg, 1996; 1997) or of the act of making an 'old' response (Neville et al., 1986; Rugg and Doyle, 1992; Wilding and Rugg, 1996; 1997). The link between the left-parietal old/new effect and recollection was established primarily on the basis of findings in studies where participants were asked to make explicit context judgements or report their experiences of remembering, and key experiments are reviewed briefly here, since the work contained in this thesis involves tasks that require explicit context judgements.

The principal evidence that supports the link between recollection and the left-parietal old new effect is the following. First, the effect is larger for test items attracting Remember rather than Know judgements (Smith, 1993; Duzel, Yonelinas, Mangun, Heinze and Tulving, 1997; Duarte, Ranganath, Winward, Hayward and Knight, 2004). In the remember/know task (Tulving, 1985; Gardiner and Java, 1993; also see Chapter 8) participants are asked to make remember judgements only when they can recollect information from a prior study episode, and to make a know judgement when the belief that a test stimulus is old is not accompanied by memory for contextual information. Larger old/new effects for remember judgements therefore suggest that the effect is linked to retrieval of contextual information.

Second, the left-parietal old/new effect is larger when associated with correct context judgements than with incorrect context judgements (Wilding, Doyle and Rugg, 1995; Wilding and Rugg, 1996). In these studies participants were tested on various details about study events. Participants were required to make an initial old-new recognition judgement and a subsequent source/context judgement for each item judged 'old'. To the extent that recollection is defined as the ability to retrieve contextual details, then trials on which source memory judgements are successful are more likely to involve recollection than are trials on which source memory judgements are unsuccessful (for review, see Allan, Wilding and Rugg, 1998).

In their two experiments, Wilding, Doyle and Rugg (1995) found that correctly recognised words attracting correct source judgements elicited a left-parietal old/new effect. No such effect was found for ERPs evoked by words associated with incorrect source judgements, leading Wilding, Doyle and Rugg (1995) to suggest that the effect was closely associated with successful retrieval of source information. In their experiments, half of the items were encoded in the visual modality while the other half were encoded in the auditory modality. At test participants were asked to make old/new judgements to a mixed list of old/new items presented visually in experiment 1 and auditorily in experiment 2. In both experiments, for each item judged old, participants were required to make a further judgement about the source ('seen' vs. 'heard') in which the item had been studied. The finding that the left-parietal old/new effect was present only for words that were assigned to the correct study modality suggests that the left-parietal old/new effect is related to recollection.

There is, however, a potential confound in the study of Wilding et al. (1995). The use of sensory modality as a contextual cue might give rise to priming (Wilding and Rugg, 1996). The behavioural data showed that in experiment 1, where all the test items were presented visually, participants correctly recognised visually presented items better that auditorily presented items, while in experiment 2, participants correctly classified auditorily presented items more than visually presented items. This pattern of behavioural data might have been be due to the procedure of presenting 50% of the items in the same modality at test and at study. Greater familiarity might be engendered for these test items, in comparison to cross-modality test items, and thus serve as the basis for modality judgements without recollection of the original study context (Kelley, Jacoby and Hollingshead, 1989). Consequently, it was possible that the left-parietal old/new effect associated with source judgement accuracy was correlated with the familiarity induced by study-test overlap rather than recollection.

In view of this, Wilding and Rugg (1996) designed a procedure that ensured source judgements would not be influenced by familiarity-related processes. They employed the same paradigm as Wilding et al. (1995) with the exception that sensory modality was replaced by a voice manipulation at study (either a male or a female voice). Participants made an initial old/new judgement to visually presented test words, and for those judged to be old, they were to identify in which voice (male or female) the words had been presented at study. The left-parietal old/new effect was larger for recognised old words that were assigned to the correct study source than for those assigned to the incorrect source.

Further support for the link between the left-parietal old/new effect and recollection comes from studies of associative recognition. Donaldson and Rugg (1998) presented participants with word pairs at study and at test. Word pairs at test were two new words, a rearranged pair, or the same pair that had been presented at study. The left-parietal old/new effects were larger for same than for rearranged pairs, which supports the link between recollection and the left-parietal old/new effect in so far as the likelihood of recollecting 'same' pairs is greater than that for rearranged pairs (Yonelinas, 1997). This pattern of data was obtained when participants had to make same/rearranged judgements, as well as when old/new judgements were required (see also Donaldson and Rugg, 1999).

A final important line of evidence comes from electrophysiological studies of memory processing in various neuropsychological populations. The general finding is that the left-parietal old/new effect is absent in neurological patients whose recollection is impaired. Smith and Halgren (1989) recorded ERPs from patients with right- and left-sided anterior temporal lobectomy and from normal participants. All participants engaged in a series of recognition test blocks containing the same study words and different new words across blocks. Smith and Halgren (1989) reported that the left-sided patients performed worse compared to normals and the right-sided patients, although their performance was improved across the test blocks. The left-parietal old/new effect was observed for all participants, except the left-sided patients. The authors argued that the low recognition performance of the left-sided patients was due to impaired recollection and preserved familiarity. Coupled with the finding that the left-parietal old/new effect was not modulated by the repetition of old words across blocks, which was assumed to influence familiarity but not recollection, Smith and Halgren suggested that the left-parietal old/new effect is indeed the signature of recollection.

In another study (Tendolkar, Schoenfeld, Golz, Fernandez, Kuhl, Ferszt and Heinze, 1999), ERPs were recorded from patients suffering from Alzheimer's disease and from controls. All participants engaged in a test of verbal recognition memory accompanied by a source decision (colour of item at study). The patient group showed above chance recognition but failed to recollect contextual information at above chance levels. There was no evidence for the left-parietal old/new effect in the patient group, which again suggests that the effect indexes recollection.

Consistent with this finding, Duzel, Vargha-Khadem, Heinze and Mishkin (2001) compared ERPs recorded from a young amnesic patient with ERPs recorded from normal controls. At study, participants were required either to make living/nonliving or concrete/abstract judgements. At test studied words were presented with an equal number of new words and participants made an old/new judgement for each test word. In comparison to controls, the recognition performance of the amnesic patient was impaired, but was above chance level. A left-parietal old/new effect was observed for controls only. It was argued that the preserved recognition memory of this patient was due to familiarity, and the absence of the left-parietal old/new effect indexed the impairment in recollection.

In another study (Mecklinger, von Cramon and Matthes, 1998), ERPs recorded from patients suffering from hypoxic brain injury were compared with those recorded from controls. All participants saw various objects presented in various locations and at test they engaged in a visual recognition task: judging whether the object or location had been seen in the previous study phase or whether it was new. No left-parietal old/new effect was observed in either object or spatial test condition for the patient group, despite their above chance level of recognition performance, suggesting that recognition based on the retrieval of an item's study episode is degraded in the patient but not in the control group (Mecklinger et al., 1998).

In combination, these different forms of evidence add considerable weight to the view that the left-parietal old/new effect can be considered to be an electrophysiological correlate of recollection. For present purposes, it is also important to highlight recent findings in which left-parietal old/new effects were not elicited by items that, at least from one theoretical perspective, should have been recollected. These data were obtained in ERP studies employing the exclusion task.

The exclusion task is one part of the process-dissociation procedure (PDP), a method developed by Jacoby and colleagues (Jacoby, 1991; Jacoby, Toth and Yonelinas, 1993) in order to assess the respective contributions of recollection and familiarity to performance on recognition memory tasks. In a typical experiment employing the exclusion task, study items are presented in two different contexts, defined by different presentation lists, different presentation modalities or encoding tasks. At test, participants are presented with the studied items from these two contexts along with unstudied items. Participants are required to give different responses to different classes of studied items. They are to make 'old' responses only for items presented in a specified study context. This class of items is classified as targets. The items previously presented in the alternative context are classified as non-targets, and participants are to respond 'new' to non-targets as well as to genuinely new items.

The exclusion task is designed such that successful completion of the task depends upon recollection, since familiarity alone will not, in most circumstances, permit discrimination of targets from non-targets. Jacoby (1991), furthermore, argued that in the exclusion task participants rely upon recollection of targets as well as recollection of non-targets in order to make task judgements. This assumption is central to the way in which the PDP is employed in order to make estimates of recollection and familiarity. If this assumption is correct then both targets and non-targets attracting correct judgements should be associated with left-parietal ERP old/new effects.

The findings from the ERP studies that have employed the exclusion task consistently reveal the existence of robust left-parietal old/new effects for target items (Wilding and Rugg 1997; Dywan, Segalowitz and Webster, 1998; Herron and Rugg 2003a; 2003b). However, some of the above studies reported that no left-parietal old/new effect was observed for non-target items. For example, in Dywan et al. (1998), no left-parietal old/new effect was observed in young participants under some circumstances. In their experiments, performance of young and old adults was compared as they responded to target words that were presented along with foils, some of which repeated after a lag of only a few trials (non-targets).

In the young adult group, target items evoked a left-parietal effect but no such effect was observed for non-targets. In contrast, in the old adult group, the ERP old/new effects evoked by non-target items were at least equal in amplitude to the effects evoked by target items. The authors proposed that there might be circumstances in which young participants were in some sense able to inhibit recollection of non-target items (Dywan, Segalowitz, Webster, Hendry and Harding, 2001; Dywan, Segalowitz and Arsenault, 2002).

In two exclusion task experiments reported by Herron and Rugg (2003b) participants completed one identical and one different encoding task. The common task that was required for half of the study words in each experiment was to incorporate each word into a sentence and to say it aloud. For the second task in experiment 1, participants were asked to rate words for pleasantness, while in experiment 2 the second task was simply to read aloud each word that was presented. Non-targets were defined as words from the common task in both experiments, and the accuracy of target judgements was superior in experiment 1, as would be expected given that this is a depth of processing manipulation (Craik and Lockhart, 1972). Non-target accuracy was equivalent in the two experiments.

Target as well as non-target items elicited left-parietal old/new effects in experiment 2, while in experiment 1 the left-parietal old/new effect was observed only for target items. These findings suggest that target items in both experiments were endorsed on the basis of recollection as reflected by the existence of the robust left-parietal positivity evoked by this class of items. By contrast, the classification of non-targets items differed between the two experiments as the left-parietal old/new effect was observed for non-targets only in experiment 2. This pattern of findings suggests that participants relied on recollection to classify non-target items in experiment 2 only. In other words, participants made more use of source information about the to-be-excluded items when memory for targets was poor, but not when memory for target was good. The authors interpreted these findings as reflecting the adoption of different retrieval strategies (orientations). They suggested that when memory for targets was good (experiment 1), classification of non-targets was done on the basis of the failure to recollect information diagnostic of the target source. They suggested that this strategy was not optimal when memory for targets was poor, hence, recollection of non-targets was prioritised in experiment 2 to a greater degree than in experiment 1.

Complementary findings and similar conclusions have been reported by Herron and Rugg (2003a), and the findings in all of the exclusion task studies reviewed here are important in this thesis because some key assumptions concerning the control of recollection are tested in Experiments Three-Five, and in those studies (also see Herron and Rugg, 2003a) the modulation of left-parietal ERP old/new effects is also employed as a means for determining the precise functional significance of ERP indices of retrieval orientations revealed by contrasts between ERPs evoked by classes of correct rejections.

1.4.2. Right frontal old/new effect

Similar to the left-parietal old/new effect, the right frontal old/new effect differentiates items correctly recognised as old from correctly rejected new items. The onset of the effect overlaps with that of the left-parietal old/new effect, and the effect can last for up to 1000 ms (Wilding and Rugg, 1997). The scalp distribution of this effect is lateralised to the right hemisphere and largest over frontal scalp. The different time courses and scalp distributions of the right frontal and the left-parietal old/new effects suggest that the brain regions generating these effects are not identical, in turn suggesting that the two effects are functionally distinct.

The right frontal old/new effect was first reported by Wilding and Rugg (1996) in the study already described (although see Johnson, 1995). In that study, the authors demonstrated that the left-parietal and right-frontal old/new effects were neurally dissociable, and in subsequent work functional dissociations between the two effects have been reported (Wilding and Rugg, 1997, see in particular Wilding, 1999). Wilding and Rugg (1996) suggested initially that the right-frontal old/new effect indexed processes that operate on the products of retrieval, and that the effect was necessary for the recovery of contextual information to form a coherent representation of a prior episode.

The link between the right frontal old/new effect and retrieval of source information has also been reported in a few studies which have directly contrasted ERPs elicited in item and source recognition memory tasks (Johnson et al., 1996; Senkfor and Van Petten, 1998; Johansson, Stenberg, Lindberg and Rosen, 2002). In the experiments of Senkfor and Van Petten (1998), ERPs elicited in retrieval tasks that either did or did not require recovery of source information were compared. Senkfor and Van Petten reported that frontal old/new effects were observed only when source and old/new judgements were made concurrently. The effect was equivalent for both correct and incorrect source judgements, leading the authors to suggest that the effect reflected processes specific to the retrieval of contextual information. The authors also suggested that the onset of the right-frontal old/new effect was later than the left-parietal old/new effect, suggesting that source information was searched for after retrieval of item information. This is consistent with the time course for making judgements on the basis of these two types of information proposed by the SMF (section 1.2) (Johnson et al., 1993).

A similar pattern of results was reported by Johansson et al. (2002). Participants made item and source memory judgements to words corresponding to previously perceived and imagined pictures. The right frontal old/new effect was evident only in the source recognition task and was significantly greater for imagined than for perceived items. The findings thus offer support for the proposal that the effect indexes processes associated with the requirement to make context judgements explicitly.

Converging evidence linking the right frontal old/new effect with the retrieval of source information also comes from the experiments of Rugg, Schloerscheidt and Mark (1998). In these experiments, ERP old/new effects associated with the retrieval of contextual information were compared with ERP old/new effects associated with Remember responses. Right-frontal old/new effects were observed for correctly recognised items for which voice information could be recalled, as indicated either by a correct Remember judgement or a correct context judgement. The findings add further weight to the view that the right-frontal old/new effect is associated with the retrieval of contextual information necessary to make accurate source judgements (Rugg, Schloerscheidt, Doyle, Cox and Patching, 1996; Rugg et al., 1998).

However, explicit retrieval of source information may not be necessary to elicit the right frontal old/new effect. Such evidence was reported in tests of recognition memory for associative information (Donaldson and Rugg, 1998). In their experiment 2, both 'same' and 'rearranged' pairs elicited right frontal old/new effects, a finding which indicates that the right-frontal old/new effect is not specific for source memory tasks, unless of course participants treated the task as a source rather than simply a recognition memory task.

In an attempt to establish the generality of the right-frontal old/new effect, Wilding and Rugg (1997) recorded ERPs during an exclusion task (Jacoby, 1991). In their study phase, participants were presented with words spoken in either a male or a female voice. They were required to complete different encoding tasks according to speaker gender. Only target items evoked reliable right-frontal ERP old/new effects. This finding suggests that the right-frontal ERP old/new effects is not an obligatory correlate of successful recollection because no such effect was observed for non-targets, despite the fact that non-targets were associated with reliable left-parietal ERP old/new effects in this experiment.

These findings also indicated that the effect can be obtained in paradigms where only a single binary response is required, and this claim is supported by the fact that right-frontal old/new effects have in limited instances been observed in old/new recognition memory tasks (e.g. Allan and Rugg, 1998). Of particular importance here is the study of Rugg, Allan and Birch (2000) described earlier, where right-frontal ERP old/new effects were reliable for words following shallow encoding only, despite the fact that these items were less likely to be recollected than those that had been subjected to deep encoding.

These findings led Rugg and colleagues to suggest that the right-frontal old/new effect reflects processes concerned with monitoring and evaluation of the outputs of retrieval in service of task demands, with the effect for shallowly encoded words coming about because of the difficulty associated with making correct judgements for words from this category.

A study that supports this account was conducted by Ullsperger, Mecklinger and Muller (2000), who employed a directed forgetting paradigm. At study, participants were presented with words, each of which was followed by one of two cues indicating whether they had to remember or to forget the just-presented word. At test, both the to-be-remembered (TBR) words and the to-be forgotten words (TBF) were presented with unstudied new words. Participants were asked to identify studied from unstudied words and not to consider whether the words belonged to the TBR or TBF categories. Ullsperger et al. (2000) reported that the right-frontal old/new effect was larger in amplitude for TBF words than for TBR words. The TBF words were also associated with poorer memory performance than the TBR words. This finding was interpreted as evidence that this old/new effect reflects evaluation processes that are engaged to a greater degree when the quality of retrieved information is poor (Ullsperger et al., 2000).

To summarise, the claim that the right-frontal old/new effect indexes post-retrieval processes responsible for monitoring and/or evaluation provides a general fit with the existing data, but a more precise functional account of this modulation is desirable. Whether there is more than one effect that reflects frontally mediated retrieval processes remains a distinct possibility, given apparent changes in scalp distribution across tasks (e.g. Senkfor and Van Petten, 1998; Trott, Friedman, Ritter and Fabiani, 1997; Wilding and Rugg, 1996). These changes are frequently confounded with other task requirements, however, and given the variability in human frontal cortical structure it may be that ERPs will provide only limited information about frontally mediated processes that are engaged post-retrieval (Wilding, 2001; Van Petten et al., 2000), although this remains an empirical question.

1.4.3. Late posterior negativity

This negative-going modulation is elicited by old items relative to new items, onsets around 600-800 ms and remains until the end of the recording epoch. It has a bilateral posterior parietal distribution centered on Pz (Rugg et al., 1996; Wilding and Rugg, 1996; Wilding and Rugg, 1997; Curran, 2000; Curran, Schacter, Johnson and Spinks, 2001; Cycowicz, Friedman and Snodgrass, 2001). It was suggested initially that this effect reflected response-related rather than mnemonic processes, as its magnitude was correlated with response times (Wilding and Rugg, 1997). It is only recently that this account has been challenged.

Cycowicz and colleagues (2001) offered an alternative account of the functional significance of this old/new effect. They suggested that the effect reflected the search for or evaluation of colour information. This account was based on their findings in a study where participants were presented with line drawings displayed in either red or green at encoding and at test they engaged in separate old/new recognition tasks and exclusion tasks. The late negative wave was more prominent in the exclusion task than in the item memory task. The fact, furthermore, that the reaction times to old and new items in the exclusion memory task did not differ led Cycowicz and colleagues (2001) to propose that the effect was not due to longer reaction times associated with old items.

Whether the effect indexes operations specific to colour, or whether it is related to more general retrieval processing requirements remains to be established, however, and in a recent proposal, Johannsen and Mecklinger (2003) suggested that the effect may comprise two modulations, one that is stimulus-locked and which is related to binding time and context, and one that is response-locked and which is concerned with action monitoring demands (see also Nessler, Mecklinger and Penney, 2001; Johansson et al., 2002; Nessler and Mecklinger, 2003). The late negative wave is evident via visual inspection in many studies, and its ubiquity argues against the colour-specific interpretation of Cycowicz et al. The action monitoring account of Johannsen and Mecklinger (2003) is a more parsimonious proposal, although the posterior scalp distribution of the effect is perhaps a little surprising given that the functions ascribed to this wave are those often associated with pre-frontal cortex. The functional significance of this modulation, as for the right-frontal old/new effects, will be returned to in the General Discussion (Chapter 9).

1.5. Concluding remarks

The foregoing review highlights the fact that ERPs evoked by identical retrieval cues and separated according to task demands likely index retrieval orientations, but there is little work in which the relationship between effort and orientation has been explored. The nature of this relationship is the focus in the first part (Experiments One and Two) of this thesis. The second part of this thesis is concerned with a more precise functional characterisation of retrieval orientations than is available at present. Presumably, orientations have beneficial effects on retrieval processing (Wilding and Nobre, 2001; Herron and Wilding, 2004), but precisely what the benefits are remain to be determined. These issues are addressed in Experiments Three-Five, where the link between adoption of an orientation and the success or the failure of recollection is investigated, in order to determine whether orientations might in fact influence what information is recovered from memory (for preliminary remarks, see Herron and

Rugg, 2003a). At issue in all experiments is the question of how it is most appropriate to characterise processes that occur before, after or at the point of the interaction between a retrieval cue and a memory trace.

Chapter 2

2.1. Introduction

The brain is composed of a very large number of neurons, which communicate by generating small electro-chemical signals. If the probes from an instrument for measuring electrical energy (such as a voltmeter) are placed near a neuron, they will register a voltage change whenever the neuron is active. Neurons can be active or generate potentials up to several hundred times per second. These potentials are relatively small and cannot be monitored individually from a distance. Large populations of neurons, however, can under certain conditions (see below) generate signals that are measurable at some distance from the population. This was first established over 70 years ago (Berger, 1929; Kiloh and Osselton, 1961).

Under the assumption that cognitive processes result from neuronal activity, insight into these processes can be achieved by recording brain electrical activity at the scalp. This chapter contains a description of the use of ERPs as a research tool. As described in the following section, ERPs are extracted from the Electroencephalogram (EEG), and because of this, the discussion starts with EEG.

2.2. The Electroencephalogram (EEG)

The on-going electrical activity of the brain is called the electroencephalogram (EEG). The EEG can be recorded through electrodes that are placed on the scalp. The raw EEG can distinguish between changes in state such as sleeping vs. waking, but it does not distinguish between more fine-grained changes in mental activity, for example when there is an interaction between a participant and an experimental stimulus.

2.3. Event Related Potentials (ERPs)

ERPs are segments of the EEG that are time-locked to a specific event of interest, such as the presentation of an experimental stimulus on a computer screen. To extract ERPs from EEG requires signal processing techniques, a point discussed in detail below. First, however, the electrogenesis of ERPs is discussed briefly.

2.3.1. ERPs: The underlying sources

The underlying source of ERPs is the activity of individual neurons. A neuron is the basic element of the nervous system and plays a critical role in information transmission and processing. Neurons transmit signals by means of complex changes in the membranes of axons. This results in exchanges of positive and negative ions along and through the membrane of the axons. These electrical events produce electrical currents, which can be detected from a distance.

Two factors determine whether or not the electrical fields generated by a population of neurons can be detected at the scalp (Nunez, 1981; Wood, 1987). First, the majority of neurons in the population must be active at the same time. The simultaneous polarisation of the membranes of a large number of neurons summates over space and produces an electrical field that can be recorded from outside the head. Second, the neurons must reside in an open field configuration (Coles and Rugg, 1995). This configuration is characterised by neurons whose dendritic trees are all oriented on one side of the structure and whose axons all depart from the other side. In this case, each neuron will generate an electrical field that has the same direction, and the fields will summate.

The fact that ERPs are only sensitive to a population of neurons with an open field configuration and that these neurons must be synchronously active indicates the need to interpret null results with caution. Differences between neural activities across a pair of conditions may have occurred, but it could either be the case that the neural activity differentiating the experimental conditions was generated in brain tissue configured such that the activity could not be detected at the scalp, or that the activity was too weak to be detected reliably at a distance. The central point is that ERPs are only sensitive to an unknown proportion of the total brain activity evoked by a given stimulus, since activity in some cellular configurations does not propagate to the scalp (Nunez, 1981; Nunez 1990; Scherg, 1990; Picton, Lins and Scherg, 1995).

2.3.2. ERP Recording

Stimulus locked voltage changes are small relative to the ongoing EEG. This means that the quality of ERP data depends upon the equipment, procedures and parameters that are employed during recording. The type of electrode used and the quality of the interface between skin and electrode are important in assuring high quality data. The parameters used in recording, such as the reference site and the sampling rate, influence the shape of scalp distributions, the polarity and the temporal resolution of the ERP data.

2.3.2.1. Recording Equipment and Procedures

Scalp recorded electrical activity is acquired via electrodes that are now commonly fitted in an elastic cap. The electrodes are then connected to a differential amplifier. Electrodes form the connection between electrical activity at the scalp and the input circuit of the amplifier. Non-polarizable electrodes are commonly used, since these can record slow changes in potential and at the same time avoid the formation of an 'electrical double layer' (Picton et al., 1995), resulting from the exchange of ions between the electrode and the electrolyte. This ion layer acts as a capacitor and makes the electrode interface a filter for low-frequency signals, which is undesirable.

The quality of connection between electrode and scalp is important to ensure that the transmission of signal from the scalp to the amplifier is not distorted. The electrical impedance at this interface should be markedly less than the input impedance of the amplifier (Picton et al., 1995). It is common practise to keep the impedance at each electrode location below 5 kΩ.

There are a few ways in which electrode locations are described. This nomenclature includes the guidelines from the American Electroencephalographic Society (Sharbrough, Chatrian, Lesser, Luders, Nuwer and Picton, 1991) and the International ten-twenty electrode system (Jasper, 1958). The latter is used in this thesis, where each electrode site is specified with respect to brain areas (frontal (F), temporal (T), parietal (P) and occipital (O)). The location of the electrode in the lateral plane is also specified (odd numbers for left hemisphere sites, even numbers for right hemisphere sites and the subscript $_z$ for midline). Thus, F4 is a right frontal site, O1 is a left occipital site, while P_z is a midline electrode location over the parietal lobe (see Figure

3.1. in Chapter 3 for an illustration of the locations used in the experiments in this thesis).

ERPs always reflect the difference in electrical potential between two points: one coming from the 'exploring' electrode (Coles and Rugg, 1995) and the other from a reference electrode. A 'common reference' (Binnie, 1987) recording procedure is often employed. This means that all recordings are made by connecting all electrodes to the same reference point. This reference could be a single electrode located at a relatively inactive part of the head such as the nose tip, or a pair or electrodes linked together, such as at the mastoids behind the two ears. The use of a linked mastoids reference, however, leads to a problem in that the amount of activity contributed by each mastoid might vary. One method to overcome this problem is to employ a midline electrode as reference point during recording, and monitor whether there are asymmetric electrical activities at the two mastoids. The recorded signals can then be 're-referenced' computationally to the linked mastoid reference (Picton et al., 1995). This is the procedure employed in this thesis.

The electrical activity recorded from the scalp is very small in comparison to other electromagnetic noise from the environment that is picked up by the electrode. It is thus essential that the in-phase electrical noise common to all electrodes be cancelled out by using a differential amplifier. The signals are also usually filtered to enable the recording system to pick up only signals reflecting the activity of interest. Typical recording parameters are within the range .01 – 100 Hz.

After amplification, the analogue signals are converted into digital form to facilitate data analysis (Picton et al., 1995). The rate of the analogue/digital conversion, usually in 'samples per second' form, is also referred to as the 'sampling rate'. This rate determines the temporal resolution of the ERPs. The resulting ERP waveform is a sequence of data points sampled at discrete intervals, each of which represents the difference in potential between the electrode of interest and the reference electrode.

2.3.3. ERP Signal Extraction

The electrical activity recorded from the scalp contains signal plus noise. The signal is the neural activity evoked by the particular stimulus in a given task, while the noise is unrelated to the stimulus. The latter may come from other activity that occurred during that time such as eye blinks and muscle movements. In order to reveal the patterns of activity which are related directly to events of interest, it is crucial to extract the signal of interest (the ERP) from the ongoing EEG.

2.3.3.1. Averaging

The task-related and the task-unrelated aspects of the EEG can be separated by averaging (Rugg, 1992). The application of this procedure rests on the assumption that the ERPs elicited by the same type of experimental events are constant across many repetitions of the event, whereas the noise in the signal is random. So, averaging multiple epochs of EEG time-locked to the same class of experimental events will average out the background noise, and what is left will be a representation of the average response of the brain to the external stimulus. With enough trials, the ERP emerges and the contribution of the background EEG subsides. The greater the number of trials contributing to the average, the higher the signal to noise ratio.

Although the averaging procedure is the most widely used procedure to extract signal from background noise, it is possible for an averaged ERP waveform to bear little relation to the ERPs observed in individual trials, as the latency or amplitude of the ERP can vary from trial to trial, which then can 'smear' the averaged ERPs (Picton et al., 1995). For example, the amplitude of ERPs may differ between two conditions and this might be interpreted as showing the activity of the same neural generators that differ in degree. This could come about, however, because of more jitter (smear) in one condition than the other (for a relevant example in memory research, see Spencer, Abad and Donchin, 2000). It is also possible, however, that the two conditions differed only in the proportion of trials in which the ERP is evident. This is particularly relevant in forced-choice tasks where some responses may be 'guesses' (for discussion, see Wilding and Rugg, 1996, as well as points raised in this thesis).

2.3.4. Artefacts

Artefacts are neural activities that arise from both the normal physiology of the participant and the experimental environment. They can take the form of any movement of the eyeballs and eyelids or the muscular activity of the face and neck. A common source of EEG contamination is eye blinks and eye movements, both of which cause changes in potential over anterior scalp locations (Lins, Picton, Berg and Scherg, 1993; Croft and Barry, 1998). These activities can be monitored by concurrent recording of the electro-oculogram (EOG).

In an attempt to minimise blink-related artefacts, experimenters can give instructions to participants to maintain gaze at a fixation point and to avoid blinking. Experiments can also be designed so that the participants are asked to blink only when a 'blink signal' is shown on the monitor. This experimental control, however, imposes a secondary task for participants, which may in principle interfere with the task of interest (Rugg, 1992).

Another way to counter such blink artefacts is applied at the analysis stage. EEG data can be visually monitored and trials with artefact (such as trials corresponding to large eye movements) discarded. The problem with this rejection procedure is the possibility that data are inappropriately rejected on the basis of prefrontal EEG picked up by EOG electrodes. A better elimination procedure is to algorithmically correct the contribution of blink artefact to all other recording channels (Semlitsch, Anderer, Schuster and Presslich, 1986). This involves detection of the artefact for each individual participant, calculation of the influence of blinks at each scalp location, and correction for this influence. For a related solution, see Henson, Rylands, Ross, Vuilleumeir and Rugg (2004).

Artefacts can also be caused by physical interference and muscle movements. These artefacts are usually reflected in baseline drifts and saturation. A baseline drift is a linear change in electrical potential, which persists throughout the recording epoch. It may occur because of high standing electrode potentials, or the rupture of the skin-electrode interface. Saturation occurs when the voltage of the signal exceeds the band pass of the amplifiers. It is important that these trials are rejected prior to analysis, and this can be accomplished by applying pre-set rejection criteria, and/or by visual inspection.

2.3.5. Descriptions of ERPs

ERPs are described according to some concept of waveform structure (Picton, Bentin, Berg, Donchin, Hillyard, Johnson, Johnson, Miller, Ritter, Ruchkin, Rugg and Taylor, 2000). Waveform deflections consist of a series of peaks and troughs, which have been traditionally termed as components. ERP components can be classified as 'exogeneous' or 'endogeneous'. The former are mainly determined by the form of a stimulus, while the latter reflect the functional effects of the stimulus in a given context (Sutton, Baren, Zubin and John, 1965). The exogeneous/endogeneous distinction denotes a continuum, with changes in potential which are entirely stimulus bound at one end and those that are particularly sensitive to cognitive variables and task demands at the other end (Donchin, Ritter and McCallum, 1978). The perspective on how to define an ERP component depends on whether one is adopting a physiological approach or a functional approach. Physiological approaches stress anatomical localisation and can for example define ERP components as the activity of a single neural generator within the brain (Naatanen, 1982; Naatanen and Picton, 1987). The way the generators relate to cognitive processes is not the primary concern for those who take this approach. On the other hand, functional approaches put greater emphasis on the functional significance of ERP components, which are defined in terms of the information processing operations with which they are associated (Donchin et al.,1978). By this approach, ERP data are quantified by looking at whether an experimental manipulation gives rise to a reliable waveform with a particular scalp distribution and temporal characteristics. In these circumstances it is often sufficient to quantify ERPs by measuring the mean amplitude of the selected latency regions of the waveforms. Cognitive psychologists commonly adopt the functional approach when interpreting ERP data, as greater emphasis is placed on the functional characteristics of an ERP component than the location of its anatomical sources. This is the approach adopted in analysing the ERP data in this thesis.

In order to make functional inferences from ERP data, it is necessary to assume that there is a one to one mapping between cognitive processes and their supporting neural substrate. This invariance assumption between functional and physical states allows one to make certain inferences from differences between the ERPs elicited in different experimental conditions. Inferential statistics (e.g. analysis of variance) are used to ascertain whether the differences are reliable or not. When there exist statistically reliable differences between the two ERPs, this indicates that some form of different neural processing is engaged in the two cases.

Differences between ERPs across experimental conditions can be quantitative and/or qualitative. A quantitative difference occurs when differences between the amplitudes of a pair of ERPs are not accompanied by differences between the distributions of the two ERPs over the scalp. This is assumed to reflect the fact that a common set of neural processes is engaged in the two experimental conditions. The functional interpretation would therefore be that the same cognitive processes are engaged in those conditions but to different degrees or intensities.

A qualitative difference occurs when the differences between the ERPs across experimental conditions, or across different time windows within a single condition, are associated with different scalp distributions. Qualitative differences most likely arise either because neural processes in different brain areas contribute to the ERPs or because identical brain regions contribute to the ERPs with different levels of relative activation (Urbach and Kutas, 2002).

2.3.6. ERPs: advantages and limitations

ERPs measure neural activity directly and with high temporal resolution. This is important because it takes less than a second for the human nervous system to analyse and discriminate between different classes of stimuli. The millisecond resolution of ERPs allows a real time measure of when processing takes place in the brain.

The strengths of ERPs also lie in their being a cheap and effective means for assessing the processing of sensory information in the human central nervous system. The operating costs for ERPs are low compared to positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Unlike PET, ERPs are a non-invasive procedure and can be applied in healthy individuals, patients and children with negligible risks.

One important limitation of ERPs is the fact that they provide little information about the locations of the neural generators that give rise to a particular pattern of activity at the scalp (Wood, 1987). This problem limits the functional neuroanatomical conclusions that can be drawn on the basis of ERP data alone. Greater spatial resolution can be achieved through the use of fMRI and PET. These haemodynamic techniques have superior spatial resolution, as they monitor local changes in blood flow. These techniques, however, have poor temporal resolution. Thus, in principle, integrating ERP data with haemodynamic data can help to specify where neural activity originates inside the brain along with the time course of that activity. This is important if the goal is to provide a dynamic characterisation of the way in which the brain supports cognitive processing.

Chapter 3

3.1. Introduction

This chapter details the methods common to all the experiments reported in this thesis. Experimental procedures specific to each experiment are described in the method sections of the chapters reporting the relevant experiments. The design of all experiments is based in whole or part on the exclusion paradigm employed in the process dissociation procedure (Jacoby, 1991). All experiments employ the same selection criteria for participants, and use similar experimental materials. The parameters for ERP recording were similar for Experiments Two, Three and Four, while for Experiment One some parameters were different. Data processing and data analysis were similar across all experiments.

3.2. Participants

Participants for all experiments were recruited from the undergraduate and postgraduate student populations of Cardiff University. All participants were native English speakers, right-handed (except in Experiments One and Five where 7 and 6 participants were left-handed, respectively), aged between 18 and 35 (overall average age 21), and had normal or corrected to normal vision. All were paid for their participation and gave informed consent prior to completing the experiments.

3.3. Experimental Materials and List Construction

Stimuli used in each experiment consisted of words, ranging from 4 to 9 letters in length. They were all low- frequency words (range 1-7 per million), and were drawn from the Kucera and Francis (1967) corpus for each experiment. In each experiment all stimuli were upper case white letters, presented visually on a black background in central vision on a computer monitor located 1.2 m directly in front of the participant. Stimuli subtended maximum visual angles of 2.2° (horizontal) and 1.4° (vertical).

Details concerning the construction of study and test lists are provided in each of the experimental chapters. In each case, study and test list combinations were constructed such that across participants all words were encountered as old as well as new items, and all old items occurred equally often in each encoding condition. The experiments contained variable numbers of study-test cycles, and within each cycle the order of presentation of items for each participant in each experiment was determined randomly by the stimulus presentation software. Within the cycles each participant encountered, no words appeared in more than one cycle.

3.4. Experimental Procedures

In Experiments One-Four participants were fitted with an ERP recording cap prior to the test phases of the experiment and were then seated in front of a computer monitor in a sound-attenuated booth. In Experiment Five behavioural data only was acquired. At the outset, participants were informed that the experiments would consist of study and test cycles, although the number of cycles varied between experiments.

Each study trial was preceded by one of two cues, either an asterisk or a plus sign. The asterisk indicated that the participant was required to complete a specified encoding task, while the plus sign indicated that a different encoding task was required. The cue remained on the screen for 1000 ms and was then replaced with a word. After a short gap, a message requiring the participants to respond verbally (depending on the cue that preceded the word) appeared. Following the verbal response, participants pressed a key to initiate the next trial. Equal numbers of pluses and asterisks were presented in each experiment, but the order in which pluses and asterisks occurred was random.

In each of the test phases, participants were presented with words that the participants had seen at study, along with words that were new to the experiment. Each test trial started with the presentation of a fixation point (an asterisk), which remained on the screen for 500 ms and was removed 100 ms prior to stimulus presentation. The stimulus was presented for 300 ms. The experimenter informed the participants which encoding tasks were designated as providing targets and non-targets just before each test phase began. This was done to ensure that participants encoded target and non-target words equally and they would be unable to anticipate which task would be designated as the target task. In addition, for each experiment participants were not informed that there would be an equal number of test phases for each target designation. Participants were to respond by pressing the outermost left/right button on the response pad with their left/right index finger. The task designated as the first target retrieval, and the hands used for each response, were counterbalanced across participants such that there was no correlation between hand and response type. Participants were instructed to respond as quickly and as accurately as possible. They were also instructed to remain relaxed and to maintain fixation on the point indicated by the asterisk. There were some additional features of the design of Experiment Five, and these are described in Chapter 8.

3.5. ERP recording

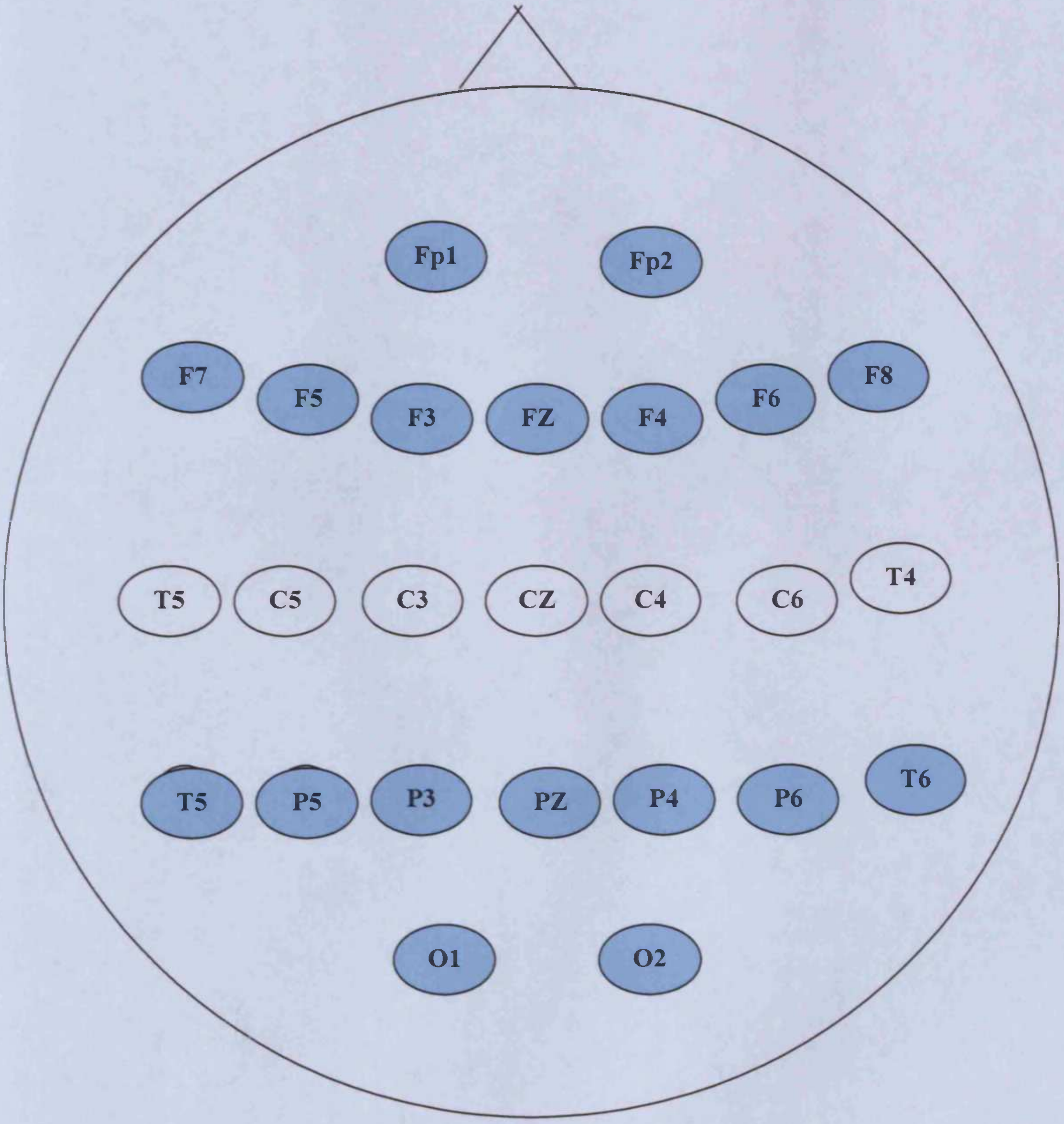
All electrophysiological data were recorded from 25 silver/silver chloride electrodes embedded in an elastic cap. EEG recording locations were based on the international 10-20 system (Jasper, 1958), and consisted of three midline sites (Fz, Cz, Pz) as well as left (FP1, F7, F5, F3, T3, C5, C3, T5, P5, P3, O1) and right (FP2, F8, F6, F4, T4, C6, C4, T6, P6, P4, O2) hemisphere sites (see Figure 3.1). Additional electrodes were placed on the right and left mastoid processes. In Experiments One and Two, all channels were referenced on-line to Cz, while in Experiments Three and Four, recordings were made with Fz as the reference electrode. All channels were re-referenced off-line to linked mastoids and the data from the online reference was recovered (see methods sections in experimental chapters for further details).

In Experiments One and Two, EOG (electro-oculogram) was recorded from electrodes situated on the outer canthus and above the supra-orbital ridge of the left eye, while in Experiments Three and Four, vertical EOG was recorded bipolarly from electrodes placed above and below the centre of the right eye, and horizontal EOG was recorded bipolarly from electrodes placed on the outer canthus of each eye.

Data were sampled at a rate of 5 ms per point (Experiment One) and 6 ms per point (Experiments Two, Three and Four) and digitised with 12-bit resolution. The duration of the recording epoch in Experiment One was 1280 ms with a 100 ms pre-stimulus baseline (the mean voltage level of the waveform in the period preceding the presentation of stimulus) while in Experiments Two, Three and Four it was 1536 ms with a 102 ms pre-stimulus baseline period.

The administration of electrodes to each participant started with light cleaning of skin under the location of each electrode site. This procedure helps to minimise the contribution of artefacts to the recorded EEG by reducing the electrical impedance levels at the scalp. For each participant, the inter-electrode impedance level at all sites was below 5 Ω at the outset of each experimental session.

FIGURE 3.1: Selected sites from the international 10/20 system (Jasper, 1958) employed in Experiments One-Four. The coloured sites denote sites that are included in the majority of the ERP analyses in this thesis.



3.6. Data Processing

EEG was recorded on-line and stored on the hard disk of an IBM compatible PC. Processing and analysis were completed off-line after the end of each experimental session. EOG was averaged separately for each response category to assess the influence of electro-ocular activity on the EEG data. Experiments One and Two employed a blink rejection procedure in which trials on which EOG fluctuations exceeded 100 μV were rejected before averaging. Trials on which baseline drift (difference between first and last data point) exceeded 80μV at any site were also rejected prior to averaging. Experiments Three and Four employed a blink correction procedure (Semlitsch et al., 1986). In order to achieve adequate signal:noise, only participants contributing a minimum of 16 artefact-free ERP trials to each of the critical response categories (defined within each experiment) were included in subsequent statistical analyses of both ERP and behavioural data.

3.7. Analysis Procedure

3.7.1. Behavioural Data

Analyses of task performance for all included participants were performed using t-tests and repeated measures ANOVAs. The analyses of variance included the Geisser-Greenhouse correction for inhomogeneity of covariance (Greenhouse and Geisser, 1959). Where appropriate, reliable main effects and interactions were followed up with *post hoc* analysis using Bonferroni corrected t-tests. Further details are provided in the relevant experimental chapters.

3.7.2. ERP Data

Averaged ERP data associated with the critical response categories was analysed using repeated measures ANOVAs. As for the analyses of variance for behavioural data, the ANOVA for the electrophysiological data also included the Geisser-Greenhouse correction for inhomogeneity of covariance (Greenhouse and Geisser, 1959). The ANOVA model assumes that all analysed data have equal covariance between levels of factors. ERP data can easily violate this assumption due to the fact that multiple recording locations are employed and inter-electrode distances vary. The correction procedure was adopted to estimate the extent to which the assumption was violated, and to reduce the degrees of freedom in the ANOVA where appropriate. Where necessary, F ratios are reported with the corrected degrees of freedom.

3.7.2.1. ERP Analyses of Amplitude Differences

The principal analyses of ERP data involved comparing mean amplitude measurements over selected time windows. Averaged ERPs were formed for response categories that were of interest, and were contrasted to determine whether the ERPs associated with these response categories differed in amplitude. All mean amplitudes were computed relative to the amplitude of the pre-stimulus baseline.

3.7.2.1.1 Analyses of ERPs evoked by new test words

Initial analyses were performed on a montage of 16 electrode sites split equally over the two hemispheres: FP1/FP2, F7/F8, F5/F6, F3/F4, T5/T6, P5/P6, P3/P4 and O1/O2 (see Figure 3.1 on page 67 for details) and including an equal number of sites at anterior and posterior scalp electrode locations. These sites will be referred to in the subsequent chapters as the standard montage. Factors entered into ANOVA were TK: target designation (defined within each experiment), HM: hemisphere (two levels), AP: anterior/posterior dimension (two levels) and ST: site (four levels). The main interest involves the factor TK; only effects involving this factor are reported. When there were significant interactions involving TK, subsidiary ANOVAs were conducted. The time windows selected for the analyses were defined within each experiment.

3.7.2.1.2 Analyses of ERP old/new effects

Two sets of analyses were carried out for each experiment. One set of analyses employed the standard montage, and the old/new effects were analysed over four time windows (300-500, 500-800, 800-1100 and 1100-1400 ms; except for Experiment One where only the first three time windows were used). These global analyses employed the same factors as above, with the addition of the factor of CC: word condition (target, new, non-target).

For each set of analyses, follow-up analyses were completed on the basis of the outcomes of the initial analysis. Whenever significant effects involving TK and CC were obtained, follow-up analysis comprised all possible paired contrasts of the critical categories, separated according to target designation. In the absence of significant effects involving TK, follow-up analysis was conducted by collapsing data across the factor of TK and comprised all possible paired contrasts of the categories of interest (see results sections in experimental chapters for further details). Finally, any reliable four-way interaction involving the factor of CC was followed up by separate analyses at anterior and posterior sites.

A second set of analyses was guided a priori by the ERP literature. The ERP old/new effect that has been consistently reported in the ERP literature and is of particular interest in this thesis is the left-parietal old/new effect. The literature related to this effect is reviewed in Chapter 1. As one of the core aspects of the work presented in this thesis builds upon the link between this effect and recollection, it was desirable to maximise sensitivity to the presence or absence of this effect under various experimental manipulations. This was accomplished by restricting some critical analyses to one parietal scalp location (P5). The details of these and other guided analyses are provided in the relevant chapters.

3.7.2.2. ERP analyses of scalp distributions

Another major part of the analyses reported in this thesis involves comparisons of scalp distributions. They were performed to examine the topographic distributions of ERP effects associated with different response categories and different time regions. Prior to the analyses, ERP data were rescaled using the max-min method suggested by McCarthy and Wood (1985). This is done by calculating, for each relevant category, the size of the effect at each electrode site relative to the maximum and minimum size of the effect at every other site. This method removes differences in amplitude of the distribution while maintaining differences in the shape of the effect, and thus avoids confounding differences between the magnitudes of ERP effects with differences between the shapes of the effects.

3.8. Presentation of statistical outcomes

In all experiments, the results of the preliminary analysis are described in the main text, while the results of the subsequent ANOVAs are shown in table form. The tables for behavioural data are shown in the main body of text, while all tables and ERP figures are presented at the ends of the chapters in which the analyses of the data are reported. While the tables show all main effects and interactions involving TK and/or CC, interpretation of the effects described in the main text is restricted for the most part to the highest order interactions only.

Chapter 4

4.1. Introduction

As discussed in Chapter 1, the prefrontal cortex is involved in strategic retrieval processing in episodic memory (Shimamura 1994; Wagner, Desmond, Glover and Gabrieli, 1998; Fletcher and Henson, 2001). In one recent ERP study by Ranganath and Paller (1999, see also Ranganath and Paller, 2000 discussed in detail in Chapter 1), for ERPs evoked by new test items, a greater left frontal positivity was observed in the retrieval task which demanded retrieval of perceptual detail, in contrast to the task where retrieval of perceptual detail was emphasised less. The difference between the ERPs evoked by the specific and general retrieval tasks was interpreted to reflect changes in the allocation of attentional resources, as well as working memory demands associated with the task in which retrieval of greater details was required.

Rugg, Allan and Birch (2000) linked modulations over left anterior scalp sites to differences in retrieval effort, on the basis of the fact that the ERPs evoked by new test items in the more difficult of two recognition memory tasks were more positive-going over scalp regions similar to those reported by Ranganath and Paller (1999). Participants in the study engaged in deep (generating sentences that incorporated the to-be-remembered words) and shallow encoding tasks (performing an alphabetic judgement task). Each of these encoding tasks was followed by a recognition memory test whereby participants had to judge whether each item had been presented in the immediate preceding phase or whether it was new to the experiment. The differences between the ERPs evoked by new test words resembled those reported by Ranganath and Paller (1999). Over the left anterior scalp, they were more positive-going in the retrieval task that contained only shallowly encoded old words than in the task that contained only deeply encoded old words. Rugg and colleagues (2000) argued that because the shallowly encoded old words were more difficult to remember than the deeply encoded old words the differences between the ERPs evoked by new words indexed retrieval effort. The interpretation offered by Rugg et al. (2000) can also be applied to the findings of Ranganath and Paller (1999) in the sense that the specific retrieval task is likely to have imposed greater demands on retrieval effort than the general task.

Experiment One was conducted with the aim of understanding more about the functional significance of the left-anterior positivity observed in the studies of Ranganath and Paller (1999; 2000) and Rugg et al. (2000). Common to both is the fact that the relatively greater positivity was associated with tasks where it is reasonable to assume that there was a greater emphasis on perceptual processing. As a result, it is an open question whether this frontal positivity reflects effort per se, or is restricted only to perceptual features. At issue is whether neural signatures of processes sensitive to retrieval demands are evident using different materials and task requirements to those employed in the studies described above. A general effort-related account of this frontal positivity would be supported if a similar effect were to be obtained when two tasks differed in retrieval effort while neither demanded processing of perceptual features.

In Experiment One, materials were all visually presented words, an equal number of which were encoded either semantically or phonologically. In separate test blocks, participants were required to respond to words that had been encoded in only one of the two encoding tasks. The encoding tasks used match those used in the studies of Rugg, Allan and Birch (2000). In a slight departure from other exclusion studies (for example, see Wilding and Rugg, 1997; Herron and Rugg, 2003b), the design in Experiment One required responses to be made only to target words. In different test phases, targets were designated as words that had required either the generation of semantic or phonological associates at study. No response was to be made to new words or to non-target words. This component of the design permits a contrast between new test words, separated according to target designation (semantic or phonological), which is not confounded with response-related factors. This approach to minimising response confounds, is an alternative to the correlation approach employed by Rugg et al. (2000). Thus, any differences between the ERPs evoked by the two classes of new words in the present study are unlikely to be related directly to differences between the reaction times across the critical test categories.

4.2. Method

4.2.1. Participants

Twenty-three participants (18 female) took part in the experiment. Each was paid at the rate of £5.00 per hour. The average age of the participants was 20 years (range 18 to 24). The data from two participants (female) were discarded because they did not contribute sufficient trials to the critical conditions after rejecting trials with artefacts (see Chapter 3 for rejection criteria). For one, this was due to poor memory for the target condition, and for another it was due to excessive EOG artefacts. Of the remaining 21 participants, 14 were right handed.

4.2.2. Experimental items

These were words (see Chapter 3) that were arranged initially in three groups of 120 words. Words from two of the three groups were combined to form three study lists. Each study list was formed by rotating the words across the groups. Each study list was divided into 6 blocks of 40 words.

Test lists were formed by combining the three initial word groups. Test lists consisted of 240 words that were presented at study (old words) and 120 words that were presented at test for the first time (new words). Test lists were divided into 6 blocks of 60 words, each block consisting of 40 old and 20 new words. One filler word was placed at the beginning of each study and test list. Altogether there were 102 words in each study-test block (40 study items, 2 filler items and 60 test items).

4.2.3. Procedure

Following electrode placement and prior to the experiment the experimenter read aloud the instructions for the experiment and the participant was also given a written description. Participants were informed that there were six study-test blocks, and that each block started with a study phase, which was then followed by a test phase. All of the study phases were exactly the same and there were two different kinds of test phase in which target designation varied.

Each study trial was preceded by one of two cues, either an asterisk (*) or a plus sign (+). The asterisk indicated that the participant was required to generate a phonological associate in response to the subsequently presented word, while the plus sign indicated that a semantic associate was required. The participants were informed that there were no right or wrong answers. Piloting indicated that for some polysyllabic words, participants struggled to generate a phonological associate. Each participant was informed that if they experienced this difficulty, it was reasonable to generate a phonological associate on the basis of the last syllable in the word only.

The cues remained on the screen for 1000 ms and were then replaced by the study word, which remained on the screen for 300 ms. This was followed by a period in which the screen was blank for 1700 ms before the cue BLINK AND SPEAK NOW appeared on the screen. Participants were required to respond verbally with the type of associate designated by the pre-stimulus cue, and to restrict eye-blinks to the period in which this instruction was on the screen. Following the verbal response, participants pressed a key to initiate the next trial. A period of 1000 ms intervened between the key press and the onset of the next trial. The order in which pluses and asterisks occurred was random for each participant, with the restriction that 20 of each cue-type appeared in each study phase.

Each test trial started with the presentation of a fixation point (an asterisk), which remained on the screen for 500 ms and was removed 100 ms prior to stimulus presentation. The test stimulus was presented for 300 ms. In three of the six blocks, targets were defined as words for which phonological associates had been generated at study, while in the remaining three blocks, targets were defined as words for which semantic associates had been generated. Each participant was assigned to one of 21 different orders of the occurrence of semantic and phonological target designation conditions.

After participants made a response on each test trial, the instruction BLINK NOW appeared on the screen. This occurred 2500 ms after the offset of each test word. Participants were requested to blink only when this instruction was present. The BLINK NOW instruction remained on the screen for 2000 ms. A period of 500 ms intervened before the next trial started. Participants were asked to refrain from blinking other than when the BLINK NOW instruction was present. A short break was given at the end of each study-test block.

4.3. EEG recording

EEG was acquired continuously at 5 ms per point over a frequency band of .03 – 40 Hertz. All EEG electrodes were referred to Cz during acquisition. EOG was recorded bipolarly from electrodes placed above and to the side of the left eye in order to monitor for eye blinks and eye movements. ERPs were re-referenced off-line to linked mastoids. Data were epoched off-line (1280 ms epochs, including 100 ms pre-stimulus baseline).

4.4. Results

4.4.1. Behavioural data

Participants were asked to make responses only to target words. The term *correct responses* will be employed to refer to a response to target, as well as to the absence of a response to non-targets and to new test words.

Table 4.1 displays the mean proportions of correct responses to target, new and non-target words, separated according to which class of old words were designated as targets (hereafter *target designation*). The likelihood of making target responses to the three critical classes of test items was compared using t-tests. The analyses revealed that in both target designation tasks, the likelihood of making target responses to target words was greater than the likelihood of making target responses to new and non-target words ($t(20) > 17.19$, $p < .001$ in all cases; see Appendix C for details).

The probabilities of correct responses to target, new and non-target words were submitted to ANOVA employing the factors of TK (phonological, semantic) and CC (target, new, non-target). The analysis gave rise to main effects of CC ($F(1.3, 25.7) = 24.24$, $p < .01$) and TK ($F(1,20) = 36.75$, $p < .01$), as well as an interaction between these factors ($F(1.8, 35.2) = 67.00$, $p < .01$). Bonferroni corrected t-tests (adjusted alpha level = 0.017) showed that the probability of a correct response to targets was higher in the semantic than in the phonological task ($t(20) = 10.14$, $p < .001$), whereas the probability of a correct response to a non-target was higher in the phonological than in the semantic target designation task ($t(20) = 2.74$, $p = .012$). The probabilities of correct responses to new words did not differ significantly across the two target designations.

Target designation task	Word condition		
	Target	New	Non-target
Phonological	0.68 (.14)	0.94 (.07)	0.92 (.05)
Semantic	0.89 (.08)	0.97 (.03)	0.87 (.07)

Table 4.1. Mean proportions of correct responses to target, new and non-target words in the phonological and semantic target designation tasks. (S.D. in brackets).

Table 4.2 shows the reaction times for correct target responses in the phonological and semantic target designation tasks. The RTs for correct target responses were reliably faster in the semantic target designation task than in the phonological target designation task (t(20) = 6.26, p < .001).

Target designation task	RTs
Phonological	1019 (162)
Semantic	822 (150)

Table 4.2. Mean reaction times (RTs: ms) and S.D. (in brackets) for correct target responses in the phonological and semantic target designation tasks.

4.4.2. ERP data analyses

4.4.2.1. Analysis of ERP old/new effects

The main purpose of Experiment One is to elucidate the functional significance of the differences between the ERPs evoked by new test words. The contrasts involving ERPs elicited by old test words do not speak to this issue, since any differences revealed by such a contrast might equally well indicate the engagement of task-specific retrieval processes, or the fact that different forms of information are being retrieved. Furthermore, the fact that in this experiment responses were required to targets only means that the old/new contrasts of principal interest – those between target and non-target old/new effects - confound target status with the presence/absence of a motor response. In light of this, this chapter focuses only on the ERPs evoked by new test words. The analyses of the ERP old/new effects for Experiment One are presented in Appendix A.

4.4.2.2. Analysis of ERPs evoked by new test words.

The grand average ERP waveforms (see Figure 4.1 at end of chapter) show the differences between the ERPs evoked by new test words and separated according to target designation. The figure shows that the ERPs evoked by new words are more positive-going when words encoded phonologically were designated as targets than when words encoded semantically were designated as targets. This relative positivity onsets at about 300 ms post-stimulus, is evident over both hemispheres, and is more pronounced at anterior than posterior electrode locations. From about 600 ms post-stimulus, the greater relative positivity evoked by new words in the phonological target designation task is evident primarily at right-anterior and central scalp electrodes.

In the absence of strong a priori hypotheses concerning the time course of differences between conditions, the ERP data were quantified by measuring the mean amplitude of consecutive 100 ms latency intervals ranging from 0-1100 ms. These time windows correspond to the latency regions used by Ranganath and Paller (1999) in their analysis of ERPs evoked by new items. The mean number of trials (range in brackets) contributing to the phonological target designation condition was 44 (24-56), while for the semantic target designation condition, the mean number of trials was 46 (23-57).

To assess differences between ERP amplitudes for the two classes of correct rejections, ANOVAs were conducted on the data from the standard montage and included the within-participant factors of TK (phonological, semantic), HM (left, right), AP (anterior, posterior) and ST (pre-superior, inferior, mid-lateral, superior). Only reliable effects that involve the factor of TK are reported. These outcomes are shown in Table 4.3 (end of chapter). These analyses were followed up by separate analyses at anterior and posterior electrode locations when interactions involving TK and the AP factor were obtained. No reliable effects involving TK were observed in the analyses over the 0-300 ms and 900-1100 ms time windows, which are thus not shown in Table 4.3.

300-600 ms

The analyses over the first three time windows revealed main effects of TK in each case, reflecting the fact that the ERPs evoked by new words when phonologically encoded words were designated as targets were more positive-going than the ERPs evoked when semantically encoded words were designated as targets. An interaction between TK and AP was significant in the 300-500 ms time windows and approached significance ($p = .10$) in the 500-600 ms time window. Follow-up analyses at anterior and posterior sites over these three epochs revealed a main effect of CC at anterior sites only (see foot of Table 4.3), each reflecting the fact that the greater positivity evoked by new words when phonologically encoded words were designated as targets was reliable only at anterior locations.

600-900 ms

The analysis over the 600-900 ms time window revealed a TK x HM x ST interaction in the 700-800 ms time window which approached significance in the two other time windows. The reason for these interactions is the more positive-going waveforms over the left hemisphere associated with new words in the semantic target designation task, whereas over the right hemisphere, particularly at inferior sites, the more positive-going ERPs are associated with new words in the phonological target designation task.

4.4.2.3. Analysis of scalp distributions

Analyses of the scalp distributions of the differences between the ERPs evoked by the two classes of correct rejections were conducted in order to determine whether the differences between the ERPs evoked by new words changed qualitatively over time. These analyses were computed on the mean difference scores that were obtained by subtracting the mean amplitude measures obtained for the correct rejections from the semantic target designation condition from those that were obtained for the phonological target designation condition. The analysis included the factors of epoch (300-600 and 600-900 ms) and site (25). No reliable interaction between epoch and electrode site was obtained, despite apparent changes in scalp distribution, as Figure 4.2 shows.

4.5. Discussion

4.5.1. Behavioural data

The levels of memory performance (accuracy and response time) were significantly different between the two target designation tasks. Target accuracy was higher for semantically encoded than for phonologically encoded words. The time taken to respond was also faster in the semantic than the phonological target designation task. To the extent that changes in memory performance across different retrieval tasks indicate changes in task difficulty (Rugg and Wilding, 2000), the behavioural findings support the view that greater retrieval effort was required in the phonological than in the semantic retrieval designation.

4.5.2. ERPs evoked by new words

The ERPs evoked by correct rejections varied according to target designation. The correctly rejected new words under the phonological target designation evoked ERPs which were more positive-going than those evoked under the semantic target designation. The differences were reliable from 300-900 ms post-stimulus. From 300-600 ms, these differences were evident primarily over anterior electrode sites and from 600-900 ms, the differences between the ERPs evoked by new test words were larger over the right than over the left hemisphere.

The differences between the ERPs evoked by the two classes of new test words are unlikely to be related to differences between reaction times across critical response categories, due to the fact that responses were required to targets only. On the basis of the behavioural performance and these considerations, therefore, it is plausible that the differences between the ERPs evoked by new test words index processes related to retrieval effort.

The putative indices of effort observed in the studies of Ranganath and Paller (1999; 2000) and Rugg et al. (2000) are, however, different from the modulations observed in the present study. The differences between the ERPs evoked by new words in the two target designation tasks in the present study are distributed over left and right anterior scalp sites from 300-600 ms, and from approximately 600 ms post-stimulus the differences between the ERPs evoked by new words are greater over right than left anterior sites. The diversity in the pattern of findings across studies can be considered in the context of Rugg and Wilding's (2000) discussion of the forms that the neural instantiation of retrieval effort might take (see Chapter 1). One possibility identified by Rugg and Wilding is that effort is associated with a dedicated and presumably task invariant neural circuit. The second is that effort will simply be reflected as changes in the levels of activity in the neural generators that are typically engaged in pursuit of retrieving specific information in accordance with task demands. The fact that the differences between the ERPs evoked by new words in the present study are not restricted to the left anterior sites does not seem to support the first possibility.

The differences between the ERPs evoked by new test words in the two target designation tasks can also, however, be attributed to processes related to the engagement of different retrieval orientations (see Introduction). According to this account, the requirement to retrieve different types of information (semantic vs. phonological) at test leads to the adoption of different retrieval orientations. Thus, rather than processes reflecting retrieval effort, the differences between the ERPs evoked by new test words indicate task-specific processes. According to this account, therefore, there should be a greater emphasis on semantic processing in the semantic target designation.

To the extent that the differences between the ERPs evoked by new test words reflect the differences between semantic and non-semantic analysis of test items, however, an immediate question would be why the N400 component is not clearly evident in the present experiment. The N400 component has been found to be larger in tasks that require semantic rather than non-semantic processing of stimuli (Rugg et al., 1988; Chwilla, Brown and Hagoort, 1995) and it was also evident in the experiment of Rugg et al. (2000). Rugg and colleagues (2000) proposed that the presence of the N400 component reflected the qualitative differences in the processing accorded to test items in their two encoding conditions. They argued that test items following the deep encoding task were processed with respect to their semantic features, and that the focus on these semantic attributes was absent or minimal for the test words following the shallow encoding task. In the present experiment, inspection of Figure 4.1 at midline sites shows there is only some evidence for a greater relative negativity in the semantic target designation condition, and Figures 4.1 and 4.2 in combination indicate that if there is indeed some modulation of the N400 then it is small compared to other neural activity that differentiates the two classes of new test words. One possible reason for this is that while Rugg and colleagues (2000) contrasted new items associated with orthographic and semantic processing, the contrast here is between new items associated with phonological and semantic processing. If it is the case that phonological processing of words is more likely to engender some semantic processing than is orthographic processing, then this would be likely to reduce any differences between the new test items in this experiment relative to those reported by Rugg et al. (2000). In addition, given the confound between orientation and effort in this experiment and in the study of Rugg et al. (2000), it may be misleading to focus on the possible implications of a modulation or overlapping modulations for which the functional significance is not well established.

4.6. Concluding remarks

The ERPs evoked by new test words varied according to target designation. New test words from the phonological target designation task evoked more positive-going ERPs compared to new test words from the semantic target designation task. These differences are unlikely to be a reflection of processes related to retrieval success because the effects were obtained from the contrasts made between new words from the two target designation tasks. The effects are likely to be electrophysiological correlates of processes that are engaged in the pursuit of memory retrieval.

Specifically, the differences can be interpreted to reflect correlates of effort-related processes or correlates of different retrieval orientations adopted by participants in order to retrieve phonologically and semantically encoded words. The fact that effort and orientation are confounded in this study does not permit a separation of these two possibilities. In Experiment Two, effort and orientation are manipulated systematically in order to achieve a better understanding of the processes indicated by differences between classes of correct rejections using the semantic and phonological encoding conditions.

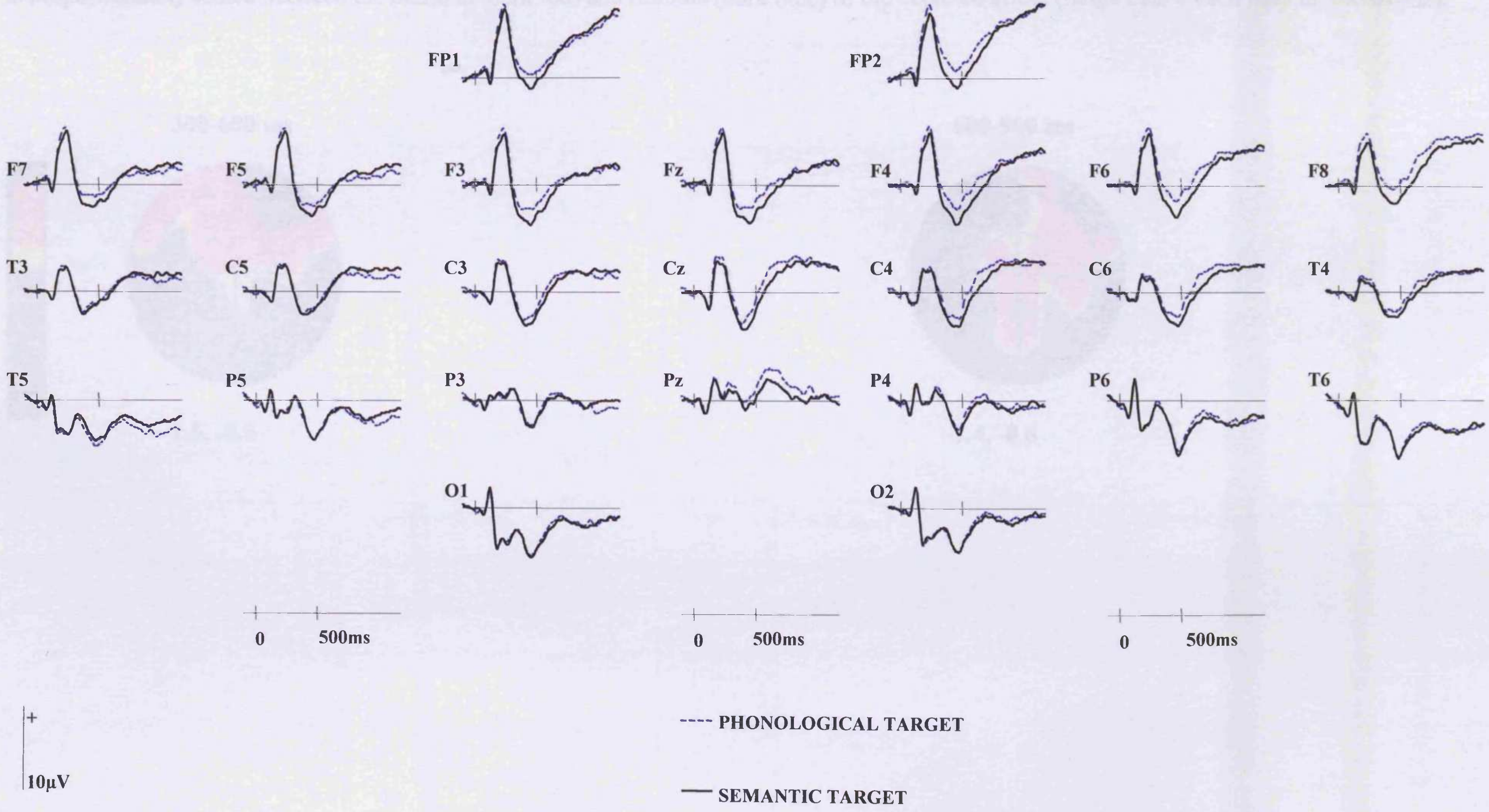


FIGURE 4.1: Grand average ERPs evoked by new words in the phonological and semantic target designation tasks. The data are shown for left and right hemisphere and midline locations at anterior (FP1/FP2, F7/F8, F5/F6, F3, F4, FZ), central (T3/T4, C5/C6, C3/C4, CZ) and posterior (T5/T6, P5/P6, P3/P4, PZ, O1/O2) electrode sites.

FIGURE 4.2: Topographic maps showing the scalp distributions of the differences between the activity elicited by new test words over the 300-600 and 600-900 ms time windows. The maps were computed from the difference scores obtained by subtracting the mean amplitudes from the ERPs elicited by new words in the semantic target designation condition from those in the phonological target designation condition. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

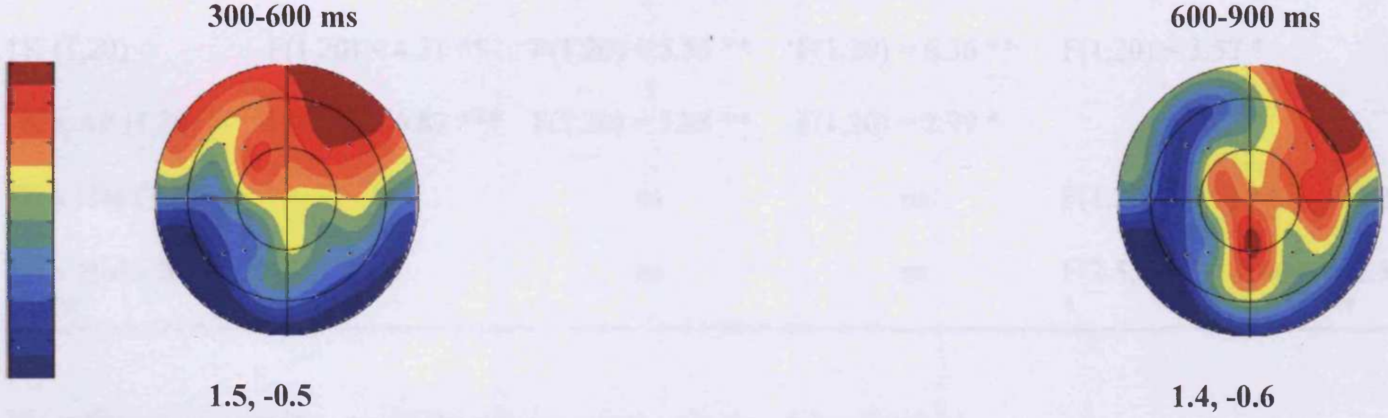


TABLE 4.3: Results of ANOVAs of the ERPs evoked by correctly rejected new words in the semantic and phonological tasks. Key: TK = target designation, AP = anterior/posterior dimension, HM = left/right hemisphere, ST = site, * = $p < .1$, ** = $p < .05$, *** = $p < .01$, n.s = non-significant ($p > .1$), full df in brackets (1st column).

	300-400 ms	**400-500 ms**	**500-600 ms**	**600-700 ms**	**700-800 ms**	**800-900 ms**
TK (1,20)	F(1,20) = 4.31 **	F(1,20) = 5.55 **	F(1,20) = 6.36 **	F(1,20) = 3.57 *	ns	ns
TK x AP (1,20)	F(1,20) = 6.87 ***	F(1,20) = 5.88 **	F(1,20) = 2.99 *	ns	ns	ns
TK x HM (1,20)	ns	ns	ns	F(1,20) = 5.91 **	F(1,20) = 7.73 **	F(1,20) = 4.89 **
TK x HM x ST (3,60)	ns	ns	ns	F(2.5,49.4) = 2.66 *	F(2.5,50.1) = 3.19 **	F(2.4, 47.4) = 2.66 *

The outcome of the follow-up ERP analysis over the anterior electrode sites.

	300-400 ms	**400-500 ms**	**500-600 ms**
TK (1,20)	F(1,20) = 8.23 ***	F(1,20) = 10.14 ***	F(1,20) = 6.55 ***

Chapter 5

5.1. Introduction

The findings in Experiment One showed that the ERPs evoked by new test words varied according to target designation. The greater positivity evoked by correct rejections in the phonological target designation task than in the semantic target designation task can be interpreted either to reflect processes related to the adoption of different retrieval orientations, or to reflect processes related to retrieval effort. The fact that both interpretations are viable arises due to the fact that retrieval orientation and effort were confounded in Experiment One.

A systematic manipulation of orientation and effort has been reported by Robb and Rugg (2002). In their study, ERPs were recorded during four separate item recognition memory tasks, all requiring responses to test words that were presented visually. In two of the four tasks, participants saw words in the study phase, while in the remainder participants were presented with pictures at study. The encoding operations associated with each type of study material were varied by manipulating the length of study lists as well as the study-test intervals.

This design permitted separate assessment of the electrophysiological correlates of retrieval orientation and effort. Robb and Rugg (2002) reported that distinct neural signatures of the two classes of process were evident. Correlates of orientation were prominent bilaterally at sites close to the vertex of the head and encompassed a broad time window, extending from approximately 300-1600 ms post-stimulus (see also

Herron and Rugg, 2003a), whereas indices of retrieval effort were smaller in amplitude and reliable in the 0-300 ms post-stimulus period at midline electrode locations only. These findings are consistent with the view (Rugg and Wilding, 2000) that orientation and effort are neurally and functionally dissociable (Robb and Rugg, 2002).

Experiment Two was designed in order to explore further the relationship between effort and orientation. At issue is whether neurally distinct signatures of these two classes of retrieval process can be obtained using different materials and task demands to those employed by Robb and Rugg (2002). As in Experiment One, retrieval orientation was manipulated by the task instructions for each retrieval phase. Retrieval effort was manipulated by separating participants into two groups on the basis of their level of behavioural memory performance (for details of how participants were split into groups, see Method section). The between-participants analysis that this procedure permits enables an analysis of the ways in which correlates of retrieval orientation vary according to retrieval effort.

5.2. Method

5.2.1. Participants

A total of 45 participants (age range 18-27, 26 female) took part in Experiment Two, and each was paid at a rate of £5/hour. The data from nine participants (six female) was discarded because, after rejecting trials with artefacts, they failed to contribute sufficient trials to one or more of the critical conditions (see Chapter 3 for rejection criteria). For one participant this was due to poor memory for targets, while for the others the reason was excessive electro-oculogram (EOG) artefact.

Participants were split into two groups on the basis of the difference between the probabilities of correct target judgements in the tasks in which either phonologically or semantically encoded words were defined as targets. The 18 participants who had the largest discrepancy (range = 0.10 to 0.58) were assigned to the high relative difficulty group, while the remainder were assigned to the low relative difficulty group (range = 0.02 to 0.09). All participants in the high relative difficulty group made more correct target judgements to words that were encoded semantically than to words encoded phonologically, whereas in the low relative difficulty group, four participants made more accurate judgements to words encoded phonologically (range = 0.02 to 0.08). There were six females (mean age 22, age range 18-27) in the high relative difficulty group, and 10 females (mean age 22, age range 19-27) in the low relative difficulty group.

5.2.2. Experimental items

Stimulus numbers and characteristics were as for Experiment One, with the exception that 12 instead of 6 study-test cycles were constructed. To accomplish this, each test list was divided into 12 blocks of 30 words, each block consisting of 20 old and 10 new words. This resulted in the formation of three task lists, each of which contained 12 study-test cycles.

5.2.3. Procedure

The stimulus presentation parameters and the procedure for Experiment Two were the same as those employed in Experiment One, with the following exceptions. In Experiment Two, each participant completed 12 study test cycles. The order of these study-test cycles was randomly determined, with the restriction that in six of the twelve blocks, targets were defined as words for which phonological associates had been generated at study, while in the remainder targets were defined as words for which semantic associates had been generated. The test presentation parameters in Experiment Two were also slightly different from those employed in Experiment One. In Experiment Two, participants were asked to respond before the instruction BLINK NOW appeared on the screen. This occurred either 2100 ms after the offset of each test word, or 500 ms after the participants responded, as long as that response occurred within 1900 ms of stimulus onset. Responses slower than 1900 ms were treated as errors. The BLINK NOW instruction remained on the screen for 2000 ms, then a period of 500 ms intervened before the next trial started

5.3. EEG Recording

The EEG acquisition procedures and rejection criteria were the same as those employed in Experiment One, except that the digitisation rate was 166 Hz (6 ms/per point). Data were epoched off-line (1536 ms epoch (256 points), including 102 ms pre-stimulus baseline).

5.4. Results

5.4.1. Behavioural Data

The behavioural data were subjected to the same initial analysis strategy that was employed in Experiment One. Table 5.1 displays the mean proportions of correct responses to each class of test words for all the 36 participants in the phonological and semantic target designation tasks. The probabilities of target responses to targets were reliably greater than the probabilities of target responses to new and non-target words in both target designation tasks (t(35) > 24.63, p < .001 in all cases; see Appendix D for details).

The likelihood of correct responses at retrieval was subjected to ANOVA with TK (phonological, semantic) and CC (target, new, non-target) as factors. The analysis revealed a main effect of CC (F(1.4, 50.0) = 78.83, p < .01) and TK (F(1, 35) = 17.68, p < .01), as well as an interaction between these factors (F (1.6, 57.2) = 27.16, p < .05). Bonferroni corrected t-tests (adjusted significance level = .017) indicated that the likelihood of correct responses differed only for target words, where words encoded semantically attracted a higher proportion of accurate target responses (t(35) = 6.01, p < .001).

Target designation task	**Word Condition**		
	Target	**New**	**Non-target**
Phonological	0.71 (.14)	0.99 (.02)	0.91 (.07)
Semantic	0.85 (.09)	0.99 (.02)	0.89 (.10)

Table 5.1: Mean proportions of correct responses for target, new and non-target words in the phonological and semantic target designation tasks for all participants. (S.D. in brackets).

Table 5.2 displays the mean proportions of correct responses to each class of test item for the high and low relative difficulty groups for the phonological and the semantic target designation tasks. Participants in both groups made more target responses to target words than to new and non-target words in both target designation tasks (t(17) > 15.24, p < .001 in all cases; see Appendix D for details).

The likelihood of correct responses to target, new and non-target words across groups was submitted to ANOVA, with factors of GP: group (low relative difficulty, high relative difficulty), TK (phonological, semantic) and CC (target, new, non-target). This analysis revealed main effects of CC (F(1.5, 52.0) = 94.25, p < .05) and TK (F(1,34) = 30.60, p < .05), as well as three interactions involving TK (GP x TK: (F(1,34) = 26.46, p < .05; CC x TK: (F(1.7, 57.3) = 38.91, p < .05; GP x CC x TK: (F(1.7, 57.3) = 16.20, p < .05).

This analysis was followed up by separate subsidiary ANOVAs for target, new and non-target words, with factors of GP and TK. Analyses involving new and non-target words did not reveal any reliable effects, but the analysis of the target words revealed main effects of GP (F(1,34) = 6.98, $p < .05$) and TK (F(1,34) = 77.77, $p < .05$), as well as an interaction between these factors (F(1,34) = 41.49, $p < .05$). Bonferroni corrected t-tests (adjusted significance level = .013) indicated that the likelihood of correct target judgements differed significantly according to target designation in the high relative difficulty group only, where words encoded semantically attracted a higher proportion of correct target responses (t(17) = 8.30, $p < .001$) than words encoded phonologically. The probability of a correct target judgement differed according to group only for words encoded phonologically, where participants in the low relative difficulty group made a higher proportion of correct target responses (t(17) = 4.39, $p < .001$).

Difficulty	**Target Designation**	**Word Condition**		
		Target	**New**	**Non-target**
High	**Phonological**	0.62 (.14)	0.98 (.02)	0.92 (.06)
	Semantic	0.86 (.08)	0.99 (.02)	0.92 (.06)
Low	**Phonological**	0.80 (.06)	0.99 (.01)	0.89 (.08)
	Semantic	0.83 (.10)	0.99 (.02)	0.86 (.13)

Table 5.2. Mean proportions of correct responses for target, new and non-target words in the phonological and semantic target designation tasks for the high and low relative difficulty groups. (S.D. in brackets).

Mean reaction times (RTs) for correct target responses in the two target designation tasks are shown in Table 5.3. The RTs for target judgements that were made to non-targets and to new words are not shown because the mean numbers of trials contributing to the RTs for each participant when separated according to difficulty were 6 and 1 respectively. The RTs for correct target responses were subjected to ANOVA employing the factors of GP and TK, and revealed a main effect of TK (F (1, 34) = 24.77, $p < .001$), reflecting the fact that reaction times to targets in the phonological target designation task were markedly slower than reaction times to targets in the semantic target designation task. The analysis also gave rise to a main effect of GP (F(1,34) = 8.12, $p < .01$), indicating that RTs were slower in the high relative difficulty group than in the low relative difficulty group. The interaction between these two factors was not significant.

Group	Task	RTs
All participants	Phonological	1190 (287)
	Semantic	1122 (266)
High-relative difficulty	Phonological	1297 (286)
	Semantic	1162 (270)
Low relative difficulty	Phonological	1153 (293)
	Semantic	1083 (263)

Table 5.3. Mean reaction times (ms) for correct target judgements in the phonological and semantic target designation tasks for all participants and for the high and low relative difficulty groups. (S.D. in brackets).

5.4.2. ERP Data Analyses

5.4.2.1. Analysis of ERP old/new effects

For the same reason stated in section 4.4.2.1 (Chapter 4), the analysis of ERP old/new effects is presented in Appendix B.

5.4.2.2. Analysis of ERPs evoked by new test words

As in the analyses for the behavioural data, the analysis of ERPs evoked by correctly rejected new words was completed initially on data for all 36 participants.

Within-participants analysis

Figure 5.1 displays the grand average ERP waveforms for new words in the phonological and semantic target designation tasks for all participants. The figure shows that the pattern of ERPs for correctly rejected new words resembles that seen in Figure 4.1 for Experiment One (see Chapter 4). The relative positivity evoked by correctly rejected new words in the phonological target designation task onsets at about 300 ms post-stimulus, is evident bilaterally, and is more pronounced at anterior than posterior scalp sites. In contrast with the effects observed in Experiment One, however, the differences between the ERPs evoked by new words in Experiment Two persist beyond the end of the recording epoch.

The ERPs evoked by the two classes of correct rejections were subjected to ANOVA over three post-stimulus time windows: 300-600 ms, 600-900 ms and 900-1400 ms. The choice of the first two time windows was guided by the outcomes of the analysis of ERPs evoked by correct rejections in Experiment One, while the 900-1400 ms time window was chosen to capture the differences between the ERPs that were observed later in the recording epoch. The mean numbers of trials (range in brackets) were 47 (30-58) and 46 (20-59) for the phonological and semantic target designation tasks respectively.

The analysis over the three time windows included the data from the same array of electrode sites as employed in Experiment One. The data were subjected to ANOVA, employing the same factors as in Experiment One. Only reliable effects involving the factor of TK are shown in Table 5.4. These analyses were followed up by separate analyses at anterior and posterior electrode locations when interactions involving TK and the AP dimension were obtained.

As shown in Table 5.4, the analysis over the 300-600 ms time windows revealed a main effect of TK. The main effect of TK approached significance ($p = .07$) in the 600-900 ms time window. This reflects the fact that overall, the ERPs evoked by new words were more positive-going when words encoded phonologically were designated as targets than when words encoded semantically were defined as targets. The differences between the ERPs evoked by the two classes of new words in Experiment Two onset at about the same time as those in Experiment One. Unlike in Experiment One, the effects in the present experiment did not show any hemisphere bias in the second half of the epoch (see Figure 5. 1) and no reliable effects involving TK and HM were observed in the analysis over the later time windows.

Between-participants analysis

Figures 5.2 and 5.3 show that the relative positivity evoked by new words when phonologically encoded words were designated as targets is carried almost entirely by the ERPs associated with the high relative difficulty group. For this group (Figure 5.2), this relative positivity onsets at about 300-400 ms post-stimulus, and is initially larger at left- than at right-frontal electrode locations. As the epoch progresses, the differences between these classes of ERPs become more bilateral, and more pronounced at anterior in comparison to posterior electrode locations.

The ERPs evoked by correct rejections, separated according to target designation and relative difficulty, were subjected to the same analysis strategy as outlined above, with the addition of the between-participant factor of GP (low relative difficulty, high relative difficulty). Where these analyses revealed reliable interactions involving GP they were followed up by separate analyses for the high and the low relative difficulty groups. Separate analyses at anterior and posterior electrode locations were carried out when the analyses revealed reliable effects involving AP and either TK or GP. The mean numbers of trials (range in brackets) for the high-relative difficulty group were 44 (20-59) and 47 (31-58) for words from the semantic and phonological target designations, respectively. The corresponding values for the low-relative difficulty group were 48 (25-59) and 47 (30-58).

The analysis over the 300-600 ms time window revealed a main effect of TK ($F(1,34) = 4.22$, $p < .05$), reflecting the fact that overall the ERPs evoked by correct rejections were relatively more positive when words encoded phonologically were defined as targets than when words encoded semantically were defined as targets. While no interactions involving GP reached significance at the .05 level, the interactions between GP, TK and the AP dimension, and between GP, TK, HM and ST, both approached significance ($p < .08$ and .10, respectively).

The analysis over the 600-900 ms time window revealed an interaction between GP and TK ($F(1,34) = 4.21$, $p < .05$). The interactions involving these two factors and the AP dimension approached significance ($p = .10$). Separate analyses for the high and the low relative difficulty group revealed a main effect of TK in the high relative difficulty group only ($F(1,17) = 6.67$, $p < .01$), reflecting the fact that while the ERPs evoked by the two classes of correct rejections did not differ in the low relative difficulty group, in the high relative difficulty group, the ERPs evoked by new words were more positive-going when words encoded phonologically were designated as targets than when words encoded semantically were designated as targets.

The analysis over the 900-1400 ms post-stimulus time windows revealed an interaction between GP and TK ($F(1,34) = 4.70$, $p < .05$), which was moderated by a three-way interaction between these two factors and the AP dimension ($F(1,34) = 4.86$, $p < .05$). Subsequent separate analyses at anterior and posterior electrode locations revealed a reliable interaction between GP and TK at anterior electrodes only ($F (1,34) = 6.27$, $p < .05$). Separate analyses for each group at anterior sites gave rise to a main effect of TK in the high relative difficulty group only ($F(1,17) = 5.85$, $p < .05$), showing that the ERPs evoked by correct rejections differed according to target designation in the high relative difficulty group only, with the difference being most prominent at anterior scalp sites.

5.4.2.3. Analysis of scalp distribution

The analyses of scalp distribution were restricted to the high relative difficulty group since the foregoing analyses gave no indication that the two classes of correct rejections for the low relative difficulty group were associated with reliably different patterns of neural activity. The analyses of scalp distributions were conducted, therefore, in order to determine whether the differences between the ERPs evoked by new words for the high relative difficulty group changed over time. The scalp distributions of the differences between the ERPs evoked by the two classes of correct rejections in the high relative difficulty group for the 300-600, 600-900 and 900-1400 ms epochs can be seen in Figure 5.4. The analysis strategy was the same as that employed in Experiment One (Chapter 4). While Figure 5.4 shows that the scalp distributions did undergo some morphological changes over time, the interaction between epoch and electrode site – the statistical signature of differences between scalp distributions – was non-significant.

5.5. Discussion

5.5.1. Behavioural Data

The analysis of the behavioural data showed that participants were able to discriminate target words from both non-target and new words at a level well above chance. For the high relative difficulty group, the accuracy of target judgments was superior for words to which semantic associates were generated than for words to which phonological associates were generated. The behavioural performance for the low relative difficulty group was statistically equivalent for both target designation tasks. While four participants made more correct target judgments to words associated with the phonological study manipulation, the disparities across target designations were small, and all four were included in the low relative difficulty group. This is important, because it means that the separation of the ERPs according to difficulty does not confound level of difficulty with the kind of information associated with the more difficult task. Participants were quicker to respond to words that were semantically encoded, and participants in the low relative difficulty group responded quicker than those in the high relative difficulty group.

It is important to note the fact that performance was at ceiling for new test items in both groups. This means that variations in difficulty (or the lack of variations in difficulty) cannot be inferred from these data alone. The inference about variations in difficulty is made on the basis of the relative levels of performance for judgments to targets and to non-targets. The assumption is that differences between the ERPs evoked by correct rejections may be an index of processes that are engaged to greater or lesser degrees in pursuit of retrieval because of the difficulty associated with recovering task-relevant information when a retrieval cue is encountered (Wilding and Sharpe, 2003). The fact that overt responses to new items were not required in this experiment means that there is no reaction time data that can speak to this issue. We return briefly to this point in Chapter 6.

5.5.2. ERPs evoked by new words

The ERPs elicited by new test words were separated according to retrieval requirements and task difficulty in order to contribute to current understanding of the relationship between retrieval orientation and effort. Retrieval orientation was manipulated by requiring participants to focus on retrieval of words with different study histories in separate test phases. Retrieval effort was manipulated by separating participants into two groups according to the similarity of their performance across the two target designation tasks.

The ERPs evoked by new words and separated according to target designation were not reliably different for the group where the relative difficulty of the two retrieval tasks was low. In contrast, for the group where relative difficulty was high, the ERPs evoked by new words were reliably different. The differences took the form of a relatively greater positivity for the ERPs evoked by new words when the requirements were to respond to words that had been subjected to phonological encoding at study than when the requirements were to respond to words that had been semantically encoded. The differences, which were more prominent at anterior than posterior electrode sites, onset at about 300 ms post-stimulus and remained until the end of the recording epoch. While Figure 5.4 suggests that the scalp distributions of the differences between the ERPs evoked by the two classes of new words change with time, the analyses of scalp distribution did not provide statistical support for this impression.

As in Experiment One, in Experiment Two responses were required to targets only. Thus, the differences between the ERPs evoked by the two classes of unstudied words in the high relative difficulty group cannot be related directly to differences between reaction times across critical categories. One possibility, however, is that the modulations can be explained by differences between the time taken to decide to withhold a response to the critical test words. This account is also unlikely, given the fact that reaction times to targets varied according to target designation and group, but these factors did not interact. To the extent that this pattern of RTs can be employed to infer response-related processing to new words, and when coupled with the fact that response accuracy for new words was statistically equivalent across groups and target designation tasks, a reasonable assumption would be that any ERP modulations related to withholding responses would be evident in the contrast for the high as well as for the low relative difficulty group.

The findings for the high relative difficulty group share some correspondences with those in previous studies (Ranganath and Paller, 1999; Ranganath and Paller, 2000; Rugg et al., 2000) and those observed in Experiment One (Chapter 4), notably the greater relative positivity in the more difficult of the two tasks. To the extent that retrieval effort was greater for participants in the high than in the low relative difficulty group, the present findings mandate an interpretation that incorporates retrieval effort. The fact that orientation and effort were not systematically manipulated in the studies of Ranganath and Paller (1999; 2000), Rugg et al. (2000), and Experiment One does not licence an unequivocal interpretation of the differences between the ERPs evoked by new test words in terms of either orientation or effort. In the present experiment, by contrast, orientation was manipulated by the requirement to respond in separate test phases to words that had been subjected to either phonological or semantic encoding at study. Retrieval effort was manipulated by separating participants into two groups on the basis of the similarity in their behavioural performance in the two target designation tasks. Therefore, the findings in the present experiment suggest that the differences between the ERPs evoked by the two classes of unstudied words evident in the high relative difficulty group need to be explained by an account that includes the concept of retrieval effort.

One possibility is that the differences evident in the high relative difficulty group reflect solely changes in effort, and that these differences are a general index of retrieval effort that is task invariant. This account is, however, challenged by the findings reported in Robb and Rugg (2002), who also manipulated orientation and effort independently in order to separate and examine electrophysiological indices of these two classes of process. They reported reliable electrophysiological correlates of both retrieval effort and orientation which did not overlap in time: while the correlates of effort were reliable in the analyses conducted over the 0-300 ms period, the correlates of retrieval orientation were reliable only from 300 ms onwards. In the present experiment, by contrast, no reliable differences between the ERPs evoked by correctly rejected new words were obtained in the 0-300 ms time period. This temporal separation between the putative indices of effort across these studies suggests that it is difficult to sustain an account of the data reported in the present experiment in terms of processes related to effort-related changes in activity in a dedicated neural circuit.

A second possibility discussed earlier (see Chapter 1) is that changes in effort are manifest as changes in the level of activity of the generators that are responsible for task-specific processing. That is, the amplitude of any indices of orientation will simply be changed by variations in effort. One explanation, therefore, for the absence of reliable differences in the low relative difficulty group is that it is a consequence of less activity in the generators that are responsible for the differences that are evident for the high relative difficulty group. Thus, the differences between the ERPs evoked by the two classes of unstudied words can be interpreted to reflect the engagement of different retrieval orientations, and consequently the degree to which task-specific retrieval processes are engaged is modified by task difficulty. Strong support for this interpretation would have accrued from the finding that the ERPs evoked by new words in the low relative difficulty group diverged in a qualitatively similar manner to those in the high relative difficulty group, but to a lesser, albeit statistically reliable extent. The pattern of data in the low relative difficulty group, however, does not have this profile, but the null result is still consistent with this account. It is also a possibility that the uniformly high level of response accuracy in both target designation tasks in the low relative difficulty group minimised the need to engage in task-specific retrieval processing for at least some participants.

A further challenge for the above account is the fact that in the study of Robb and Rugg (2002), the indices of orientation were insensitive to task difficulty. One potential explanation for this is that the differences between response accuracy in the high and the low relative difficulty groups in the present experiment were markedly larger than those in the study of Robb and Rugg. Furthermore, in the study of Robb and Rugg (2002), effort and orientation were manipulated within participants, while in the present experiment, effort was manipulated between participants. These different aspects of the experimental designs may have contributed to the disparities observed across these studies.

On the basis of the above arguments, it is reasonable to interpret the differences between the ERPs evoked by new test words in the high relative difficulty group as indices of retrieval orientation that are modulated by effort. As discussed in Chapter 1, the identification of electrophysiological indices of retrieval orientation is important, since investigating this class of retrieval process offers a means of understanding how, and in what way, memory search operations are carried out. In relation to this, one possibility is that the putative indices of orientation reported here reflect memory control processes that are necessary for the maintenance of task-specific retrieval cue representations in the period prior to the decision to make a response to the test items. This interpretation is supported by the extended time course of the differences between the ERPs evoked by the two classes of new words as well as the fact that there was no statistical evidence that the processes differentiating these two classes of unstudied test words change over time. This functional account, along with competing accounts, will be discussed in detail in later chapters.

5.6. Concluding remarks

In sum, differences between the ERPs evoked by classes of new words varied according to target designation only when the difficulty of the two target designation tasks was not the same. These findings suggest that for this task pair at least, changes in retrieval effort are manifest for the most part as changes in the levels of activity in the neural generators that are typically engaged in pursuit of task-specific information – retrieval orientations.

The sensitivity of retrieval orientations to specific demands of the retrieval tasks is further explored in Experiment Three. At issue is whether the differences between the ERPs evoked by new words observed in Experiment One and in the high relative difficulty group in Experiment Two can be obtained by employing different task pairs that promote high and equivalent levels of memory accuracy. Evidence supporting the engagement of task-specific retrieval processing would take the form of the presence of reliable differences between the ERPs evoked by new words and separated according to target designation that differed from those observed in the present experiment.

FIGURE 5.1: Grand average ERPs evoked by new words in the phonological and semantic target designation tasks for all participants in Experiment Two. Electrode montage as in Figure 4.1 (Chapter 4).

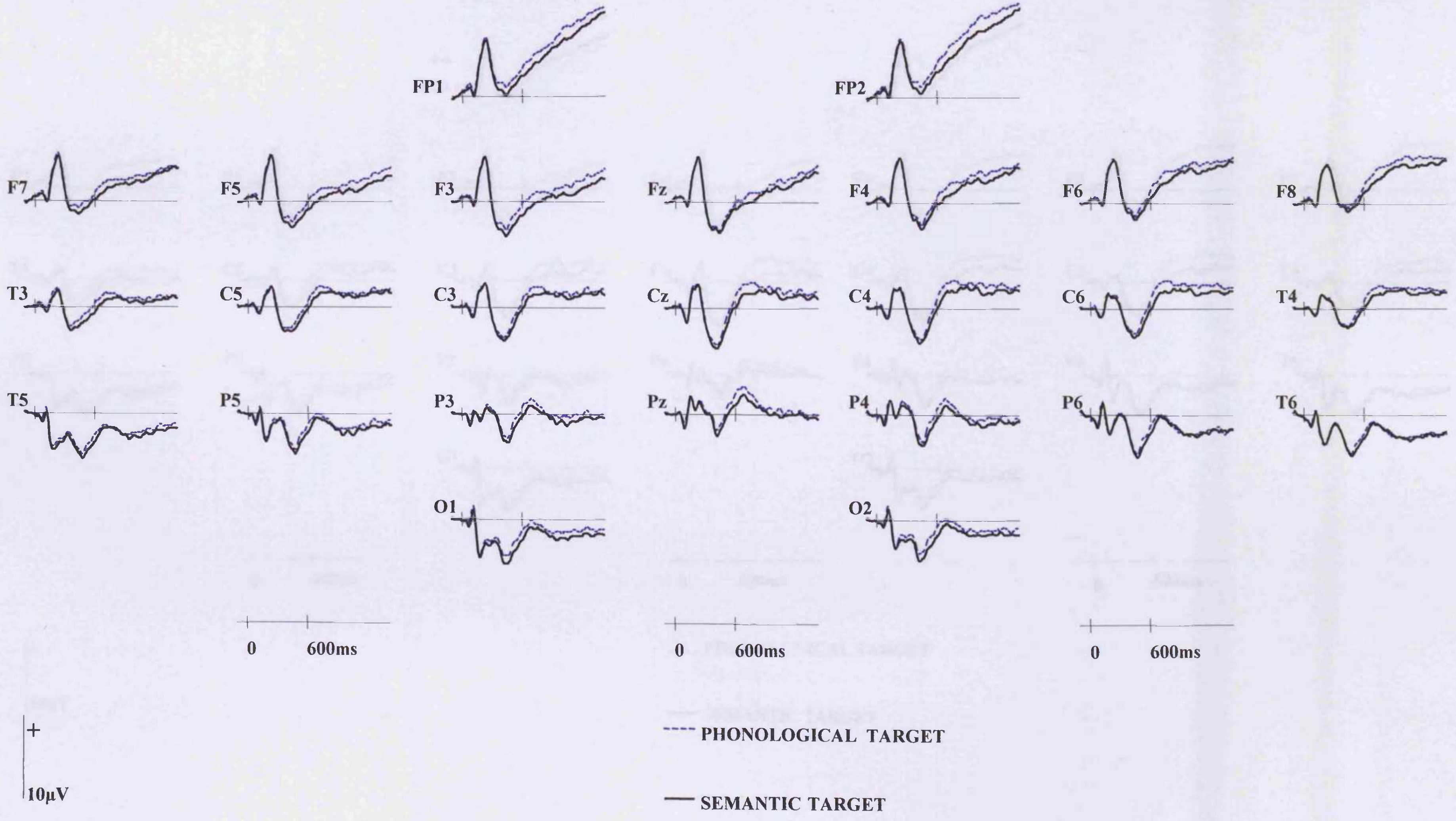


FIGURE 5.2: Grand average ERPs evoked by new words in the phonological and semantic target designations tasks for the high relative difficulty group. Electrode montage as in Figure 4.1 (Chapter 4).

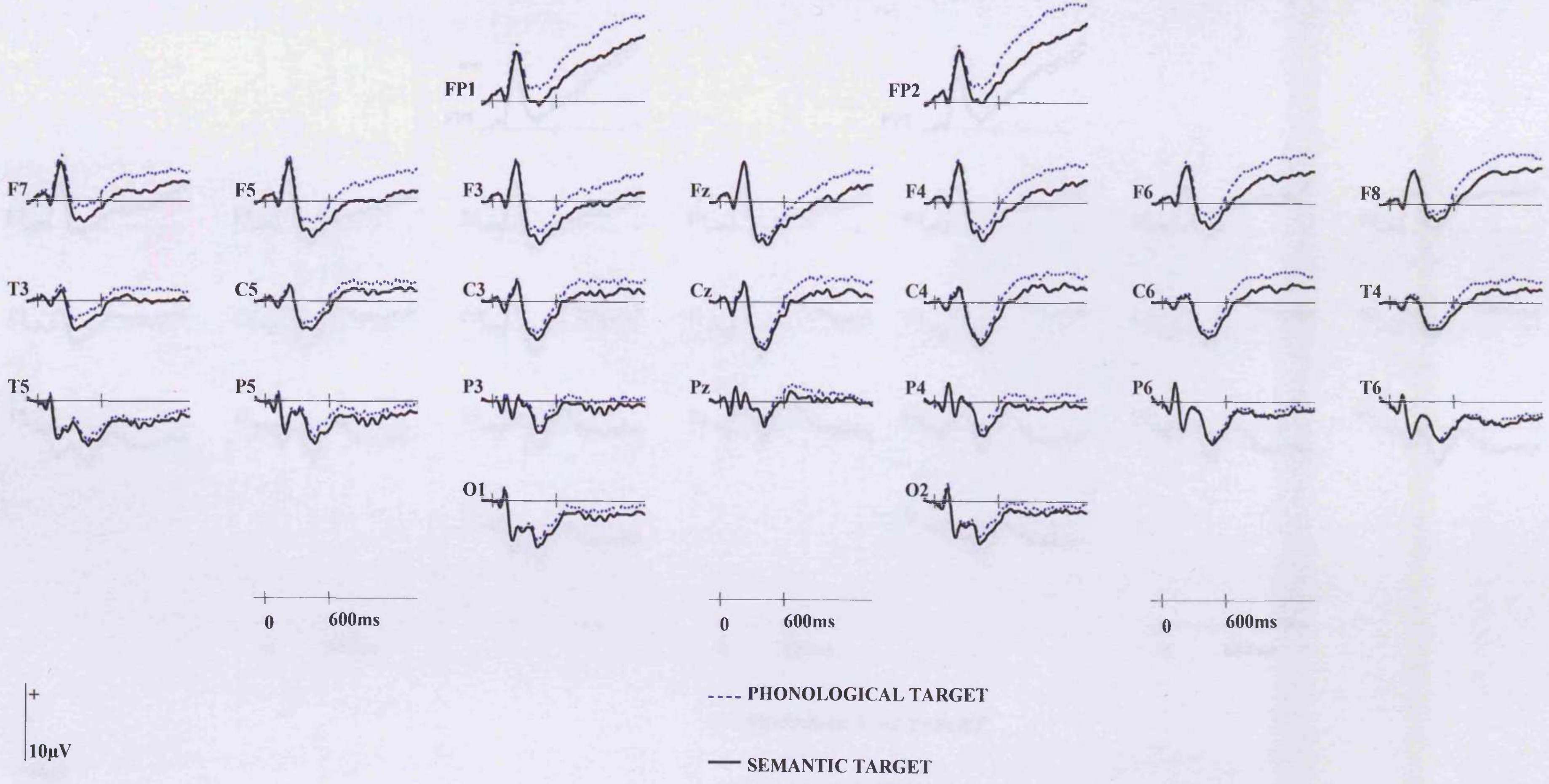


FIGURE 5.3: Grand average ERPs evoked by new words in the phonological and semantic target designations tasks for the low relative difficulty group. Electrode montage as in Figure 4.1 (Chapter 4).

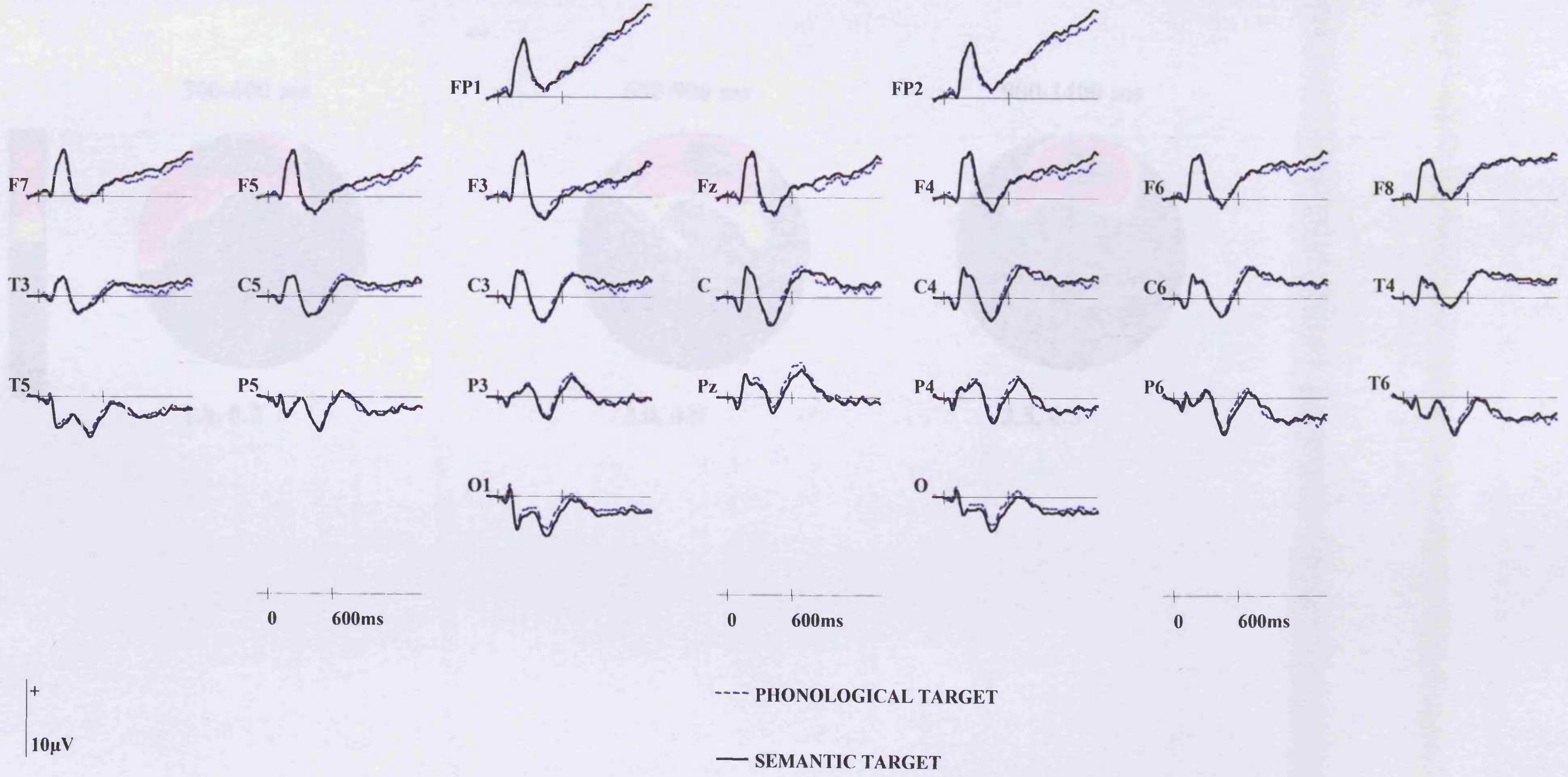


FIGURE 5.4: Topographic maps showing the scalp distributions of the differences between the activity elicited by new test words for the high relative difficulty group over the 300-600, 600-900 and 900-1400 ms time windows. The maps were computed from the difference scores obtained by subtracting the mean amplitudes from the ERPs elicited by new words in the semantic target designation condition from those in the phonological target designation condition. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

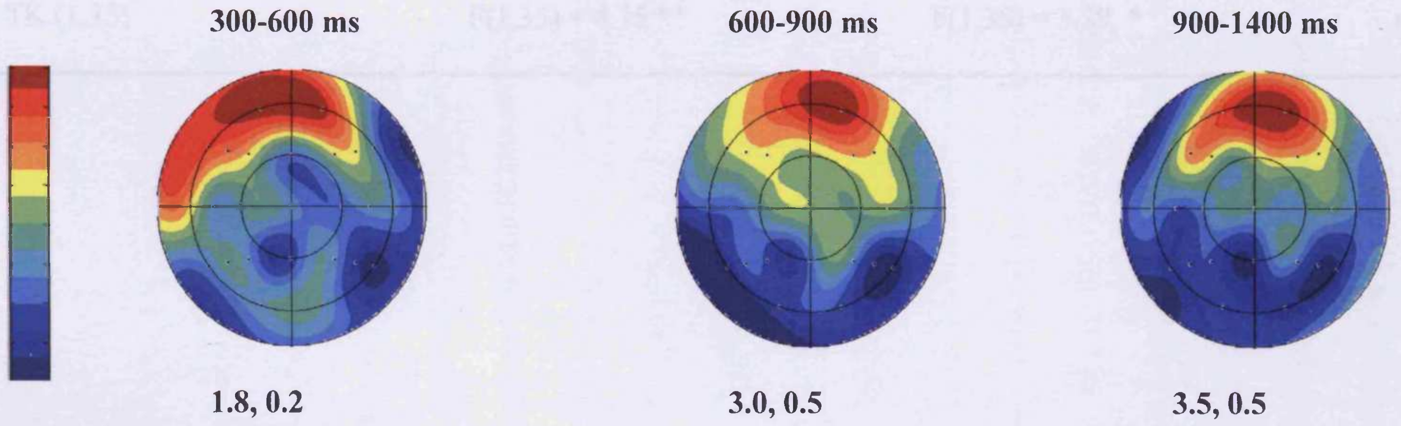


TABLE 5.4: Results of ANOVAs of the ERPs evoked by correctly rejected new words in the semantic and phonological tasks for all participants. Key: TK = target designation. * = $p < .1$, ** = $p < .05$, *** = $p < .01$, n.s = non-significant ($p > .1$), full dfs in brackets (1st column).

Effect	**300-600 ms**	**600-900 ms**	**900-1400 ms**
TK (1,35)	F(1,35) = 4.15 **	F(1,35) = 3.39, *	ns

Chapter 6

6.1. Introduction

The findings in Experiment Two are consistent with the view that ERPs index retrieval orientations, and in some circumstances are sensitive to task difficulty. Experiment Three used different encoding tasks that promoted high and equivalent levels of memory accuracy in the course of attempting to provide further support for the concept of orientation. Evidence that supports the view that different retrieval orientations are adopted according to task demands would take the form of the presence of reliable differences between the ERPs evoked by new test words in this experiment that are not equivalent to those observed in Experiments One and Two.

The second aim of Experiment Three was to start to investigate the functional significance of orientations. In one recent exclusion task study by Herron and Rugg (2003a), reliable indices of orientation were reported, and interestingly they were accompanied by electrophysiological correlates of successful retrieval (the left-parietal ERP old/new effect; see Chapter 1 for details) that varied in a manner consistent with the view that recollection of some forms of information was prioritised. In their study, participants were presented with an equal number of words and pictures at study. All stimuli were words at test. The old words were either re-presentations of words, or presentations of words corresponding to the objects denoted by the pictures. In separate retrieval phases, targets were designated as old words that had been encountered either as words or as pictures.

Consistent with the findings of Robb and Rugg (2002), Herron and Rugg (2003a) reported that ERPs evoked by new test items varied according to target designation. These indices of orientation comprised a relatively greater positivity in the ERPs evoked by new words in the word-target designation condition than in the picture-target designation condition. The effect onset approximately 300 ms post-stimulus, remained for 500-600 ms and was largest at central midline sites. Reliable left-parietal old/new effects for targets in both word and picture target designation conditions were also reported. The left-parietal ERP old/new effects evoked by non-target items were, however, evident only when pictures were designated as targets (for a description of related findings, see Chapter 1).

The absence of such effects for non-targets when words were designated as targets suggests that recollection of non-target items did not occur in this condition. The authors suggested that the absence of a left-parietal old/new effect for non-targets came about because of the high level of cue-target compatibility, which allowed participants to search memory with a high degree of specificity. On the other hand, the presence of a non-target left-parietal old/new effect in the picture target condition was due to the fact that under this task condition, it was not possible to recollect information specific to studied pictures, perhaps because all test stimuli (and critically non-targets) were words. According to this account, the cue-target incompatibility in the picture target condition impeded participants from searching memory with a high degree of specificity, thereby explaining the left-parietal old/new effect for non-targets. In sum, the findings in Herron and Rugg (2003a) can be explained in terms of the different circumstances under which selective recollection can be accomplished.

The important point from the Herron and Rugg (2003a) findings for present purposes is that the ERP data are consistent with the view that recollection can be restricted to certain kinds of memory representations under some circumstances. On the basis of these findings, Herron and Rugg (2003a) suggested that the indices of orientation they observed in the same study reflected processes that increased the relative accessibility of some kinds of studied information, and a consequence of this was the selective retrieval of task-relevant information only, as indicated by the conditions under which the left-parietal old/new effects – the electrophysiological signature of recollection – were obtained.

Experiment Three provides an opportunity to acquire data consistent with the view that participants adopt task-specific retrieval strategies that result in selective control of recollection in a design employing different study materials and tasks to those used in Herron and Rugg (2003a). In Experiment Three, all study and test materials were visually presented words and participants engaged in two encoding tasks that required different cognitive operations. In the function task, participants were asked to think of a suitable function for the object denoted by each word, while in the drawing task, participants were asked to rate how easy the object denoted by each word would be to draw. The drawing task will presumably entail a greater degree of visual imagery compared to the function task. The latter will involve more access to abstract semantic information that is related to the uses to which objects can be put. Thus, the function and drawing tasks can reasonably be assumed to engage distinct cognitive operations at encoding. In separate retrieval phases, words encoded in either the function or the drawing task were designated as targets. These two tasks were also employed because they have been reported to give rise to indices of retrieval orientation (Johnson et al., 1996). Both tasks require a relatively deep level of processing, and accuracy in the study of Johnson et al. (1996) was comparable for the two tasks. Thus, it should be possible to equate memory performance more straightforwardly than in Experiment Two. Since effort (as indexed by task difficulty) can be assumed to be equivalent when accuracy is equivalent, any reliable differences between the ERPs evoked by classes of new words and separated according to target designation in this experiment should reflect task-specific retrieval orientations rather than effort. The use of tasks promoting high levels of memory accuracy, furthermore, creates circumstances under which, on the basis of previous work, non-target left-parietal ERP old/new effects should be attenuated in comparison to target left-parietal old/new effects (Herron and Rugg, 2003a; 2003b).

In Experiment Three, in contrast to Experiments One and Two, participants were required to respond to targets by pressing one key and to respond to non-target and new words by pressing a different key. This design matches that used in other exclusion task studies (e.g. Wilding and Rugg, 1997; Herron and Rugg, 2003a; 2003b) and permits a better approach to the investigation of the electrophysiological signature of recollection, the left-parietal ERP old/new effect, than in Experiments One and Two, in the sense that it minimises the response-related confound inherent in those experiments.

The design employed in Experiment Three, therefore, permits a test of the possibility that, in a task where modality at encoding and retrieval is held constant, selective control of recollection can be exerted at the level of the kinds of cognitive operations that are engaged at encoding. Evidence consistent with this possibility would take the form of the presence of attenuated left-parietal old/new effects for non-targets compared to targets in retrieval phases in which either words from the function or drawing tasks were designated as targets. Reliable indices of retrieval orientation, as revealed by differences between ERPs evoked by unstudied words and separated according to target designation, would also provide converging evidence for the view that one function of orientations is to engage processes that influence the likelihood of recollecting only specific kinds of contextual information.

6.2. Method

6.2.1. Participants

There were 21 participants (15 female) in Experiment Three. Each was paid at the rate of £5.00 per hour. The data from one participant were discarded due to experimenter error. The data from a further two participants were excluded due to excessive EOG artefacts. Of the remaining 18 participants, 12 were female. The average age of the participants was 21 years (range 18 to 29).

6.2.2. Experimental items

These consisted of 360 words, and were split into six groups of 60 words to create two study-test cycles. Three groups were assigned to the first study-test cycle and the remainder to the second cycle. Each cycle contained an equal number of words and no word appeared in more than one cycle.

The study phase of each cycle comprised two word groups (120 words). One group of study words was preceded by an asterisk, the other by a plus sign. These cues signalled the task that participants would have to complete when encountering these items (see Procedure). Within each cycle, the groups of words across study and test were rotated to create three task lists. Across lists, all words appeared after an asterisk and a plus sign and all words were presented at study and test as well as at test only. The order of presentation of words at study and at test within each cycle was determined randomly for each participant. One filler word was placed at the beginning of each study and test phase. In total there were 302 words in each study-test cycle (120 study stimuli + 1 filler, 180 test stimuli + 1 filler).

6.2.3. Procedure

The stimulus presentation parameters and the procedure resemble those described in Experiments One and Two, the principal departure being that each participant completed only two study-test cycles. In each study phase, participants were asked to make either a function or a drawing judgement for each study word. In the function task, they were asked to think of and say aloud a suitable function for the object denoted by the study word, while in the drawing task, participants were asked to rate verbally on a 5 point scale how difficult the object denoted by the word would be to draw. A rating of 1 signalled 'very easy to draw' while a rating of 5 signalled 'very difficult to draw'. For 50% of the participants, an asterisk preceding study words signalled that a function judgement should be made, and a plus sign signalled that a drawing judgement should be made. This correspondence was reversed for the remaining participants.

The present experiment also differs from Experiments One and Two in that the message PLEASE SPEAK NOW in Experiment Three during the study phases appeared on the screen after a gap of 1500 ms. Participants were asked to withhold their verbal response (either a function word or drawing rating) until they saw this message. In Experiment Three, after the presentation of the test stimulus, the screen was blanked until the participant responded. The next trial started 1200 ms after a response was made.

For each test phase, participants were informed that they were to respond with one hand to words presented at study in the function/drawing task (targets), and with the other to words encountered in the alternate study task (non-targets), as well as to words presented at test for the first time. Equal numbers of participants completed the function and the drawing target designation conditions first. Participants were not informed prior to the second test phase that target designation would differ across cycles or of the overall number of cycles.

6.3. EEG recording

The recording locations were the same as those employed in Experiments One and Two. As in Experiment Two, EEG was acquired continuously at 6 ms per point. The frequency band was the same as in Experiments One and Two. All EEG electrodes were referred to Fz during acquisition. Vertical and horizontal EOG were recorded bipolarly from electrodes placed above and below the right eye, and on the outer canthi. ERPs were re-referenced off-line to linked mastoids. The data from the site used as the reference during acquisition (Fz) were recovered. Data were epoched off-line (1536 ms (256 points) epochs, including 102 ms pre-stimulus baseline). The criteria for trial rejections were the same as those used in Experiments One and Two with the exception of EOG artefact rejection. EOG correction using a linear regression algorithm (Semlitsch et al. (1986) was performed prior to analysis.

6.4. Results

6.4.1. Behavioural Data

Table 6.1 displays the probabilities of correct responses to target, new and non-target words, separated according to the function and drawing target designations. Analyses using t-tests revealed that participants made reliably more target responses to targets than to non-targets and new words in both target designation tasks (t(17) > 15.61, p < .001 in each case, see Appendix C for details). The likelihoods of correct responses at retrieval were subjected to ANOVA with target designation (function, drawing) and condition (target, new, non-target) as factors. The analysis revealed a main effect of condition only (F(1.4, 24.6) = 44.52, p < .01). In the absence of reliable effects involving target designation, follow-up analyses were completed by collapsing data across the factor of target designation, and comprised all possible paired comparisons of the likelihood of correct responses to target, new and non-target words. The outcomes from Bonferroni corrected t-tests (adjusted significance level = 0.017) indicated that the likelihood of correct responses to new words was reliably greater than the likelihood of correct responses to either target (0.82 vs. 0.98; t(17) = 7.41, p < .001) or non-target words (0.89 vs. 0.98; t(17) = 6.06, p < .001). The likelihood of correct responses to non-target words was superior to the likelihood of correct responses to target words (0.82 vs. 0.89; t(17) = 5.25, p < .001).

Target designation task	Word Condition		
	Target	**New**	**Non-Target**
Function	0.83 (.09)	0.99 (.12)	0.89 (.08)
Drawing	0.81 (.12)	0.98 (.04)	0.90 (.09)

Table 6.1. Mean proportions of correct responses to target, new and non-target words in the function and drawing target designation tasks. (S.D in brackets).

Table 6.2 shows the reaction times (RTs) for correct responses to target, new and non-target words in the function and drawing target designation tasks. The RTs for incorrect responses to these critical categories are not shown because of the small numbers of trials (range in brackets) on which incorrect responses were made: mean numbers of trials for target misses, false alarms and non-target false alarms were 10 (1-21), 0 (0-2) and 6 (0-18), respectively in the function target designation task. The corresponding values in the drawing target designation task were 11(1-25), 1 (0-9) and 6 (0-21). ANOVA of the RTs, employing the same factors as for the ANOVA for response accuracy, revealed a main effect of condition only ($F(1,17) = 46.61$, $p < .01$). In keeping with the approach employed for the follow-up analysis for memory accuracy, Bonferroni corrected t-tests (adjusted alpha level = 0.017) for the RTs indicated that correct responses to new words were faster than those to either type of old word: targets (1287 vs. 1046; $t(17) = 7.47$, $p < .001$); non-targets (1322 vs. 1046; $t(17) = 8.08$, $p < .001$). RTs to targets and non-targets did not differ significantly.

Target designation task	Word Condition		
	Target	**New**	**Non-Target**
Function	1357 (418)	1086 (377)	1357 (450)
Drawing	1209 (166)	1005 (166)	1287 (305)

Table 6.2: Mean reaction time (RTs: ms) for correct responses to target, new and non-target words in the function and drawing target designation tasks. (S.D. in brackets).

6.4.2. ERP data analyses

6.4.2.1. Analyses of ERPs evoked by new test words

The ERPs evoked by new test words to which correct judgements were made are shown in Figure 6.1. It can be seen that the ERPs evoked by new words in the function target designation condition are relatively more positive-going than those in the drawing target designation condition from about 300–1000 ms post-stimulus. This relative positivity tends to be smaller at left hemisphere than at right hemisphere locations.

The analyses of the ERPs evoked by the new test words were conducted over successive 100 ms time windows, extending from 0-1400 ms post-stimulus. These time windows were chosen because of the lack of a strong a priori hypothesis concerning the time course of differences between conditions. The mean number of trials (range in brackets) contributing to the function target designation condition was 47 (30-59), while for the drawing target designation condition, the mean number of trials was 46 (22-60).

The initial analysis of the differences between ERP amplitudes for the two classes of correct rejection included the standard array of electrode locations, as used in Experiments One and Two (FP1/FP2, F7/F8, F5/F6, F3/F4, T5/T6, P5/P6, P3/P4, O1/O2). The factors employed were also the same as in Experiments One and Two (target designation (TK): function/ drawing, hemisphere (HM): left/right, the anterior/posterior dimension (AP): anterior/posterior and site (ST): pre-superior/ inferior/mid-lateral/superior). The outcomes of these analyses are shown in Table 6.3. The table shows statistical outcomes for the 100 ms epochs within the 500-800 ms range only, since reliable and marginal effects involving TK were restricted to these time windows.

The analyses over the 500-700 ms time windows revealed main effects of TK, which was moderated by an interaction between this factor and ST in the 600-700 ms time window. The main effect of TK and an interaction between this factor and ST approached significance in the 700-800 ms time window. The reliable main effects reflect the relatively greater positivity for the ERPs evoked by new words when words from the function, rather than the drawing target designation were designated as targets. The TK by ST interaction reflects the fact that this relative positivity is greater at superior than at central and inferior sites. Figure 6.1 shows that there is a tendency for the distribution of the differences between the ERPs evoked by the two classes of new words to be larger at anterior than at posterior scalp sites. To assess this, a further analysis was conducted on the data from superior scalp sites in the time region of 600-700 ms, separated according to anterior and posterior scalp locations. While the analysis at posterior sites did not reveal significant differences involving target designation, the analysis at anterior sites gave rise to a main effect of TK (F(1,17) =

8.84, $p < .05$), reflecting the greater positivity in the ERPs evoked by new words in the function than in the drawing target designation at superior anterior sites.

6.4.2.2. Analyses of ERP old/new effects

Figures 6.2 and 6.3 show the ERP old/new effects that were obtained in the function and drawing target designation tasks, respectively. In both target designation tasks, the ERPs evoked by targets are more positive-going than those evoked by correct rejections. From about 400 ms at posterior locations, this relative positivity is larger at left- than at right-hemisphere scalp locations, while later in the epoch, this asymmetry is reversed at anterior electrodes.

For both target designations, the ERPs evoked by non-targets differ minimally from those evoked by correct rejections at posterior scalp sites, while at anterior sites, they are relatively more positive-going from approximately 800 ms post-stimulus. The positivity is more pronounced over the right than the left hemisphere. In this time region as well, more positive-going waveforms are associated with new in comparison to target and non-target words at posterior electrode sites (see Pz in particular). The ERP old/new effects also differ according to target designation, in that at midline and anterior scalp locations from approximately 400-800 ms, the target old/new effects are more prominent in the drawing than in the function target designation tasks. Furthermore, in the function target designation task only, at right hemisphere central locations, the ERPs evoked by correct rejections are relatively more positive-going than those evoked by targets and by non-targets from about 600-800 ms post-stimulus.

The ERP old/new effects were subjected to a series of global analyses incorporating data from the same array of electrode locations that was employed for the analyses of the ERPs evoked by new words described in the foregoing paragraphs. The analyses were completed over four post-stimulus time-windows: 300-500, 500-800, 800-1100 and 1100-1400 ms, incorporating the factors of TK (function, drawing), CC (target, new, non-target), HM (left, right), AP (anterior, posterior) and ST. The mean numbers of trials (range in brackets) contributing to averaged ERPs associated with targets and non-targets in the function target designation task were 42 (28-49) and 39 (18-60), respectively. The corresponding values for the drawing target designation task were 40 (17-59) and 42 (18-59). The outcomes of the analyses are described below, separated according to epoch. Reliable four-way interactions involving CC, AP, HM and ST are followed up by separate analyses at anterior and posterior electrode locations.

300-500 ms

The initial analysis over the 300-500 ms time window revealed a main effect of CC ($F(1.8, 30.4) = 5.65, p < .01$) and an interaction between this factor and ST ($F(2.6, 44.8) = 3.64, p < .01$). No reliable effects involving TK were observed, so follow-up analyses were completed on data collapsed across this factor, and comprised all possible paired comparisons of the ERPs evoked by correct judgements to targets, non-targets and new test words. The outcomes of these follow-up analyses are displayed in Table 6.4. The analyses of the ERPs involving new words revealed main effects of CC, which were moderated by interactions between this factor and ST in each case. These outcomes reflect the fact that the ERPs evoked by both classes of old word are reliably more positive-going than those evoked by new words, with this relative positivity being largest at superior and smallest at inferior scalp sites. The contrast of the ERPs evoked by targets and non-targets revealed no reliable effects.

500-800 ms

The initial analysis revealed an interaction between CC and ST (F(2.6, 44.3) = 5.37, p < .01) and two three-way interactions: CC x AP x HM (F(1.4, 23.1) = 5.90, p < .01) and CC x HM x ST (F(3.2, 54.0) = 4.25, p < .01). Two interactions involving target designation - TK x CC x AP and TK x CC x ST - approached significance (F(1.6, 27.9) = 3.18, p = .07 and F(2.8, 48.0) = 2.51, p =.07, respectively). The four-way interaction between CC, AP, HM and ST also approached significance (F(2.9, 49.4) = 2.55, p = .07). As in the analysis for the previous time window, follow-up analyses were completed by collapsing data across the factor of TK, and comprised all possible paired comparisons of the ERPs evoked by correct judgements to targets, non-targets and to new test words. As displayed in Table 6.5, the target vs. new contrast revealed two reliable three-way interactions between CC, AP and HM and CC, HM and ST. This interaction is due to the fact that the relatively greater positivity associated with targets in comparison to new words is largest at left posterior electrode locations, particularly at left superior and mid-lateral sites. The four-way interaction between CC, AP, HM and ST was reliable for non-targets only and follow-up analyses, completed separately for anterior and posterior scalp locations, revealed an interaction between CC and HM (F(1,17) = 7.11, p < .01) which was moderated by a CC x HM x ST (F(1.9, 32.7) = 4.23, p < .05) interaction at posterior locations only, reflecting the fact that over the left hemisphere, particularly at P3, the ERPs evoked by non-targets are more positive-going than those evoked by new words. The reverse is true over the right hemisphere, particularly at P8. The CC x HM x ST interaction revealed from the contrast of the two categories of old words reflects the fact that the mean amplitudes for targets are more positive than those for non-targets, particularly at left superior sites.

800-1100 ms

The initial analysis revealed a main effect of CC (F(1.6, 26.9) = 6.88, p < .01) and several interactions involving this factor: CC x ST (F(2.3, 39.1) = 5.23, p < .01), CC x AP x HM (F(1.6, 28.0) = 6.65, p < .01), CC x AP x ST (F(3.4, 57.5) = 5.93, p < .01), CC x HM x ST (F(2.7, 45.2) = 3.77, p < .05) and CC x AP x HM x ST (F(2.9, 49.1) = 2.96, p < .05). The analyses also revealed a three-way interaction involving target designation: TK x CC x ST (F(3.0, 51.0) = 3.11, p < .05). These analyses were followed up by all possible paired contrasts of the ERPs evoked by the three critical word conditions, separated according to target designation. For the function target designation (see Table 6.6), the follow-up analysis following the four-way interaction for targets at anterior sites revealed an interaction between CC and ST (F(1.9, 32.0) = 4.42, p < .05), which was moderated by a three-way interaction between CC, HM and ST (F(1.5, 25.2) = 4.77, p < .05). This reflects the fact that over the right hemisphere, the relatively greater positivity is associated with targets while over the left hemisphere, particularly at F7, the relatively greater positivity is associated with new rather than target words. The follow-up analysis at posterior sites revealed a main effect of CC (F(1,17) = 5.76, p < .05) and an interaction between CC and HM (F(1,17) = 4.69, p < .05), reflecting the fact that at posterior locations, the ERPs evoked by targets are more positive-going than those evoked by new words at left hemisphere sites only.

The non-target vs. new contrast (see Table 6.6) revealed a CC x AP x ST interaction, reflecting the relatively greater positivity for non-targets than for new words, which is largest at anterior locations, particularly at superior sites. The contrast involving the two classes of old words revealed an interaction between CC and AP, reflecting the fact that the greater relative positivity for targets is larger at posterior than at anterior scalp locations.

For the drawing target designation task (see Table 6.7), the contrasts involving new words revealed two three-way interactions: CC x AP x HM and CC x AP x ST for both targets and non-targets. The CC x HM x ST interaction was also revealed in the target vs. new contrast. These effects primarily reflect the fact that targets are associated with greater positivity compared to new words, with the effects being largest at right anterior superior sites. For non-targets, the two three-way interactions reflect the fact that the relatively greater positivity for non-targets than new words is right lateralised over anterior locations, with an inferior maximum while over the posterior locations there is less hemisphere asymmetry. The CC x HM x ST interaction, revealed from the direct contrast of the ERPs evoked by the two classes of old words, reflects the fact that the greater relative positivity for targets is most prominent over the right-hemisphere, particularly at superior sites.

1100-1400 ms

The initial analysis revealed a main effect of CC ($F(1.5, 26.0) = 5.89$, $p < .01$), and six interactions involving this factor: CC x HM ($F(1.7, 28.9) = 7.42$, $p < .01$), CC x ST ($F(2.6, 43.5) = 3.97$, $p < .05$), CC x AP x HM ($F(1.9, 32.9) = 14.04$, $p < .01$), CC x AP x ST ($F(3.9, 67.0) = 4.39$, $p < .01$), CC x HM x ST ($F(2.9, 50.0) = 4.08$, $p < .05$) and

CC x AP x HM x ST (F(3.8, 64.8) = 3.67, $p < .01$). The analyses also revealed a significant effect involving target designation: TK x CC x HM (F(1.8, 30.9) = 3.98, $p < .05$). In keeping with the approach adopted for the analysis over the 800-1100 ms epoch, the follow-up analyses were conducted on data separated according to target designation, and comprised all possible paired comparisons of the ERPs evoked by correct judgements to targets, non-targets and new words.

For the function target designation task (see Table 6.8), the interaction involving CC, AP and HM for targets reflects the fact that the relatively greater positivity for targets than for new words is maximal at right anterior sites. For the non-target vs. new contrast, the follow-up analyses at anterior sites for the CC x AP x HM x ST interaction revealed an interaction between CC and HM (F(1,17) = 10.99, $p < .01$), which was moderated by a CC x HM x ST interaction (F(1.8, 31.0) = 5.93, $p < .01$), reflecting the fact that over the left hemisphere the ERPs differ minimally, while over the right hemisphere the ERPs evoked by non-target words are more positive-going particularly at inferior and mid-lateral frontal locations. The follow-up analysis at posterior locations revealed an interaction between CC and ST (F(2.1, 35.5) = 4.33, $p < .05$), reflecting the fact that the relatively greater positivity for new compared to non-target words is largest at occipital sites (O1/O2). The three-way interaction involving CC, HM and ST revealed from the contrasts of the two categories of old words reflects the fact that the relatively greater positivity for targets in comparison to non-targets is largest at left superior scalp sites.

In the drawing target designation task (see Table 6.9), the reliable three-way interactions for targets - CC x HM x ST, CC x AP x HM and CC x AP x ST - reflect the fact that the relatively greater positivity for the ERPs evoked by targets than by new words is largest at right anterior locations, particularly at superior sites. For non-targets, the CC x AP x HM and CC x AP x ST interactions reflect the fact that the relative positivity is greater at right than left anterior sites, while at right posterior sites, the mean amplitudes of non-targets are more negative-going than those to new words. The two-way interactions - CC x ST and CC x HM - were reliable for the direct contrast of the two classes of old words, reflecting the fact that the relatively greater positivity for targets than for non-targets is more prominent at right-hemisphere than at left-hemisphere sites, particularly at superior scalp locations.

Analysis at P5.

The ERP old/new effects were also subjected to a specific analysis involving the data obtained from P5 over the 500-800 ms time window. This analysis was implemented in order to determine the relationship between the ERP signature of recollection – the left-parietal ERP old/new effects for target and for non-target words. The combination of location and time window corresponds to that over which parietal ERP old/new effects are typically largest (Wilding and Sharpe, 2003), and relatively uncontaminated with P300-related activity (Herron and Rugg, 2003a).

The initial analysis included the factors of TK (function, drawing) and CC (target, new, non-target). The only reliable effect revealed by this analysis was a main effect of CC ($F(1.5, 25.1) = 8.89$, $p < .01$). Follow-up analyses, collapsed across the factor of target designation, revealed that the ERPs evoked by targets are more positive-going than those evoked by non-targets ($F(1,17) = 12.64$, $p < .01$) and by new words ($F(1,17) = 17.71$, $p < .01$). The ERPs evoked by new words and by non-targets are not reliably different. In order to determine whether the old/new effects at this site are influenced by the ERPs evoked by new test words, contrasts of ERPs evoked by new words separated according to target designation were also included in the analysis over this time window. The analysis, which incorporates all other factors as above, did not reveal any reliable difference between the ERPs evoked by new words in the function and drawing target designation tasks.

Over this time region (500-800 ms), a further analysis was completed for the data from the three midline sites (Fz, Cz and Pz). The reason for conducting this additional analysis was to capture the differences between the ERP old/new effects in the function and drawing target designation tasks. As displayed in Figures 6.2 and 6.3, the ERPs evoked by targets and non-targets are more positive-going than those evoked by new words, in the drawing target designation task, and markedly less so in the function target designation task.

ANOVA of the data (factors as above plus ST) revealed a TK x CC ($F(1.7, 28.5) = 3.56$, $p < .05$) interaction, which was moderated by a three-way interaction involving TK, CC and ST ($F(3.0, 51.6) = 2.78$, $p < .05$). This analysis was followed up by all possible paired contrasts of the ERPs evoked by target, new and non-target words, separated according to target designation. Reliable effects involving CC were obtained in the analysis for the drawing target designation task only. The contrast between new words and targets revealed a main effect of CC ($F(1,17) = 10.79$, $p < .01$), reflecting the fact that the ERPs evoked by targets are more positive-going than those evoked by new words. The analysis for non-targets and new words revealed a CC x ST interaction ($F(1.8, 30.8) = 4.67$, $p < .05$), reflecting the fact that at the Fz and

Cz locations, the relatively greater positivity is associated with non-targets than with new words, while at Pz the ERPs differ minimally. The target vs. non-target contrast revealed a main effect of CC (F(1,17) = 20.02, $p < .01$), reflecting the fact that the mean amplitudes for targets are more positive-going than those for non-targets.

Additional analyses were also completed over the 600-800 and 800-1400 ms epochs, involving the data from C6 and Pz, respectively. These analyses were done in order to capture the relatively greater positivity evoked by new words in comparison to that evoked by correct judgements to old words, which was evident at the right-hemisphere central electrode location (C6) in the 600-800 ms epoch and the midline posterior electrode location (Pz) in the 800-1400 ms time window. The data were submitted to ANOVA with factors of TK and CC.

The initial analysis over the 600-800 ms time window revealed a main effect of CC (F(1.5, 26.3) = 5.86, $p < .01$) and an interaction between this factor and TK (F(1.7, 29.6) = 5.34, $p < .01$). This analysis was followed up by all possible paired contrasts of the ERPs evoked by the three word conditions, separated according to TK. For the function target designation, the contrast between the two categories of old words revealed no reliable effects, while for the contrasts involving new words, main effects of CC were obtained in each case: targets (F(1,17) = 5.96, $p < .05$), non-targets (F(1,17) = 7.89, $p < .01$), reflecting the relatively greater positivity for new words in comparison to either type of old word. For the drawing target designation, the only reliable effect involving CC was obtained from the target vs. non-target contrast (F(1,17) = 20.14, $p < .01$), reflecting the fact that the mean amplitude for targets was more positive-going compared to that for non-targets.

The initial analysis over the 800-1400 ms time window at Pz revealed a main effect of CC (F(1.5, 25.1) = 6.19, p < .01) only. Follow-up analyses (collapsed across the factor of target designation) comprised all possible paired contrasts of the ERPs evoked by the three word conditions. The contrasts involving new words revealed a main effect of CC for non-targets only (F(1,17) = 8.56, p < .01), reflecting the relatively greater positivity for new than for non-target words. The contrast of the two categories of old words also revealed a main effect of CC (F(1,17) = 16.32, p < .01), reflecting the relatively greater positivity for targets than for non-targets.

6.4.2.3. Analyses of scalp distribution

Figure 6.4 shows the topographic maps for the ERPs evoked by new words in the function and drawing target designation tasks for the three time windows over which reliable or marginal effects involving target designation were obtained in the analysis of ERPs evoked by new words. The analysis of scalp distribution was restricted to the 500-600 and 600-800 ms epochs, since the foregoing analyses gave no indication that the two classes of correct rejections were associated with reliably different patterns of neural activity later in the recording epoch. The analysis thus included the same factors as in Experiment One (epoch: 500-600 and 600-800 ms; site: 25 levels). The epoch x site interaction – the statistical signature of qualitative differences between the scalp distributions of ERPs evoked by the two classes of new words – was non-significant, indicating that the scalp distributions of the ERPs evoked by the two classes of correct rejections do not change with time.

The magnitude analyses of the old/new effects described in the foregoing paragraphs revealed reliable interactions involving target designation and location in the 800-1400 ms time period as well as earlier across task differences at the midline between 500 and 800 ms post-stimulus. Topographic maps showing the scalp distributions of the ERP old/new effects evoked by targets and non-targets in the function and drawing target designation tasks are shown in Figures 6.5 and 6.6, respectively. These maps suggest that the scalp distributions of the target and non-target old/new effects change with time and target designation.

In order to determine whether the interactions observed in the magnitude analyses reflected in part the fact that the old/new effects were qualitatively different in the function and drawing target designation tasks, the ERP old/new effects were submitted to an analysis of scalp distribution. The analysis was computed using subtraction scores obtained by subtracting the mean amplitudes of the ERPs evoked by new words from those evoked by targets and non-targets, respectively, and separated according to target designation as well as epoch. The analysis thus included the factors of epoch (4 levels; 300-500, 500-800, 800-1100, 1100-1400 ms), condition (2 levels; target, non-target), target designation (2 levels; function, drawing) and site (25 levels).

The analysis revealed an interaction between epoch and site ($F(5.9, 99.8) = 4.62$, $p < .01$), indicating that the scalp distributions of ERP old/new effects changed with time. The principal reasons for this are the attenuation of the left-parietal positivity over time and the growth in magnitude of the late posterior negativity as well as the right sided anterior positivity – a pattern that has been documented in several studies in which ERP old/new effects have been acquired (for reviews, see Friedman, 2000; Allan, Wilding and Rugg, 1998). The absence of reliable effects involving target designation is arguably surprising, given the apparent disparities across designation that are most prominent in the 500-800 ms epoch, and this may reflect a lack of statistical power by virtue of the analysis approach that was adopted here.

6.5. Discussion

6.5.1. Behavioural Data

In both tasks, participants were able to discriminate between target and non-target words at a level well above chance. Thus, on a significant proportion of trials, recognition of target words is likely to have been accompanied by retrieval of the context in which the words were encoded, a defining feature of recollection. It is, however, difficult to establish the proportion of non-target words that were recollected on the basis of the behavioural data alone, since non-targets were responded to on the same key as new words. But presumably the fact that these words were encoded to a relatively deep level suggests that the encoding episodes accompanying these items should have been available during retrieval.

Reaction times were faster for correct new judgements than for correct judgements to either type of old words. While the RTs to correctly rejected new words were generally quicker in the drawing than in the function target designation condition, this difference was not reliable. Therefore, any differences between the ERPs associated with these two response categories cannot be attributed with confidence to differences between response times.

Because the likelihood of correct new responses is at ceiling in both tasks here, the absence of reliable differences between RTs is important, since there is effectively no ceiling for RTs, thus the absence of reliable RT differences is consistent with the view that judgments to new items were of equivalent difficulty, hence differences between ERPs evoked by new items in this experiment are likely to be correlates of orientation rather than effort.

A second complication, however, arises from the fact that there was considerably greater variance in reaction times for correct responses in the function task in comparison to the drawing task, as Table 6.2 shows. For the contrast between the ERPs elicited by new items, this raises the concern that perhaps the differences between them are a consequence of latency jitter, whereby greater variability in the time course of the processes engaged in the drawing condition results in a 'flattening' of the ERP waveform, hence greater positivity in the function condition. While this possibility cannot be ruled out entirely, inspection of the ERP data in Figure 6.1 provides little support for this account, since the peaks in the ERP data, while lower in amplitude, are as prominent in the drawing condition as they are in the function condition (see, for example, the data at Cz). An important goal for future studies, however, will be to incorporate similar contrasts without this disparity between the standard deviations of the reaction time distributions.

6.5.2. ERPs evoked by new words

In contrast to the pattern of behavioural data for both target designation tasks, the ERPs evoked by new words in the function target designation task were more positive-going than those in the drawing target designation task from 500-700 ms. The interaction between target designation and site – reliable from 600-700 ms – reflects the fact that the differences between the ERPs evoked by the two classes of correct rejections were greater at superior than at mid and inferior scalp sites. An analysis focusing on superior sites, separated according to the anterior/posterior dimension, revealed that the differences were reliable only at anterior locations. Despite the rightward bias of the distribution of the effects over the anterior sites (see Figure 6.1), no reliable interactions involving hemisphere were obtained.

These differences, as for Experiments One and Two, are unlikely to be a consequence of different processes that occurred at encoding, since participants were informed of target designation only at the start of each retrieval phase. Thus, it is unlikely that at study participants put more emphasis on certain types of information by virtue of inferring what the target designation in the subsequent retrieval phase would be. The effect, therefore, likely indexes processes that occur at retrieval rather than at encoding. The differences between the ERPs evoked by new words are also unlikely to reflect factors related to changes in task difficulty, since no differences were found between the function and drawing target designation tasks with respect to accuracy or RTs.

The data obtained in this experiment correspond with the findings from Experiments One and Two in the sense that the ERPs evoked by new items diverged according to task demands. In comparison to the data from Experiment Two, however, the differences between the ERPs in this experiment have dissimilar time courses, and the scalp distribution, as well as varying minimally with time, has a relatively less anterior focus, as the data in Figures 5.4 and 6.4 show.

These disparities across studies provide support for the concept of orientation in so far as different orientations should be adopted as a consequence of the task demands that are imposed. In this experiment, an interpretation in terms of effort is ruled out by virtue of the equivalent levels of memory accuracy in the two target designations, but of course this raises the question as to why there were no reliable differences between the ERPs evoked by correct rejections in the low relative difficulty group in Experiment Two. In that group, as in this experiment, memory accuracy was high, and in fact markedly similar in the two cases (compare the data in Tables 5.2 and 6.1).

One explanation for this disparity across studies is that it is due to the degree of overlap between the processing requirements for each target designation in each experiment. According to this account, the degree of overlap between the orientations adopted by participants in the semantic and phonological representations in the low relative difficulty group in Experiment Two is greater than that for the orientations adopted by participants in the function and drawing designations in this experiment. If this was correct, perhaps because there is more access to shared levels of representation in the semantic/phonological than the function/drawing case, then it would explain this disparity across studies. Another explanation is that the activity indexing different orientations in the low relative difficulty group is generated in structures in which activity does not propagate to the scalp, but this seems unlikely, given that there were reliable differences between the ERPs evoked by new items in the high relative difficulty group in Experiment Two.

Whichever account turns out to be correct, the data in this experiment indicate that reliable indices of orientation can be obtained even when memory accuracy is high, and thus in addition to providing additional support for the concept of orientation, these data argue against the earlier suggestion that the absence of differences between ERPs evoked by new words in the low relative difficulty group came about because high levels of memory accuracy – and presumably ease of access to stored information – reduced the need to adopt task-specific orientations.

6.5.3. Left-parietal old/new effects

Correctly classified target words in both target designation tasks evoked robust left parietal old/new effects. By contrast, the correctly classified non-target words in both target designation tasks failed to show reliable left parietal old/new effects. The absence of the ERP signature of recollection for non-targets suggests that despite the high levels of memorability for both targets and non-targets, participants can exert control over what information is recollected. The findings in the present study are therefore consistent with Herron and Rugg's proposal that when target accuracy is high, participants adopt a strategy of attempting to recollect information about targets only (Herron and Rugg, 2003b). Non-target words, on the other hand, are successfully excluded on the basis of the failure of this class of items to elicit contextual information diagnostic of target source.

One factor to be considered, however, is whether the disparities between the target and the non-target old/new effects can be explained in terms of modulations of the P300 component. The P300 component is negatively correlated with the probability of stimulus occurrence, and is typically larger for task-relevant than for task-irrelevant stimuli (Donchin, 1981; Donchin and Coles, 1988). In the present experiment, targets can be regarded as target-relevant in that the success or failure of recollection of target information is assumed to be a basis for task judgements. The design of the experiment also has a response probability imbalance built in: an equal number of new, non-target and target words were presented at test and responses to non-targets as well as new words were made on one key while responses to targets were made on another. This means that the likelihood of a target response is substantially lower than that of a non-target/new response.

The data in the present experiment do not, however, suggest a substantial contribution from the P300 to the target/non-target disparity. The marked left-lateralisation and left parietal maximum of the target old/new effects over the 500-800 ms epoch suggests that processes other than those underlying P300 are engaged during this epoch, since P300 shows no strong hemisphere bias. This does not, however, preclude the possibility that a larger P300 for targets is responsible for some of the amplitude differences between targets and non-targets over this critical epoch. However, the fact that the amplitude differences between target and non-target old/new effects are also larger at left hemisphere than at right hemisphere locations suggests that P300 modulations are not responsible for all of the target/non-target disparity. For the target/non-target differences to be accounted for wholly in terms of P300 modulation, the amplitude differences between targets and non-targets would have a Pz maximum and would fall off with increasing distance from Pz. The data in Experiment Three do not have this profile. In addition, in studies designed to assess the correspondence between P300 and the left-parietal old/new effect, it has been established that the ERP old/new effects are not sensitive to variations in the proportions of old and new items (Friedman, 1990; Smith and Guster, 1993; Herron, Quayle and Rugg, 2003).

6.5.3.1. Linking orientation effects and old/new effects.

On the basis of this pattern of ERP old/new effects, therefore, the differences between the ERPs evoked by new words in the two target designation tasks can be interpreted as reflecting processes that are engaged in the pursuit of retrieval of task-relevant information only. This interpretation is broadly similar to that offered by Johnson and colleagues (1996) in their ERP study of source monitoring: they suggested that differences between ERPs evoked by classes of unstudied words reflected the different ways in which memory was probed for different kinds of information. While Johnson and colleagues (1996) emphasised the processes that evaluate the information that is evoked by test items, however, the findings in the present experiment suggest that these operations may in fact influence what is retrieved from memory.

6.5.4. Right-frontal old/new effect

In addition to the ERP old/new effects evoked by targets in both target designation tasks over left-parietal scalp sites, the ERP old/new effects that were obtained in the two tasks also showed the characteristic right-anterior distribution which onset around 800 ms post-stimulus, a finding similar to that observed in a number of other ERP studies in which source judgements have been required (e.g. Rugg et al., 1996; Wilding and Rugg 1996; Rugg et al., 1998). The right-frontal old/new effect was elicited by targets and non-targets in both target designation tasks. This suggests that the effect is not contingent on recollection, as no left parietal old/new effects were elicited by non-target words. This pattern of results therefore supports the view that the right frontal old/new effect is not tied closely to recollection, but it rather reflects processes related to monitoring and evaluation that are required for accurate task performance (Rugg et al., 2000; Ullsperger et al., 2000).

These findings are inconsistent with those of Herron and Rugg (2003a), where no right-frontal old/new effects are evident for targets or non-targets in either the word or the picture target condition. One possible explanation is that the high behavioural performance in both target designation conditions in the study of Herron and Rugg (2003a) meant that there was no need for participants to evaluate the retrieved information to maintain accurate task performance. This possibility is, however, unlikely given that the level of behavioural performance in the present experiment is similar to that in Herron and Rugg (2003a). This disparity across studies is presumably related to the different information to be retrieved in the two cases: cognitive operations in one case and modality of stimulus presentation in the other. What is common across these two studies is that the relationship between old words (targets and non-targets) and new words is the same, and in combination the findings in the two studies reinforce the functional separability of the left-parietal and right-frontal ERP old/new effects, as well as providing data that is broadly consistent with a monitoring/evaluation account of the latter effect.

6.5.5. Late posterior negativity (LPN)

From about 800 ms post-stimulus until the end of the recording epoch, non-targets elicited greater negativity over mid posterior sites than new test words in both target designation tasks. This late negative wave (Chapter 1) was initially interpreted as reflecting response-related rather than mnemonic processes, as the magnitude of the effect was correlated negatively with response times (Wilding and Rugg, 1997). In the present experiment, the RTs associated with both types of old words were significantly longer than the RTs to new words, a finding consistent with the above view. However, the late negative wave in the present experiment was reliable only for non-targets in both target designation tasks. The data therefore support the view that the late posterior negativity reflects processes that are not response related (Cycowicz et al., 2001). The possibility that the negativity reflects retrieval of contextual information, either colour-specific information (Cycowicz et al., 2001) or more general information has been discussed (Johannsen and Mecklinger, 2003).

In both target designation tasks, however, non-targets did not elicit left parietal old/new effects. Thus, it is unlikely that the late negative wave evoked by non-targets reflects processes related to retrieval of contextual information. The fact that the LPN is observed only for non-target words in both target designation tasks does, however, support the proposal offered by Johannsen and Mecklinger (2003) regarding the engagement of action monitoring processes resulting from the presence of response conflict. As described in Chapter 1, in an exclusion task, an 'old' response is to be made to only one class of old items and a 'new' response is to be made to the other class of old items as well as to genuinely new items. It is possible that such a requirement produces conflict in responses. Therefore, to the extent that responding to non-target words involved greater action monitoring mechanisms compared to responding to targets, this explains the presence of the LPN for non-targets, but not for targets.

6.5.6. Right central negative modulation

From about 600-800 ms post-stimulus, the ERPs evoked by old words are relatively more negative-going than those evoked by new words in the function target designation. This negativity is right-lateralised and most marked at central scalp locations. Similar modulations were reported by Wilding and Sharpe (2004), when a 2.5 s upper limit was imposed on the time to respond. The fact that this negativity is also observed in the present experiment, in which no explicit upper limit is imposed, suggests that the modulations are not a consequence of the differential engagement of retrieval processes due to response-time demands. Inspection of the ERP waveforms in Figures 6.1, 6.2 and 6.3 suggests that the appropriate way to characterise these differences across tasks is a greater relative positivity for new words in the function target designation task than in the drawing target designation task. That is, the differences between the old/new effects in the two target designation tasks are carried primarily by the ERPs evoked by new test words. This pattern of data suggests that the ERP old/new effects in the present experiment varied not according to the old/new status of the test words, but due to the engagement of task-specific retrieval processes that may modulate the likelihood of information retrieval from memory. The finding also reinforces the necessity for caution when making inferences about changes in scalp distribution on the basis of difference waves (Dzulkifli and Wilding, in press).

6.6. Concluding remarks

The findings in Experiment Three confirm the view that when memory for targets is high participants adopt a strategy of engaging in recollection of target information only. The data are therefore consistent with the claim made by Herron and Rugg

(2003b) regarding the retrieval strategies that participants adopt in some exclusion tasks.

The differences between the ERPs evoked by new items in the function and the drawing target designation tasks were interpreted as reflecting processes that are important for the selective retrieval of information from memory – in particular, the selective retrieval of information about targets. This proposal is, however, based only on the observed correlation between the presence and absence of the left-parietal old/new effects for targets and non-targets, and the differences between the ERPs evoked by new test words separated according to target designation. Experiment Four is an attempt to provide further support for this account.

FIGURE 6.1: Grand average ERPs evoked by new words in the function and drawing target designation tasks. Electrode montage as for Figure 4.1 (Chapter 4).

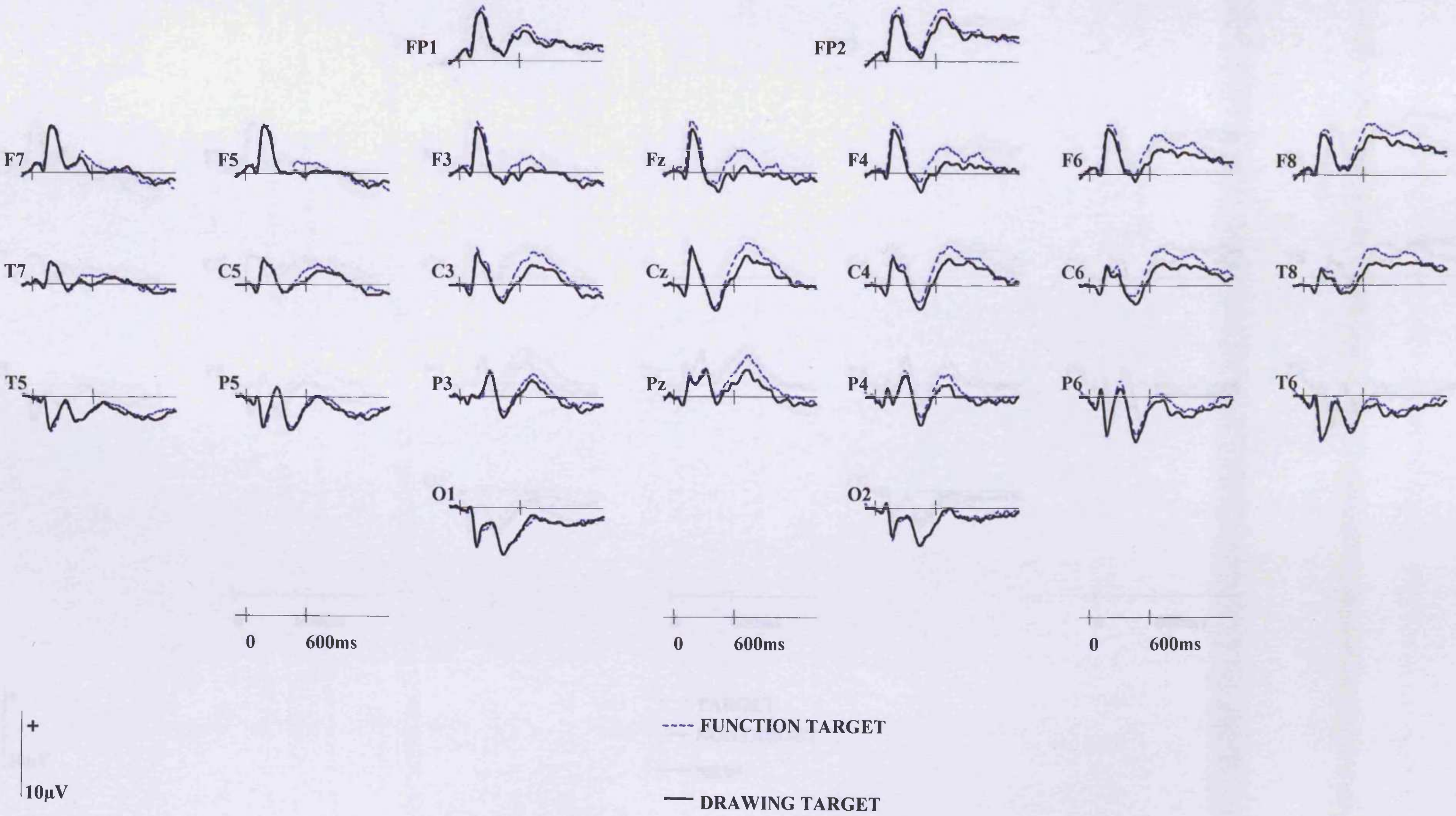


FIGURE 6.2: ERP old/new effects for targets and for non-targets in the function target designation task. Electrode montage as in Figure 4.1 (Chapter 4).

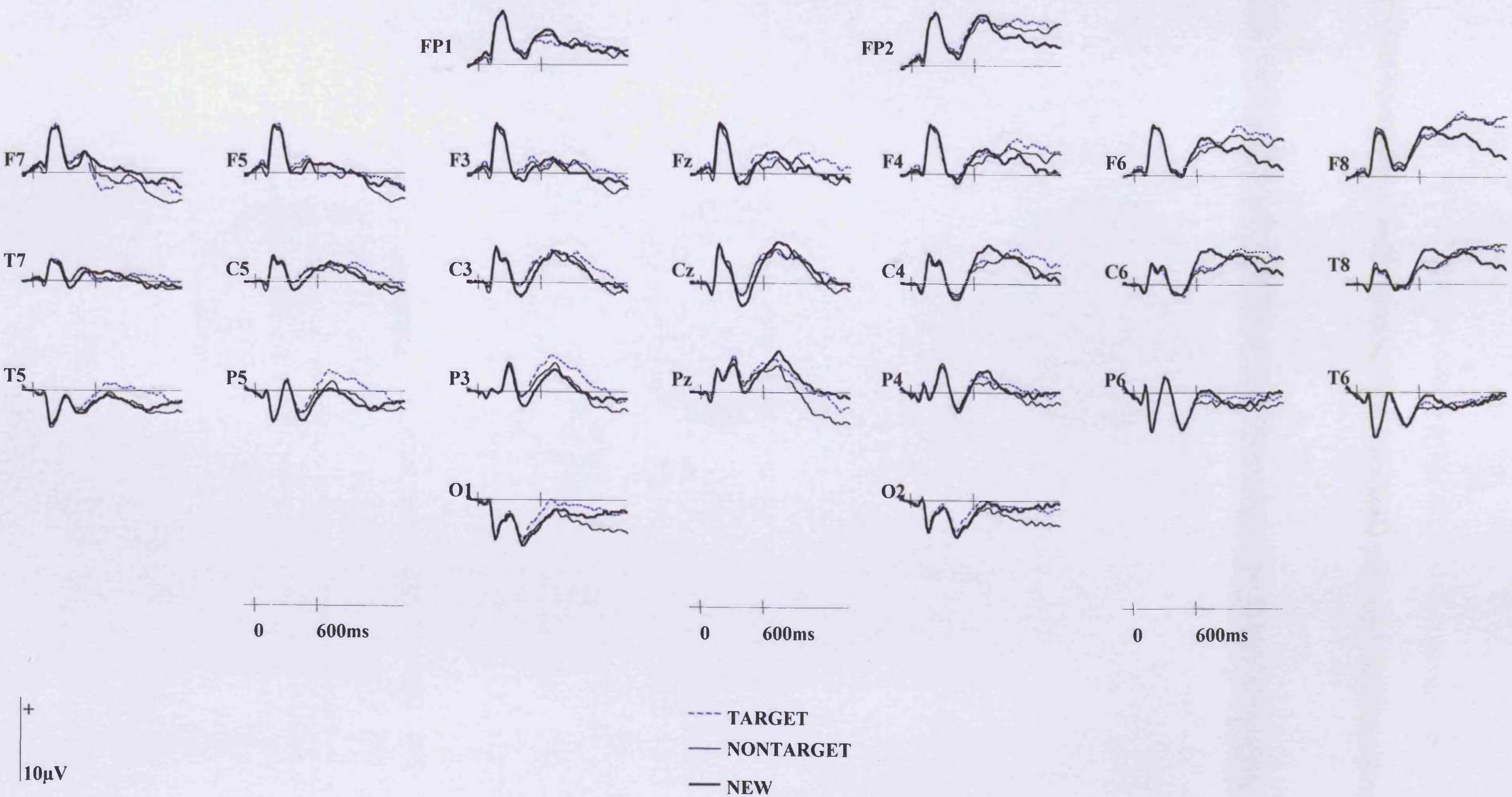


FIGURE 6.3: ERP old/new effects for targets and for non-targets in the drawing target designation task. Electrode montage as in Figure 4.1 (Chapter 4).

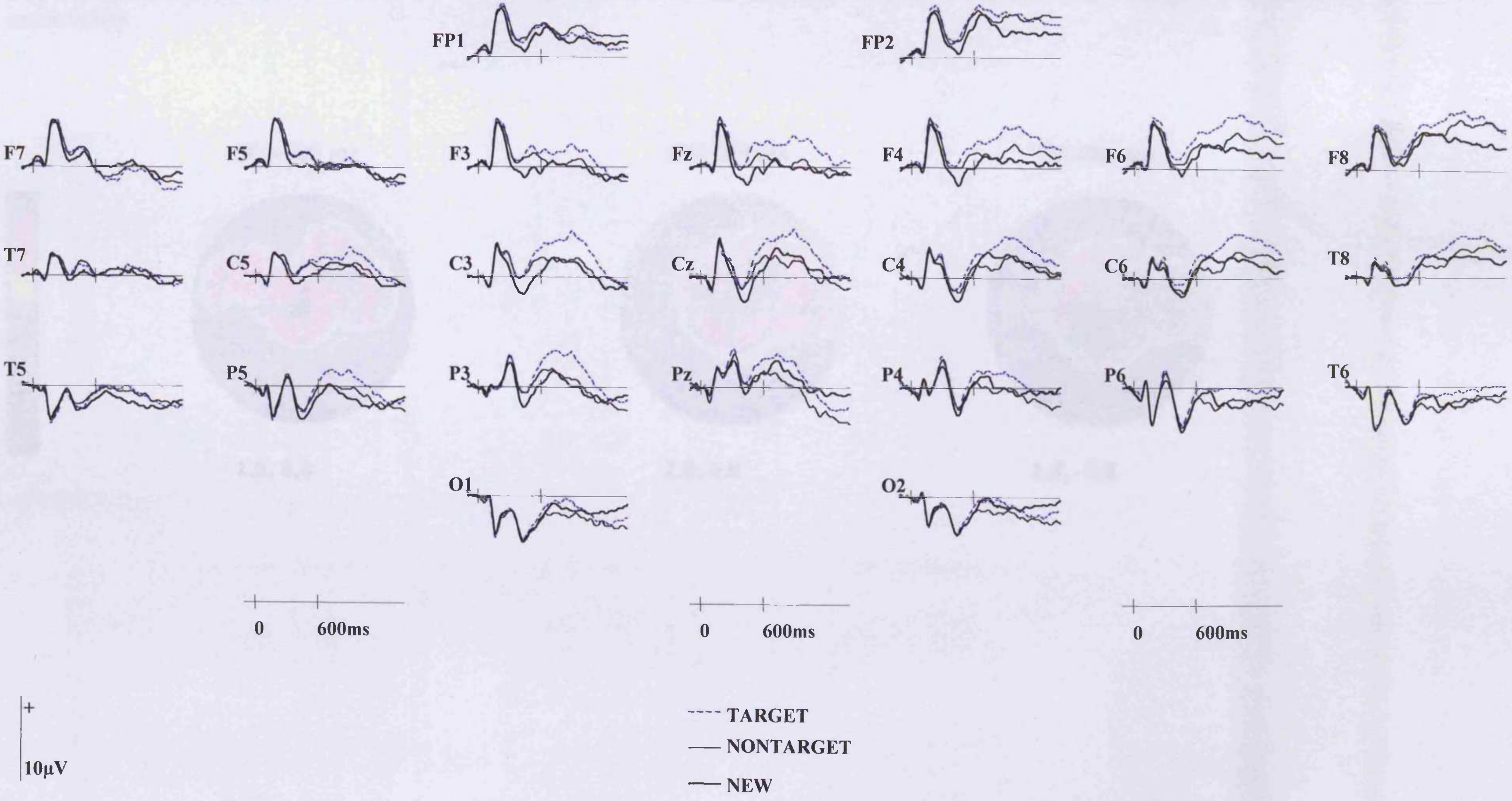


FIGURE 6.4: Topographic maps showing the scalp distributions of the differences between the activity elicited by new test words over the 500-600, 600-700 and 700-800 ms time windows. The maps were computed from the difference scores obtained by subtracting the mean amplitudes from the ERPs elicited by new words in the drawing target designation condition from those in the function target designation condition. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

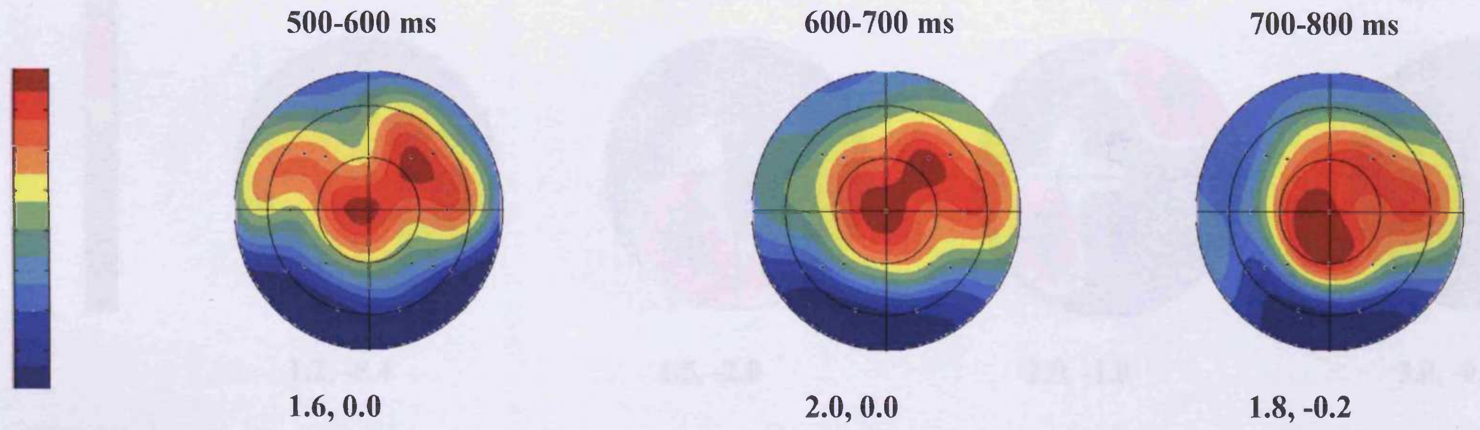


FIGURE 6.5: Scalp distributions of the ERP old/new effects for targets and non-targets in the function target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

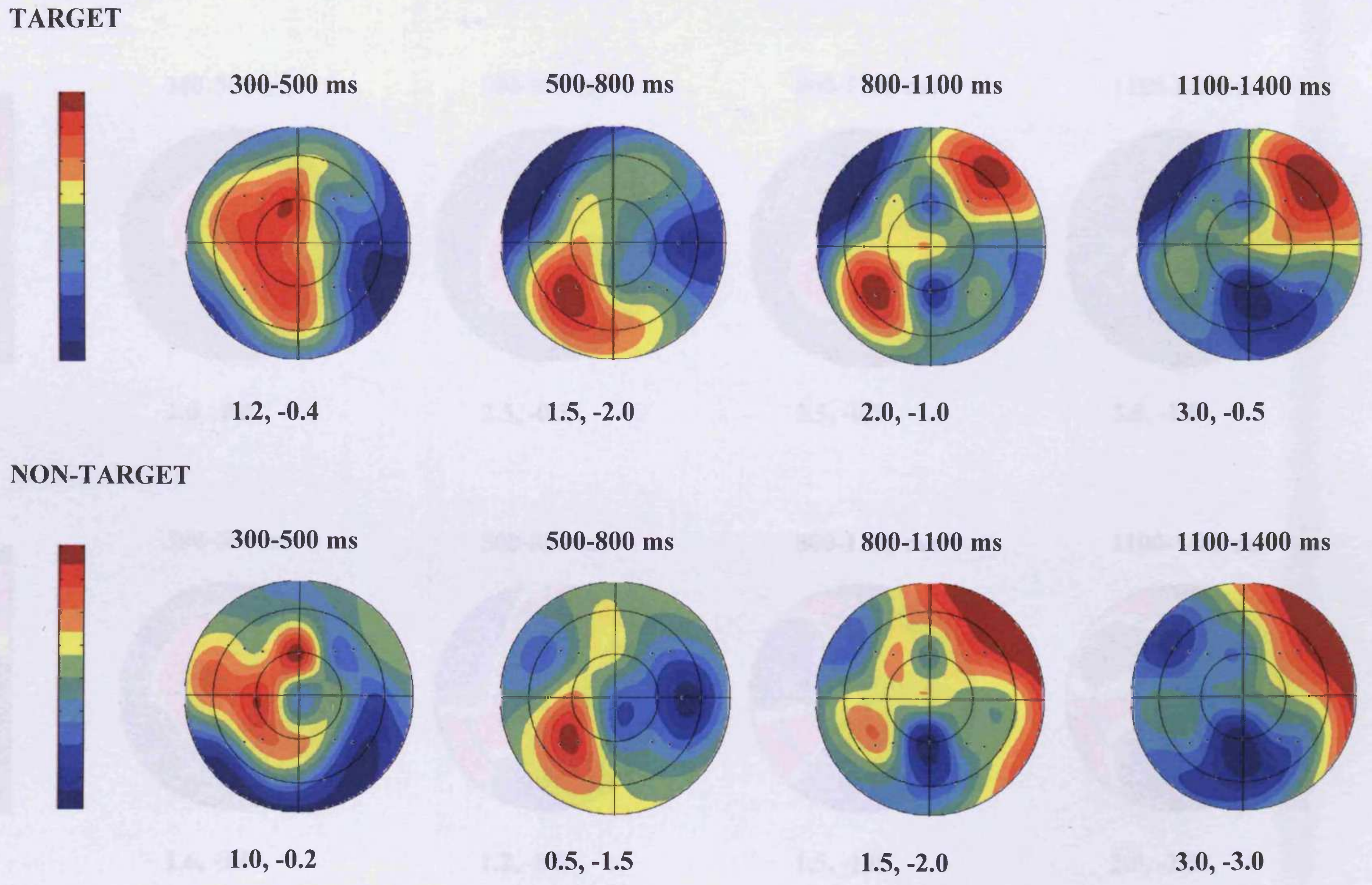


FIGURE 6.6: Scalp distributions of the ERP old/new effects for targets and non-targets in the drawing target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

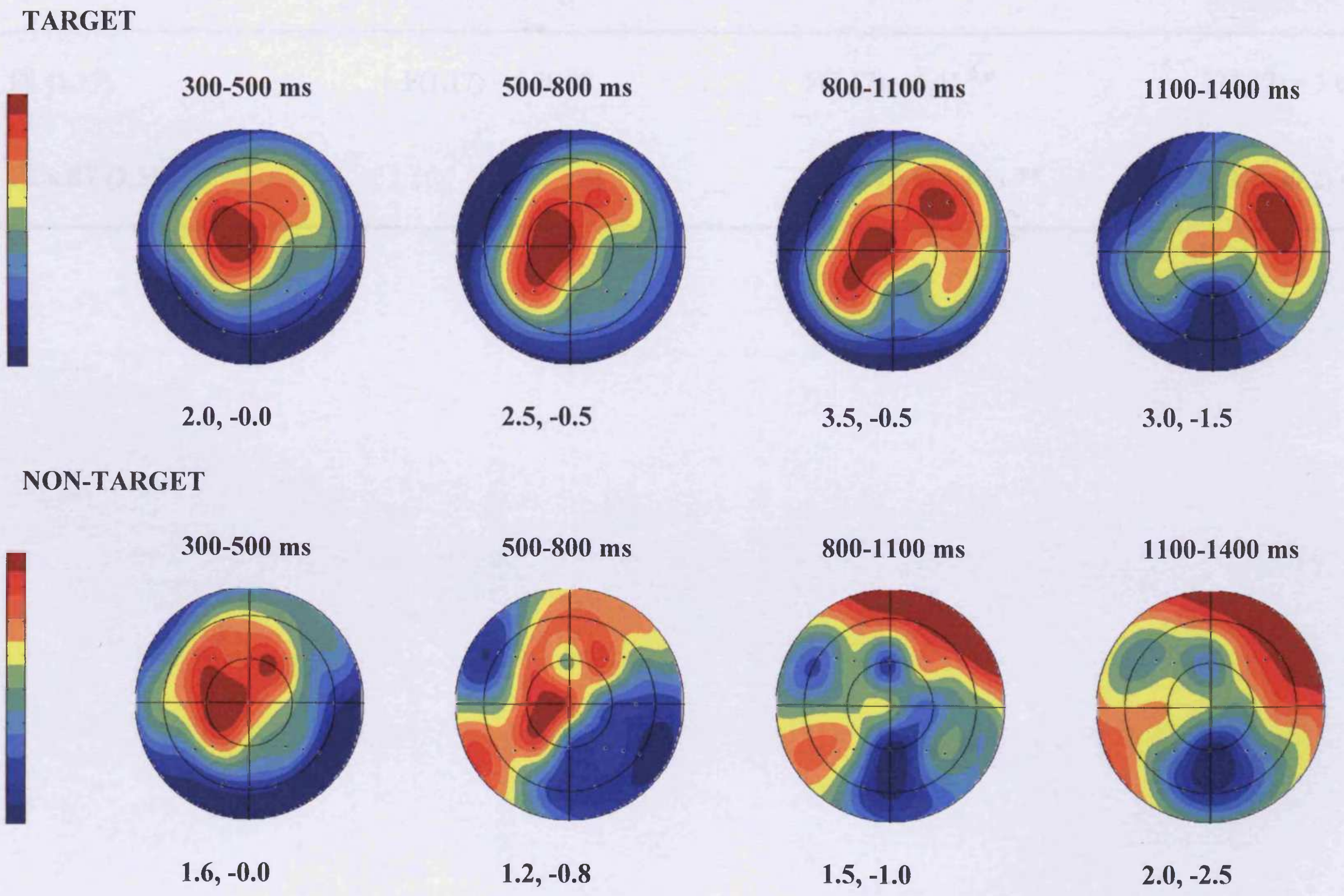


TABLE 6.3: Results of ANOVAs of the ERPs evoked by correctly rejected new words in the function and drawing target designation tasks. Key: TK = target designation, ST = site, * = p < .1, ** = p < .05, full df in brackets (1st column).

	500-600 ms	**600-700 ms**	**700-800 ms**
TK (1,17)	F(1,17) = 5.20 **	F(1,17) = 6.41 **	F(1,17) = 3.69 *
TK x ST (3,51)	ns	F(1.6, 27.6) = 4.21 **	F(1.8, 30.2) = 3.28 *

TABLE 6.4: The outcomes of follow-up analyses for ERP old/new effects over the 300-500 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1^{st} column).

300-500 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 7.56 ****	F(1, 17) = 7.59 ****	ns
CC x ST (3,51)	F(1.8, 31.4) = 5.95 ****	F(1.3, 21.9) = 4.60 **	ns

TABLE 6.5: The outcomes of follow-up analyses for ERP old/new effects over the 500-800 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

500-800 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	ns	ns	F(1,17) = 7.72 ***
CC x ST (3,51)	F(2.0, 34.5) = 9.14 ****	ns	F(1.9, 32.5) = 5.35 ***
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	ns	ns	ns
CC x HM x ST (3,51)	F(1.8, 30.5) = 6.06 ***	ns	F(2.1, 36.1) = 4.89 ***
CC x AP x HM (1,17)	F(1,17) = 7.16 ***	F(1,17) = 4.58 **	F(1,17) = 4.03 *
CC x AP x ST (3,51)	ns	F(1.9, 33.1) = 2.85 *	ns
CC x AP x HM x ST (3,51)	ns	F(2.1, 36.2) = 3.93**	ns

TABLE 6.6: The outcomes of follow-up analyses for ERP old/new effects in the function target designation task over the 800-1100 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

800-1100 ms
Function target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	ns	ns	ns
CC x ST (3,51)	F(1.8, 31.2) = 2.91 *	ns	ns
CC x AP (1,17)	ns	ns	F(1,17) = 7.32 ***
CC x HM (1,17)	ns	ns	ns
CC x HM x ST (3,51)	F(1.4, 23.4) = 3.45 *	ns	ns
CC x AP x HM (1,17)	F(1,17) = 6.91 ***	ns	F(1,17) = 3.71 *
CC x AP x ST (3,51)	F(2.1, 36.2) = 4.99 ***	F(1.9, 32.3) = 4.63 ***	ns
CC x AP x HM x ST (3,51)	F(2.0, 33.9) = 3.98 **	F(2.3, 39.7) = 2.57 *	ns

TABLE 6.7: The outcomes of follow-up analyses for ERP old/new effects in the drawing target designation task over the 800-1100 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant full df in brackets (1^{st} column).

800-1100 ms
Drawing target designation task

Effect	**Contrast**		
	Target vs. New	*Non-target vs. New*	*Target vs. Non-target*
CC (1,17)	F(1,17) = 13.85 ***	ns	F(1,17) = 8.98 ***
CC x ST (3,51)	F(1.7, 28.2) = 9.33 ****	ns	F(2.4, 40.3) = 14.71 ****
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	ns	ns	F(1,17) = 5.07**
CC x HM x ST (3,51)	F(1.8, 30.4) = 6.48 ***	ns	F(2.4, 40.8) = 4.97 ***
CC x AP x HM (3,51)	F(1,17) = 10.12 ***	F(1,17) = 4.59 **	ns
CC x AP x ST (3,51)	F(1.8, 30.3) = 3.50 **	F(2.0, 34.0) = 5.66 ***	ns
CC x AP x HM x ST (3,51)	ns	F(2.0, 34.0) = 2.92 *	ns

TABLE 6.8: The outcomes of follow-up analyses for ERP old/new effects in the function target designation task over the 1100-1400 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

1100-1400 ms
Function target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1, 17) = 9.90 ***	ns	F(1,17) = 11.65 ***
CC x ST (1,17)	ns	ns	ns
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	ns	F(1,17) = 8.48 ***	F(1,17) = 4.72 **
CC x HM x ST (3,51)	ns	F(1.6, 27.3) = 4.68 **	F(1.6, 27.8) = 4.72 **
CC x AP x HM (1,17)	F(1,17) = 9.72 ***	F(1,17) = 11.08 ***	ns
CC x AP x ST (3,51)	ns	F(1.9, 32.5) = 3.55 **	ns
CC x AP x HM x ST (3,51)	ns	F(2.3, 39.7) = 4.49 ***	ns

TABLE 6.9: The outcomes of follow-up analyses for ERP old/new effects in the drawing target designation task over the 1100-1400 ms epoch. Key: * $p < .1$, ** $p < .05$, *** $p < .01$, **** $p < .001$, ns = non-significant, full df in brackets (1st column)

1100-1400 ms
Drawing target designation task

Effect	**Contrast**		
	Target vs. New	*Non-target vs. New*	*Target vs. Non-target*
CC (1,17)	F(1,17) = 3.09 *	ns	ns
CC x ST (3,51)	F(1.3, 22.9) = 5.36 **	ns	F(2.0, 34.8) = 6.97 ***
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	F(1,17) = 12.03 ***	ns	F(1,17) = 4.31**
CC x HM x ST (3,51)	F(1.8, 31.2) = 4.79 **	ns	ns
CC x AP x HM (1,17)	F(1,17) = 21.69 ****	F(1,17) = 16.61 ****	ns
CC x AP x ST(3,51)	F(2.0, 34.7) = 3.28 **	F(2.2, 36.8) = 5.18 ***	ns
CC x AP x HM x ST (3,51)	ns	F(2.1, 36.0) = 2.53 *	ns

Chapter 7

7.1. Introduction

Herron and Rugg (2003b) proposed that when the likelihood of recollecting information about targets is high, then in exclusion tasks participants adopt a strategy of attempting to recollect information about targets only. The corollary to Herron and Rugg's account, therefore, is that left-parietal old/new effects for non-targets should re-emerge as the likelihood of target accuracy declines. Herron and Rugg reported data consistent with this account, but as well as target accuracy the information associated with targets and with non-targets was not equivalent in the two experiments where the presence and absence of the critical effects was reported (see Chapter 1). The findings in Experiment Three provide a means of testing the account due to Herron and Rugg (2003b) in a design that does not have this confound. This was one of the motivations for Experiment Four, in which the same tasks were used as in Experiment Three, but study-list lengths were increased as were study-test intervals. The presence of reliable left-parietal old/new effects in Experiment Four would therefore provide strong evidence supporting the view that as the likelihood of recollecting information about targets diminishes participants are more likely to attempt to recollect information about non-targets as well as targets.

A second motivation for Experiment Four follows from the proposal that the differences between the ERPs evoked by new items in the function and the drawing target designation tasks reflect processes that are important for the selective retrieval of information from memory – in particular, the selective recollection of information about targets. There have to date been no tests of this proposal, and as already noted the findings in Experiment Three provide simply a correlation between the conditions under which non-target parietal old/new effects are attenuated and the conditions under which differences between classes of ERPs evoked by new items were obtained (see also Herron and Rugg, 2003a).

Experiment Four, however, provides a means of testing this proposal. The logic behind this is that if the differences between the ERPs evoked by new items in Experiment Three are indeed reflections of processes that are engaged in order to restrict recollection to targets, then these differences should be attenuated when recollection of targets as well as non-targets is prioritised. Therefore, if left-parietal old/new effects are obtained for targets as well as non-targets in Experiment Four, and the differences between the ERPs evoked by new test words are smaller than in Experiment Three, these findings would in combination support the functional account of the orientation effects that has been offered here. As detailed below, these possibilities were investigated by effectively replicating Experiment Three, with the exception of reducing the number of study-test cycles and increasing list lengths and study-test intervals in order to reduce overall memory accuracy.

7.2. Method

7.2.1. Participants

22 participants (15 female) took part in Experiment Four. Each was paid at the rate of £7.50 per hour. The data from four participants were discarded due to excessive EOG

artefacts (see Chapter 3 for details). Of the remaining 18 participants, 13 were female. The average age of the participants was 21 years (range 18 to 23).

7.2.2. Experimental items

360 experimental items were used to create an experimental list that comprised one study phase and two test phases. The study phase was composed by combining the two study phases in Experiment Three. In contrast to Experiment Three, in Experiment Four, 20 filler words were placed at the beginning of the study phase and another 20 filler words were added after the last item. These filler words were not presented in the test phase.

The two test phases consisted of 360 critical words, 240 of which were from the study phase. These words were split into two test lists, each containing 180 words. In each test list, 120 words had been presented at study. The remainder were words that had not appeared in the study phase. One filler word was added to the beginning of each test list.

Three task lists were created, consisting of different orderings of the 360 critical words and fillers. Across lists, all words appeared after an asterisk and a plus sign and all words were presented at study and test as well as at test only. The order of presentation of words at study and at test within each cycle was determined randomly for each participant. In total, each participant saw 642 words (240 study items + 40 fillers, 180 'test one words' + 1 filler and 180 'test two words' + 1 filler).

7.2.3. Procedure

The procedure for Experiment Four was similar to Experiment Three, with two exceptions: participants commenced the experiment by completing a study phase. In each study trial, less time was given to respond as the message PLEASE SPEAK NOW appeared on the screen 1000 ms after the presentation of a study stimulus. This is in contrast to Experiment Three, where participants saw the message 1500 ms after stimulus presentation. After completing the study phase, participants had a 40-minute break, during which they were fitted with the electrode cap. Each participant then completed two test phases. Target designation differed in the two test phases and the designation given first was balanced across participants. The procedure for completing each test trial was the same as in Experiment Three.

7.3. EEG recording

The EEG recording parameters and trial exclusion criteria were the same as those employed in Experiment Three.

7.4. Results

7.4.1. Behavioural data

Table 7.1 displays the probabilities of correct responses to each class of test words in the function and drawing target designation tasks. Analyses using t-tests revealed that in both target designation tasks, the likelihood of target responses to targets was higher than the likelihood of target responses to either new or non-target words ($t(17) > 6.41$, $p < .001$; see Appendix C for details).

The likelihoods of correct responses at retrieval were subjected to ANOVA with TK (function, drawing) and CC (target, new, non-target) as factors. The analysis revealed only a main effect of CC (F(1.9, 31.9) = 33.25, p < .01). As in the analyses completed in Experiment Three, in the absence of reliable effects involving TK, follow-up analyses were conducted by collapsing data across this factor, and comprised all possible paired comparisons of the likelihood of correct responses to target, new and non-target words. The outcomes from Bonferroni corrected t-tests (adjusted alpha level = 0.017) indicated that new words were associated with significantly more accurate responses than were targets (0.67 vs. 0.92; t(17) = 7.22, p < .001) and non-targets (0.81 vs. 0.92; t(17) = 4.05, p < .001). The likelihood of correct responses to non-targets was superior to the likelihood of correct responses to targets (0.67 vs. 0.81; t(17) = 4.56, p < .001).

Target designation task	**Word Condition**		
	Target	**New**	**Non-target**
Function	0.69 (.15)	0.89 (.12)	0.82 (.17)
Drawing	0.65 (.17)	0.94 (.05)	0.80 (.15)

Table 7.1. Mean proportions of correct responses to target, new and non-target words in the function and drawing target designation tasks. (S.D. in brackets).

The reaction times for correct responses for target, new and non-target words in the function and drawing target designation tasks are shown in Table 7.2. The analysis of RTs is restricted to these three critical word conditions, since they are of primary interest in this experiment. ANOVA of RTs incorporated the same factors as above and revealed a main effect of CC only (F(1.4, 24.6) = 19.74, p < .001). Bonferroni corrected t-tests (adjusted alpha level = 0.017), conducted on data collapsed across the factor of TK, indicated that new words were associated with significantly faster RTs than either targets (1374 vs. 1179; t(17) = 3.65, p = .002) or non-targets (1422 vs. 1179; t(17) = 6.60, p < .001). RTs to targets and non-targets did not differ significantly.

Target designation task		**Word Condition**	
	Target	**New**	**Non-Target**
Function	1352 (349)	1178 (308)	1408 (323)
Drawing	1396 (446)	1181 (273)	1437 (364)

Table 7.2. Mean reaction time (ms) for correct responses to target, new and non-target words in the function and drawing target designation tasks. (S.D. in brackets).

7.4.1.2. Between-experiment analysis

The probabilities of correct judgements and the RTs to target, non-target and new words were also compared between Experiments Three and Four, in order to determine whether the level of memory accuracy differed between the two experiments. ANOVA incorporating the factors of experiment (EX) and CC revealed a main effect of EX (F(1,34) = 11.13, p < .01) and CC (F(1.8, 60.7) = 69.91, p < .01). The EX x CC interaction approached significance (p = .09). The main effect of experiment confirms that the likelihood of correct judgements was higher for all conditions in Experiment Three than in Experiment Four. RTs to the three classes of word conditions in Experiments Three and Four did not differ significantly, although RTs were as expected somewhat slower in Experiment Four.

7.4.2. ERP data analyses

7.4.2.1. Analyses of ERPs evoked by new test words

Figure 7.1 displays the grand average ERP waveforms evoked by correct rejections in the function and drawing target designation tasks. Some differences between the ERPs evoked by the two classes of correct rejections are evident from approximately 500 ms post-stimulus. The differences are evident primarily at left inferior sites, and take the form of relatively more positive-going ERPs evoked by new words when drawing rather than function is designated as the target category. As the epoch progresses, a small relative positivity is associated with new words from the function target designation task, with the differences evident primarily at right anterior scalp locations.

The ERPs evoked by the two classes of correct rejections were subjected to ANOVA over three time windows: 500-700, 700-900, 900-1400 ms post-stimulus. The first two time windows were selected on the basis of the outcomes of the analyses of ERPs evoked by new words in Experiment Three (Chapter 6). The 900-1400 ms time window was chosen to encompass the differences that can be seen later in the recording epoch. The analysis strategy was the same as that employed in Experiment Three. The mean number of trials (range in brackets) contributing to the ERPs were 45 (30-58) and 46 (31-58) in the function and drawing target designation tasks, respectively.

The only reliable effect involving CC was a CC x HM x ST (F(2.1, 35.0) = 3.54, $p < .05$) interaction, revealed in the analysis over the 900-1400 ms time window. The outcome of this analysis reflects the fact that at right inferior sites, the ERPs evoked by new words are more positive-going when function was the target designation than when drawing was the target designation. On the other hand, at left inferior sites, the relatively greater positivity is associated with the ERPs evoked by new words when drawing was the target designation.

7.4.2.2. Analyses of ERP old/new effects

Figures 7.2 and 7.3 show the ERP old/new effects that were obtained in the function and drawing target designation tasks, respectively. In both target designation tasks, the ERPs evoked by targets and non-targets are more positive-going than those evoked by correct rejections, onsetting at around 500 ms post-stimulus, and evident markedly at left posterior scalp locations. Both targets and non-targets in the function and drawing target designation tasks also show an enhanced positivity relative to new words at right anterior sites from about 800 ms until the end of the recording epoch. From approximately 1200 ms post-stimulus, both targets and non-targets show a greater negativity than new words at Pz and P4, particularly in the function target designation condition. This negativity is sustained until the end of the recording epoch.

The ERP old/new effects were subjected to a series of global analyses identical to those employed in Experiment Three. Mean numbers of trials (range in brackets) contributing to the analyses were 36 (21-51) and 41 (21-54) for targets and non-targets in the function target designation task. The corresponding values for the drawing target designation task were 33 (18-51) and 40 (23-55). The outcomes of the analyses are described below, separated according to epoch. The initial analyses over the four time windows did not reveal any reliable effects involving target designation (TK). Thus, the follow-up analyses were completed on data collapsed across this factor, and comprised all possible paired comparisons of the ERPs evoked by correct judgements to target, non-target and new test words.

300-500 ms

The initial analysis over the 300-500 ms time window revealed a main effect of CC ($F(1.8, 29.8) = 7.77$, $p < .01$) and an interaction between CC and ST ($F(3.0, 51.5) = 3.10$, $p < .05$). As shown in Table 7.3, follow-up analyses revealed main effects of CC for both types of old word, each of which was moderated by an interaction between CC and ST. The interactions reflect the fact that the ERPs evoked by both classes of old word are reliably more positive-going than those evoked by new words, with a tendency for the positivity to be largest at superior and smallest at inferior scalp sites. The direct contrast of the ERPs evoked by targets and non-targets revealed no reliable effects.

500-800 ms

The initial analysis revealed a main effect of CC ($F(1.7, 28.5) = 6.03$, $p < .01$), and several interactions involving CC: CC x ST ($F(2.6, 43.4) = 5.32$, $p < .01$), CC x AP x HM ($F(1.5, 25.9) = 4.32$, $p < .05$), CC x AP x ST ($F(3.5, 59.8) = 5.55$, $p < .01$) and CC x AP x HM x ST ($F(4.0, 68.8) = 2.94$, $p < .05$). Table 7.4 (columns 1 and 2) shows that reliable effects in the follow-up analyses were restricted to those involving new words. The four-way interaction revealed by the target vs. new contrast was followed up by separate analyses at anterior and posterior sites. The analysis at anterior sites revealed a CC x ST interaction (F(2.0, 33.2) = 6.13, p < .01), indicating that at anterior locations, the relative positivity for targets is smallest at inferior and largest at the FP1/FP2 electrode sites. The follow-up analysis at posterior sites revealed a main effect of CC (1,17) = 10.55, p < .01), and several interactions: CC x HM (1,17) = 14.43, p < .01), CC x ST (1.5, 25.0) = 11.93, p < .01) and CC x HM x ST (2.4, 40.4) = 7.34, p < .01). These reflect the fact that the relatively greater positivity for targets in comparison to new words is largest at left posterior sites, particularly at superior sites. The CC x HM x ST and CC x AP x ST interactions revealed by the non-target vs. new contrast is due to the fact that the relatively greater positivity for non-targets in comparison to new words is largest at left hemisphere superior sites, and larger at posterior superior than anterior sites.

800-1100 ms

The initial analysis revealed a main effect of CC (F(1.5, 25.5) = 5.84, p < .01) which was moderated by three-way interactions (CC x AP x HM (F(1.5, 25.9) = 7.65, p < .01), CC x AP x ST (F(2.6, 43.5) = 8.06, p < .01, and CC x HM x ST (F(2.7, 46.6) = 2.94, p < .05) as well as a four way interaction between CC, AP, HM and ST (F(3.8, 64.7) = 3.27, p < .01). Follow-up analyses involving new words revealed identical patterns of interactions involving condition for both types of old word (see Table 7.5). Subsequent analyses at anterior locations revealed a main effect of CC (F(1,17) = 4.59, p < .05) only for non-targets, while for targets the main effect of CC approached significance (F(1,17) = 4.38, p = .05), reflecting the fact that there is a relatively greater positivity associated with old compared to new words. The follow-up analysis at posterior locations revealed CC x HM (targets: F(1,17) = 7.12, p < .05; non-targets:

F(1,17) = 9.39, p < .01), CC x ST (targets: F(1.6, 28.0) = 8.74, p < .01; non-targets: F(2.0, 34.4) = 6.42, p < .01) and CC x HM x ST interactions (targets: F(2.6, 44.5) = 5.66, p < .01; non-targets: F(2.0, 33.7) = 6.21, p < .01). These interactions reflect the fact that the relatively greater positivity for old words in comparison to new words is largest at left posterior sites, particularly at P5.

1100-1400 ms

The initial analysis revealed two three-way interactions: CC x AP x HM (F(1.6, 27.3) = 14.49, p < .01) and CC x AP x ST (F(3.7, 63.0) = 4.61, p < .01), which were moderated by a CC x AP x HM x ST interaction (F(3.6, 61.6) = 4.13, p < .01). As displayed in Table 7.6, analyses involving new words revealed the same three-way interactions for both types of old words, which were moderated by a four-way interaction involving CC, AP, HM and ST in each case. Follow-up analyses at anterior sites revealed main effects of CC for both targets (F(1,17) = 7.45, p < .01) and non-targets (F(1,17) = 11.89, p < .01), as well as CC x HM interactions (targets: F(1,17) = 5.12, p < .05; non-targets: F(1,17) = 5.57, p < .05), indicating that old words evoked greater positivity than new words, with the effect being larger over the right than the left hemisphere. For targets only, a CC x HM x ST interaction was also significant (F(2.1, 35.4) = 5.37, p < .01), reflecting the fact that the relative positivity for targets is largest at F6. Follow-up analyses at posterior sites revealed a CC x HM interaction (targets: F(1,17) = 10.87, p < .01; non-targets: F(1,17) = 8.30, p < .01), a CC x ST interaction (targets: F(2.0, 34.6) = 8.04, p < .01; non-targets: F(2.4, 40.6) = 5.42, p < .01) and a three-way interaction involving CC, HM and ST (targets: F(2.4, 40.8) = 3.54, p < .05; non-targets: F(2.5, 43.0) = 4.14, p < .01). The main reason for these interactions is the polarity reversal evident at posterior locations. At left hemisphere sites, particularly at P5, the relatively greater positivity is associated with old words, while over the right hemisphere, particularly at P6, the relative positivity is associated with new words.

Analysis at P5

As in Experiment Three, the ERP old/new effects in this experiment were also subjected to a specific analysis to determine the relationship between the ERP signature of recollection – the left-parietal ERP old/new effect - for targets and for non-targets separated according to target designation task. The analysis strategy was the same as described in Experiment Three. The initial analysis revealed only a main effect of CC (F(1.6, 26.7) = 15.81, p < .01). Follow-up analyses, collapsed across the factor of target designation, revealed that the ERPs evoked by targets were more positive-going than those evoked by non-targets (F(1,17) = 11.89, p < .01) and by new words (F(1,17) = 20.80, p < .01). The mean amplitudes of the ERPs evoked by non-targets were also more positive-going than the ERPs evoked by new words (F(1,17) = 9.65, p < .01).

Consistent with the additional analyses completed in Experiment Three, in Experiment Four additional analyses were also completed over the 600-800 ms and 800-1400 ms epochs at C6 and Pz, respectively. The purpose of these analyses and the sites that were used is the same as described in the previous experiment. The data were submitted to ANOVA, employing the same factors as in Experiment Three. The analysis over these two time windows revealed no reliable effects involving CC.

7.4.2.3. Analysis of scalp distributions

The analysis of scalp distributions was completed on the ERP old/new effects only, since the foregoing magnitude analyses conducted on the ERPs evoked by the two classes of correct rejections revealed reliable differences between this pair of conditions in one time window only.

Figures 7.4 and 7.5 display the topographic maps for the ERP old/new effects evoked by targets and non-targets in the function and drawing target designation tasks. The magnitude analysis did not reveal any effects involving target designation. Thus, the analysis of scalp distributions was completed by collapsing data across this factor and included the factors of epoch (300-500, 500-800, 800-1100 and 1100-1400 ms), CC (target, non-target) and site (25). The analysis revealed an interaction between epoch and site ($F(6.2, 104.6) = 4.49$, $p < .01$), reflecting the fact that the scalp distributions of the ERP old/new effects changed over time. The scalp distributions of the ERP old/new effects are focused at left posterior sites in the 500-800 ms time region, diverge to right anterior scalp regions in the 800-1100 ms epoch and extend to the central regions in the 1100-1400 ms epoch. Also evident from 800 ms onwards is the late posterior negativity focused on Pz.

7.5. Discussion

7.5.1. Behavioural Data

The accuracy of target judgements was less than .70 and significantly lower than that associated with either non-targets or new words in both target designation tasks. While the RTs for correct responses for both type of old words in the function and drawing target designation tasks did not differ from each other, those to correct target responses were slower compared to the RTs to new words. In comparison to Experiment Three, the accuracy of judgements at test was reliably lower here. The RTs associated with correct responses did not differ significantly between the two experiments. Therefore, as intended, the longer study phase and the 40-minute interval between study and test phases in Experiment Four decreased memory accuracy not only for targets, but for non-targets and new words as well. Therefore, if the hypothesis that low target accuracy discourages participants from attempting to recollect information about targets only is correct, then in comparison to Experiment Three, attenuation of the differences between the ERPs evoked by the two classes of correct rejections should be observed.

7.5.2. ERPs evoked by new words

As shown in Figure 7.1 and in the statistical analyses, the ERPs evoked by the two classes of new words did not differ from each other in the pre-900 ms post-stimulus interval. From 900 ms onward, the ERPs evoked by the two classes of new words diverged at left posterior as well as at right anterior locations. Given the statistically equivalent levels of behavioural performance, and in keeping with the logic of the contrast, these differences are indices of retrieval orientation. The fact that comparable modulations were not evident in Experiment Three is not in line with the pre-experimental predictions. The time course of these differences, particularly those at anterior locations over the right hemisphere, suggests that the effects reflect processes that work on recovered information. One possibility is that different evaluation requirements are in fact engendered by the two different target designations, and that these are required to a greater degree when memory accuracy –

and presumably the confidence in memory judgments – is low, as it is in relative terms in Experiment Four in comparison to Experiment Three.

Of more importance for present purposes, however, the differences between the ERPs evoked by new words in the function and drawing target designation tasks in Experiment Three took the form of more positive-going waveforms evoked by new words in the function rather than the drawing target designation task, and were reliable from 500-700 ms post-stimulus. No reliable effects involving target designation were obtained in the analysis over the same time windows in Experiment Four. As Experiments Three and Four differed primarily in terms of the level of overall memory accuracy, the absence of these differences can be explained in terms of the behavioural data. The differences between the ERPs evoked by correctly rejected new words in the function and drawing target designation tasks in Experiment Three were interpreted as reflecting the adoption of different orientations, which involved prioritising recollection of information about targets. The absence of the same effects in Experiment Four suggests that participants did not adopt different retrieval orientations, at least with respect to prioritising recollection, and this account is supported further by the ERP old/new effects that were obtained in Experiment Four.

7.5.3. Left-parietal old/new effects

It was argued that no left-parietal old/new effects were observed for non-targets in Experiment Three because participants prioritised recollection of target words. In keeping with earlier accounts (Herron and Rugg, 2003b), it was proposed that this retrieval strategy was adopted due to the ease of retrieving source information for targets, making the failure to elicit information diagnostic of the target source a good basis for classifying non-targets.

It was anticipated that by reducing the likelihood of recollection for targets in Experiment Four, participants would shift retrieval strategies and attempt to recollect information about targets as well as non-targets. If this hypothesis was correct, then left-parietal old/new effects should be observed for both targets and non-targets. The findings from Experiment Four supported this hypothesis, as the ERPs to targets and non-targets are significantly more positive-going than ERPs to new words at left parietal scalp sites between 500 and 800 ms. The differences between the non-target left-parietal old/new effects in the two experiments can therefore be explained in terms of the manipulation of memory accuracy. The findings in Experiment Four suggest that participants are more likely to retrieve source information for non-targets when the likelihood of recollecting information about targets is reduced, thereby providing support for the account offered by Herron and Rugg (2003b) in a task where accuracy and content are not confounded. The data from the left-parietal old/new effects therefore support the claim that the differences between the ERPs evoked by new words and separated according to target designation in Experiment Three reflect processes that influence the likelihood of restricting recollection to only some kinds of information that may be available.

The left-parietal old/new effects were, however, reliably smaller for non-targets than for targets in Experiment Four, and there is more than one possible explanation for this. First, some reduction in the magnitude of non-target old/new effects relative to target effects is to be expected because responses to non-targets and to new items are made on the same key in the exclusion task. As a result, a correct non-target response can come about because of the belief that a non-target item is in fact new. Since ERPs associated with misses typically resemble closely the ERPs associated with correct rejections (Neville et al., 1986; Smith, 1993; Wilding and Rugg, 1996; 1997), a consequence of this is that non-target old/new effects are likely to be of smaller amplitude than are the associated target effects.

Whether this explanation is sufficient to explain the disparity between the target and non-target effects in Experiment Four is not easy to establish, and another possibility is that perhaps some participants, or some participants some of the time, attempted to recollect information about targets only in Experiment Four, which would also result in the pattern of left-parietal ERP old/new effects that was obtained. Whichever of these accounts is correct, however, does not challenge the general claim that the extent to which participants depended upon recollection of targets rather than non-targets was greater in Experiment Three than in Experiment Four.

7.5.4. Right-frontal old/new effects

Both targets and non-targets in the function and drawing target designation tasks elicited an enhanced positivity at right anterior sites from about 800 ms post-stimulus onwards. This right-frontal old/new effect appears to be larger in amplitude in the drawing target designation task as in Experiment Three, but the magnitude analysis did not reveal any reliable effects involving target designation. The findings in the present experiment are again broadly consistent with the view that the right-frontal old/new effect reflects control processes that are engaged during and/or after retrieval

(Wilding and Rugg, 1996; Senkfor and Van Petten, 1998; Wilding, 1999; Friedman and Johnson, 2000), but they add nothing further to this account.

7.5.5. Late posterior negativity

The relatively greater positivity for new than for either type of old words is evident to a limited extent at the Pz electrode location, particularly in the function target designation task. There was, however, no statistical evidence for the presence of the effect. In Experiment Three, a late posterior negativity was reliable for non-target words only and was interpreted as reflecting processes related to action monitoring that operate when there is response conflict. To the extent that the effect reflects action monitoring processes, the fact that the effect was not reliable in the present experiment suggests that action monitoring processes are less likely to operate here than in Experiment Three, or that the action monitoring account is incorrect.

The extended time course of the left-parietal ERP old/new effects in Experiment Four compared to Experiment Three, however, may also be a reason for the smaller late posterior negativities in Experiment Four. By this account, the smaller negativities at posterior locations in Experiment Four are in part a reflection of the offsetting influence exerted by the positive-going parietal old/new effects. While likely having some influence, this explanation does not account for the fact that in the function target designation task the negativity – albeit not statistically significant – is comparable for targets and for non-targets, which is counter to the findings in Experiment Three. There is no straightforward explanation for this pattern of data.

7.6. Concluding remarks

Memory for targets was significantly lower in Experiment Four than in Experiment Three. Evidence suggesting that participants in Experiment Four did not engage in the retrieval strategies that were adopted in Experiment Three stems from the fact that reliable left-parietal old/new effects were obtained for both types of old words. Furthermore, there was no evidence for indices of different orientations in the present experiment in the time windows where there were effects in Experiment Three. These findings are the basis for claiming that one function of orientations is to influence the likelihood of recollection of task-relevant information. Under conditions where target accuracy is low, there is less incentive for participants to engage in selective recollection, and in order to optimise task-performance, participants may attempt to recollect both targets and non-targets, a claim supported by the presence of left-parietal old/new effects for both targets and non-targets.

Several mechanisms have been proposed to support this kind of selective retrieval processing (Anderson and Bjork, 1994). One process that might facilitate successful selective retrieval operates directly on the memory representations themselves. These representations may become more or less accessible, thereby making recollection of some kinds of information more likely than others. Another possibility is that the process operates on retrieval cues, rather than on memory representations themselves. According to this account, specific units or aspects of retrieval cues influence the access to the memory representations, such that they are more likely to interact with some memory representations than others. Selective recollection of information with only one of the two study tasks could also have come about because of the bias in the allocation of attention to some of the products of retrieval. All these possible mechanisms for selective retrieval processing are discussed further in the next chapter (Experiment Five), which was designed to partially distinguish between these competing accounts of the mechanisms responsible for the pattern of ERP effects reported in the present experiment as well as in Experiment Three.

FIGURE 7.1: Grand average ERPs evoked by new words in the function and drawing target designation tasks. Electrode montage as in Figure 4.1 (Chapter 4).

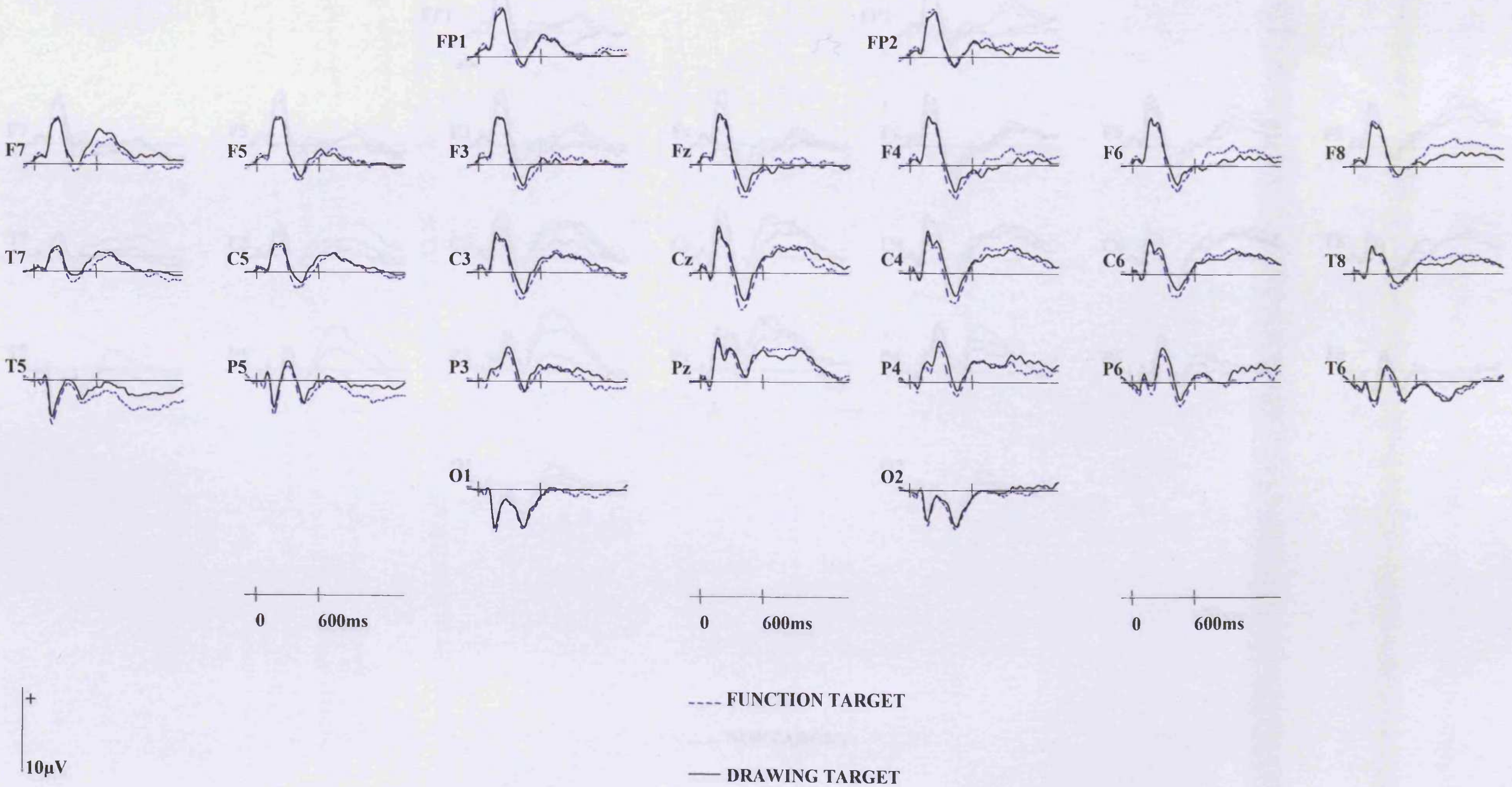


FIGURE 7.2: ERP old/new effects for targets and for non-targets in the function target designation task. Electrode montage as in Figure 4.1 (Chapter 4).

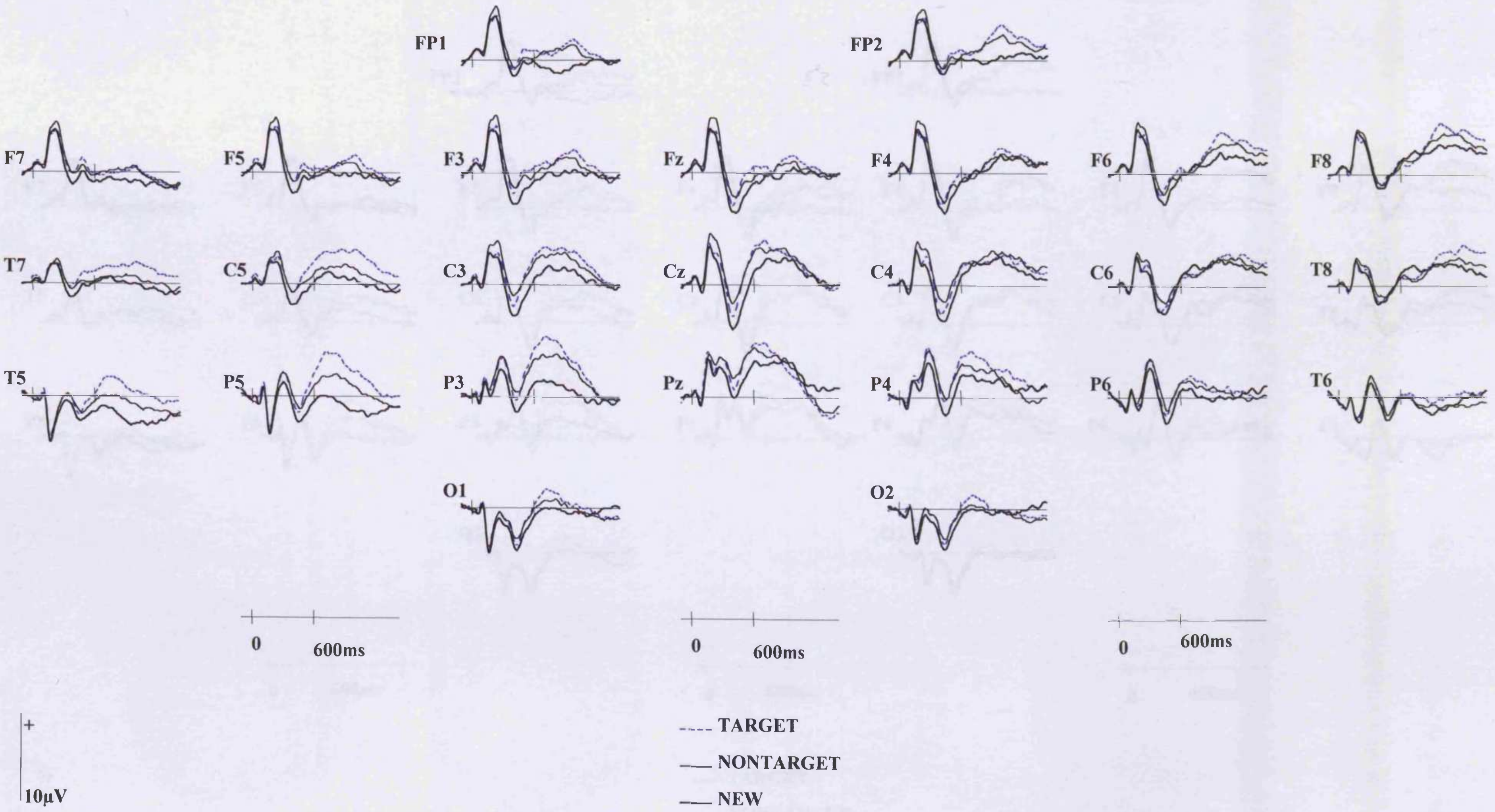


FIGURE 7.3: ERP old/new effects for targets and for non-targets in the drawing target designation task. Electrode montage as in Figure 4.1 (Chapter 4).

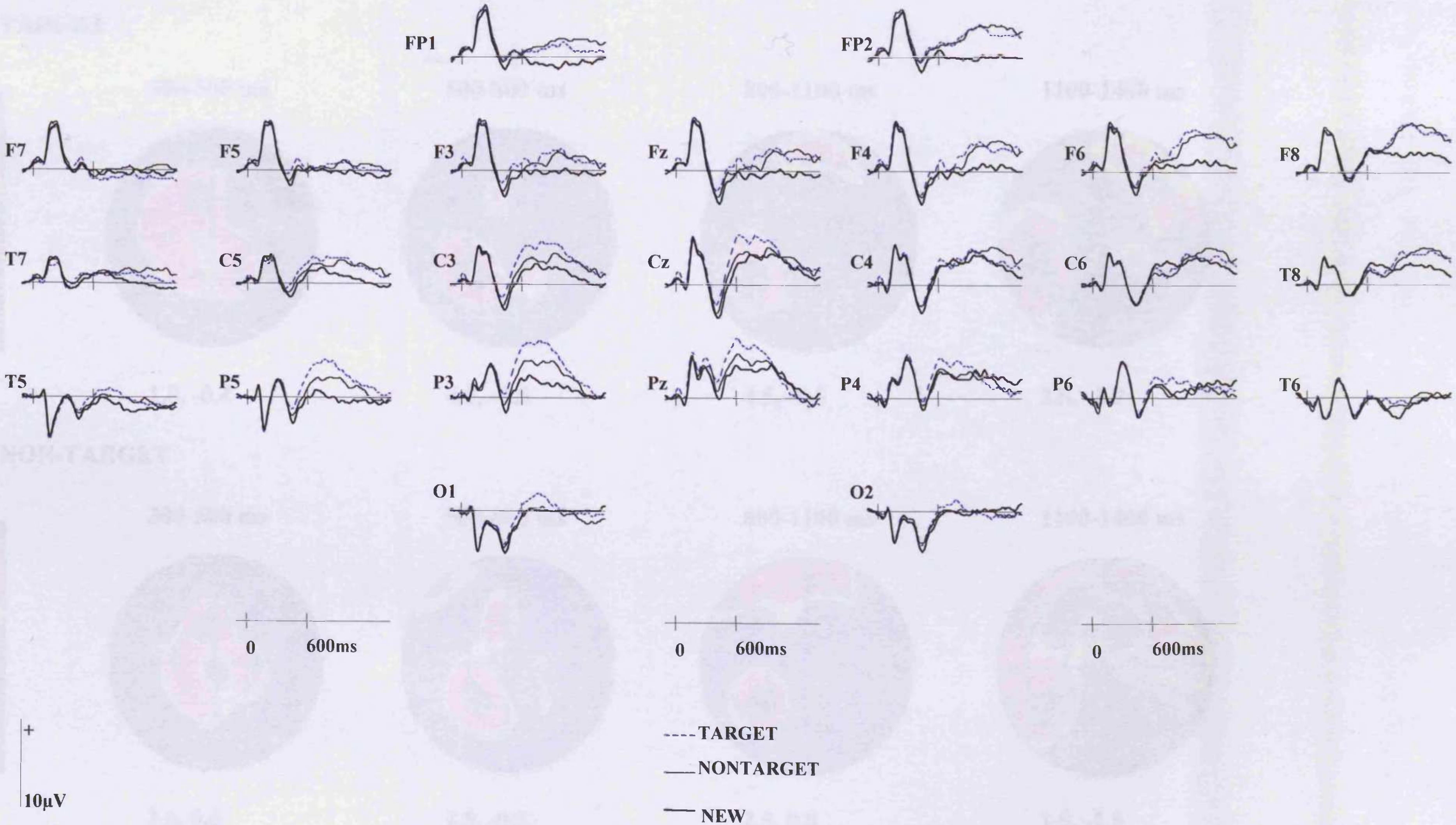


FIGURE 7.4: Scalp distributions of the ERP old/new effects for targets and non-targets in the function target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

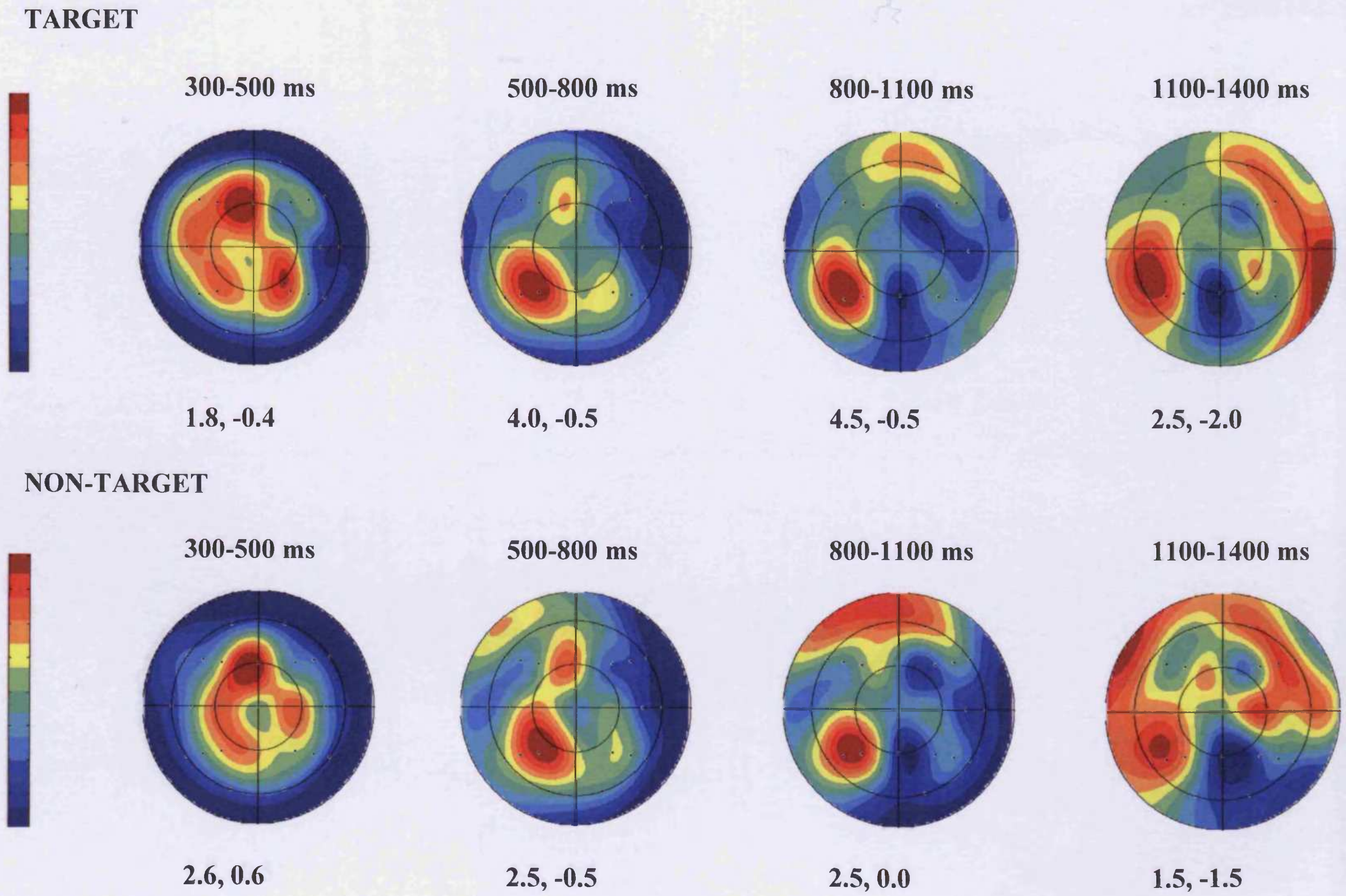


FIGURE 7.5: Scalp distributions of the ERP old/new effects for targets and non-targets in the drawing target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

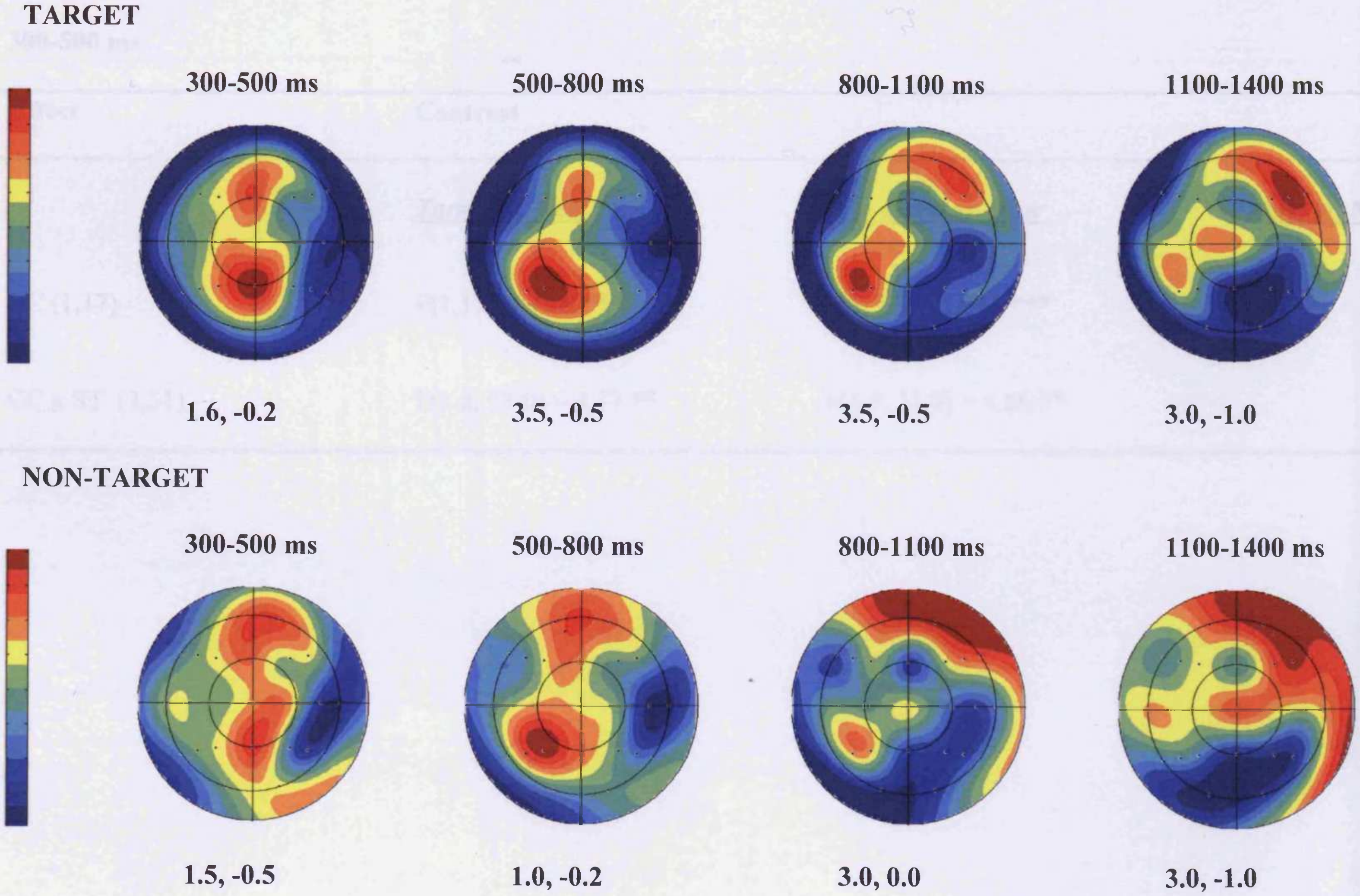


TABLE 7.3 : The outcomes of follow-up analyses for the ERP old/new effects over the 300-500 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

300-500 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 9.15 ***	F(1, 17) = 15.68 ***	ns
CC x ST (3,51)	F(1.8, 31.0) = 4.77 **	F(1.9, 31.8) = 4.86 **	ns

TABLE 7.4: The outcomes of follow-up analyses for the ERP old/new effects over the 500-800 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

500-800 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 8.52 ***	F(1,17) = 5.13 **	ns
CC x ST (3,51)	F(1.4, 24.1) = 8.67 ***	ns	ns
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	ns	F(1,17) = 4.76 **	ns
CC x HM x ST (3,51)	ns	F(2.6, 44.0) = 3.23 **	ns
CC x AP x HM (1,17)	F(1,17) = 5.61 **	ns	ns
CC x AP x ST (3,51)	F(2.6, 43.9) = 10.31 ***	F(1.9, 32.7) = 7.01 ***	ns
CC x AP x HM x ST (3,51)	F(2.5, 41.7) = 4.34 ***	ns	ns

TABLE 7.5: The outcomes of follow-up analyses for the ERP old/new effects over the 800-1100 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

800-1100 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 7.41 ***	F(1,17) = 5.44 **	ns
CC x ST (1,17)	ns	ns	ns
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	ns	ns	ns
CC x HM x ST (3,51)	F(1.6, 27.7) = 3.98 **	F(2.1, 36.3) = 3.26 **	ns
CC x AP x HM (1,17)	F(1,17) = 9.97 ***	F(1,17) = 7.11 ***	ns
CC x AP x ST (3,51)	F(1.8, 30.2) = 9.95 ***	F(1.7, 28.6) = 9.12 ***	ns
CC x AP x HM x ST (3,51)	F(2.4, 40.8) = 4.32 ***	F(2.8, 46.9) = 3.99 ***	ns

TABLE 7.6: The outcomes of follow-up analyses for the ERP old/new effects over the 1100-1400 ms epoch. Key: * $p < .1$, ** $p < .05$, *** $p < .01$, **** $p < .001$, ns = non-significant, full df in brackets (1^{st} column).

1100-1400 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 5.47 **	ns	ns
CC x ST (1,17)	ns	ns	ns
CC x AP (1,17)	ns	F(1,17) = 27.65 ***	ns
CC x HM (1,17)	ns	ns	ns
CC x HM x ST (1,17)	ns	ns	ns
CC x AP x HM (1,17)	F(1,17) = 19.31 ***	F(1,17) = 6.95 ***	ns
CC x AP x ST (3,51)	F(2.6, 43.9) = 7.38 ***	F(2.3, 38.7) = 6.06 ***	ns
CC x AP x HM x ST (3,51)	F(2.2, 38.0) = 6.19 ***	F(2.4, 41.5) = 4.82 ***	ns

Chapter 8

8.1. Introduction

The aim of Experiment Five was to investigate factors that are responsible for the selective control of information from memory. The findings in Experiments Three and Four suggest that the ease of retrieving contextual information influences the retrieval orientations that participants adopt. There are several mechanisms that might facilitate this selective retrieval processing, and the discussion here is based on the work of Anderson, Bjork and colleagues (1994; 2003).

In one influential review chapter, Anderson and Bjork (1994) discussed several types of mechanism that can permit selective retrieval. The first is target bias, which refers to processes that operate on the critical memory representations themselves. Memory representations associated with the target category may be activated, making them more accessible than the representations for other memory contents. Selective accessibility of memory representation could also occur if memory representations associated with non-targets were inhibited. It is possible that activation and/or inhibition of memory representations can support selective retrieval processing. One consequence of adopting an orientation or mode might be the continuous activation and/or suppression of memory representations for as long as is necessary, although these processes could also in principle be initiated on a trial-by-trial basis.

A second process that might be responsible for selective control of recollection is cue bias, which refers to the way in which specific units or aspects of a retrieval cue are more likely to interact with memory representations because of the way that the cues are processed. Thus this mechanism also provides a means for the implementation of selective retrieval. The notion of cue bias is somewhat comparable to Burgess and Shallice's (1996) notions of cue specification, as well as the concept of focusing in the CMF (Schacter et al., 1998).

A third account – the attention bias account - is also possible. According to this view, selective recollection does not come about because of processes that operate during the interaction between retrieval cues and memory representations. Rather, it occurs because only some of the products of retrieval are attended to. This account therefore locates selective retrieval processing at a post-retrieval locus, and so the concept of attention bias shares some similarities with the notions of monitoring and evaluation (Burgess and Shallice, 1996).

One or more of these classes of mechanism might be responsible for the selective control of recollection. Thus, correspondingly, neural correlates of retrieval orientations may reflect any of these types of control operation. One approach to distinguishing between these mechanisms starts from the observation that only target bias acts directly on memory representations. Thus, if completion of an exclusion task prior to subsequent retrieval tasks can differentially influence the subsequent memorability of items associated with the target or non-target categories, this would provide evidence in support of the view that control of recollection is accomplished by target bias rather than cue or attention bias mechanisms.

In Experiment Five, participants initially completed one study-test cycle of an exclusion task. The exclusion task was followed by a second task in which the old words were words that were presented at study but not in the exclusion task. An equal number of these old words, however, were associated with the same kind of processing that had been associated with the categories designated as targets or as non-targets in the exclusion task. The design of the experiment was similar to Experiment Four, with the exception that superior memory accuracy, hence a greater incentive to prioritise recollection of targets, was encouraged by removing the 20 fillers from the beginning and the end of the study lists and by removing the 40 minute study-test interval. The general design of Experiment Four, with one study phase and two test phases, was maintained in order to minimise contamination across tasks by having more than one study-test cycle.

The retrieval tasks employed following the exclusion task were old/new recognition memory (Experiment 5a) and the Remember/Know procedure (Experiment 5b). The key contrast in these experiments was between the likelihood of correct task judgments for old words separated according to whether they had shared the same study history with words that were designated as belonging to the target or to the non-target categories. If performance on the second retrieval tasks is superior for words associated with the target designation on the exclusion task, then this would provide evidence supporting the view that selective retrieval on the exclusion task came about because of sustained differences in the relative activation of the target and the non-target memory representations, that is, by target bias mechanisms.

8.2. Method

8.2.1. Participants

A total of 42 participants took part in Experiment Five. 12 participants (7 females) took part in Experiment 5a, while in Experiment 5b, there were 30 participants (19 females). The average age (range in brackets) of participants in Experiments 5a and 5b was 22 (19-30) and 21 years (18-30), respectively. Each participant was paid at the rate of £5 per hour. Of the 42 participants, 6 were left-handed (1 in Experiment 5a).

8.2.2. Experimental items

These were similar to those described in Experiment Four. In Experiment Five, however, only one filler word was placed at the beginning of the study phase and each test phase. The exclusion retrieval task was the same as the first test phase in Experiment Four, while the subsequent retrieval task (old/new recognition judgments in Experiment 5a or Remember/Know recognition judgements in Experiment 5b) was comparable to the second test phase in Experiment Four. In total, there were 603 words in an experimental list (240 study stimuli + 1 filler, 180 exclusion test stimuli + 1 filler and 180 subsequent test stimuli + 1 filler).

Presentation timings were identical to those in Experiment Four.

8.2.3. Procedure

In Experiment 5a, each participant commenced the experiment by completing one study-test cycle of an exclusion task similar to that described in Experiment Four. The encoding tasks employed in Experiments Three and Four (function and drawing judgements) were again used in the present experiment. Unlike Experiment Four, there was no 40-minute gap between study and test in this experiment. During the test cycle of the exclusion task, one group of participants had function as the target designation, while another group of participants had drawing as the designation. The exclusion task was followed by an old/new recognition task, where participants were required to respond to old words (irrespective of study task) on one key and to new words on another key.

Experiment 5b was the same as Experiment 5a, with the exception that the old/new recognition task was replaced with the Remember/Know procedure (Tulving, 1985; Gardiner, 1993). Participants were asked to make one of three responses to the presented words. They made a ‘Remember’ response for a word that has been presented in the study phase and for which they could remember which study task they encountered it in. A ‘Know’ response was to be made to words that they believed were in the study phase, but for which they could not remember the task they encountered them in. A ‘New’ response was to be made to words that they believed they had not encountered at study. Participants were required to press three different keys for ‘Remember’, ‘Know’ and ‘New’ responses, respectively. For both Experiments 5a and 5b, participants were not informed of the second retrieval task until the exclusion task was completed. At the start of the subsequent retrieval task, the experimenter informed the participants that all items from the preceding (exclusion) task should be regarded as ‘old’ and that their previous target/non-target status was no longer important.

8.3. Results

8.3.1. Experiment 5a

8.3.1.1. Exclusion task

The analysis strategy for the exclusion task is identical to that employed in Experiments One-Four. The mean proportions of correct responses in the exclusion task for target, new and non-target words in the function and drawing target designation groups are shown in Table 8.1. Analysis using t-tests revealed that in both groups the likelihood of target responses to target words was greater than the likelihood of target responses to either new or non-target words ($t(5) > 5.55$, $p < 0.001$ in all cases; see Appendix C for details).

The likelihoods of correct responses at retrieval to target, new and non-target words were subjected to ANOVA, employing the factors of group: GP (function, drawing) and CC (target, new, non-target). ANOVA of these data revealed a main effect CC only (F(1.7, 17.5) = 12.55, $p < .01$). Follow-up analyses using Bonferroni corrected t-tests (adjusted alpha level = 0.017) indicated that new words were associated with a higher proportion of correct responses than targets (0.94 vs. 0.75; t(11) = 4.13, $p < 0.01$) and non-targets (0.94 vs. 0.84; t(11) = 3.89, $p < 0.05$). The likelihood of correct responses to targets and non-targets did not differ reliably.

Group		**Word Condition**	
	Target	**New**	**Non-target**
Function	0.77 (.05)	0.95 (.06)	0.85 (.09)
Drawing	0.72 (.16)	0.92 (.07)	0.82 (.12)

Table 8.1: Mean proportions of correct responses in the exclusion task to target, new and non-target words in the function and drawing target designation groups. (S.D. in brackets).

Table 8.2 displays the reaction times associated with correct responses in the exclusion task to target, new and non-target words in the function and drawing target designation groups. RTs associated with incorrect responses are not shown because there was a small number of trials (range in brackets) on which incorrect responses were made: mean numbers of trials for target misses, false alarms and non-target false alarms were 14 (10-19), 5 (1-11) and 9 (4-18), respectively in the function target designation group. The corresponding values in the drawing target designation group were 16 (6-29), 4 (0-11) and 10 (1-18). ANOVA incorporating the same factors as above did not reveal any effect involving CC and/or GP.

Group	**Word Condition**		
	Target	**New**	**Non-target**
Function	1491 (373)	1276 (276)	1522 (282)
Drawing	1245 (350)	1071 (306)	1222 (252)

Table 8.2: RTs (ms) to correct responses in the exclusion task to target, new and non-target words in the function and drawing target designation groups. (S.D. in brackets).

8.3.1.2. Old/New Recognition Task

Table 8.3 shows the mean proportions of correct responses in the old/new recognition task to target, new and non-target words in the function and drawing target designation groups. Analyses using t-tests showed that the likelihood of old responses to old words was significantly greater than the likelihood of old responses to new words ($t\ (5) > 6.99$, $p < 0.001$ in all cases; see Appendix C for details). The likelihood of an old response to a word associated with the target or non-target category, however, did not differ for either designation. ANOVA incorporating the same factors as above did not reveal an effect of CC or significant interactions involving GP and/or CC.

Group	Word Condition		
	Target	New	Non-target
Function	0.86 (.06)	0.85 (.08)	0.86 (.04)
Drawing	0.78 (.09)	0.83 (.15)	0.84 (.08)

Table 8.3: Mean proportions of correct responses in the old/new recognition task to new words and words associated with the target and non-target categories in the function and drawing groups. (S.D. in brackets).

The reaction times associated with correct responses in the old/new recognition task to new and old words in the function and drawing target designation groups are displayed in Table 8.4. For the same reason as described above, the RTs associated with incorrect responses are not shown (mean numbers of trials for 'target' misses, false alarms and 'non-target' false alarms were 8 (4-14), 9 (3-16) and 9 (4-12) respectively in the function target designation group. The corresponding values in the drawing target designation group were 12 (4-17), 9 (1-26) and 10 (3-14)). ANOVA employing the factors as described above did not reveal any effects involving CC and/or GP.

Group	**Word Condition**		
	Target	**New**	**Non-target**
Function	1026 (114)	1090 (141)	993 (90)
Drawing	953 (66)	961 (143)	962 (139)

Table 8.4: RTs (ms) to correct responses in the old/new recognition task to new words and words associated with the target and the non-target categories in the function and drawing groups. (S.D. in brackets).

8.3.2. Experiment 5b

8.3.2.1. Exclusion task

Table 8.5 shows the mean proportions of correct responses in the exclusion task for target, new and non-target words in the function and drawing target designation groups. Analysis using t-tests revealed that in both groups, the likelihood of target responses to target words was greater than the likelihood of target responses to new or non-target words (t (14) > 7.57, p < 0.001 in all cases; see Appendix C for details).

ANOVA of the likelihoods of correct responses at retrieval (factors as above) revealed a main effect of CC only (F(2.0, 55.4) = 28.03, p < .01). Bonferroni corrected t-tests (adjusted alpha level = 0.017) showed that new words were associated with a higher proportion of correct responses than targets (0.92 vs. 0.74; t(29) = 8.17, p < .001) or non-targets (0.92 vs. 0.81; t(29) = 5.94, p < .001). The likelihood of correct responses to non-targets was also higher than that for targets (0.81 vs. 0.74; t(29) = 2.79, p < .05).

Group	Word Condition		
	Target	**New**	**Non-target**
Function	0.79 (.15)	0.93 (.10)	0.84 (.17)
Drawing	0.69 (.15)	0.91 (.10)	0.78 (.13)

Table 8.5: Mean proportions of correct responses in the exclusion task to target, new and non-target words in the function and drawing groups. (S.D. in brackets).

Table 8.6 displays the reaction times associated with correct responses in the exclusion task to target, new and non-target words in the function and drawing target designation groups. RTs associated with false alarms and non-target false alarms in the function and drawing target designation groups are not shown because of the small number of trials on which these responses were made: mean numbers of trials for false alarms and non-target false alarms were 5 (0-18) and 10 (0-41) respectively in the function target designation group. The corresponding values in the drawing target designation group were 5 (0-21) and 12 (4-28), respectively. The mean numbers of trials for the RTs associated with target misses in the function and drawing target designation groups were 14 (4-39) and 18 (4-35), respectively. The RTs associated with target misses in the drawing target designation group were not analysed because there were only 9 participants who contributed a minimum of 16 trials to this category. ANOVA employing the factors as above did not reveal any effects involving CC and/or GP.

Group	Word Condition		
	Target	**New**	**Non-target**
Function	1548 (398)	1285 (296)	1626 (397)
Drawing	1351 (235)	1220 (230)	1473 (281)

Table 8.6: RTs (ms) to correct responses in the exclusion task to target, new and non-target words in the function and drawing groups. (S.D. in brackets).

8.3.2.2. Remember/Know recognition task

Three sets of analyses were completed on the Remember/Know data. The first (Analysis A) was for the probabilities of correct old and new responses, where the likelihood of old responses was computed by collapsing the data across 'Remember' and 'Know' responses. The purpose of this initial analysis was to provide an estimate of overall recognition performance comparable to Experiment 5a. In the second analysis (Analysis B) the probabilities of each response (Remember, Know and New) were analysed to investigate the contribution of each response to each critical word condition, and in the third analysis (Analysis C), the proportion of corrected 'Know' responses was analysed. This is due to the fact that in experiments employing the Remember/Know procedure, participants are asked to respond 'remember' only when they can recollect something about the prior presentation of the item. Thus, the likelihood of 'remember' responses can provide a relatively pure measure of the likelihood of recollection. 'Know' responses, however, may not provide a pure measure of the likelihood of familiarity if recollection and familiarity are independent, since participants are instructed to respond 'Know' only when an item is familiar but not recollected. In this sense, 'Know' responses reflect familiarity in the absence of recollection. On the basis of this and for the purpose of calculating the probability that an item is familiar assuming independence, Yonelinas and Jacoby (1995) suggested that the proportion of 'know' (K) responses must be divided by the opportunity the participant has to make a 'know' response (K/(1-R)).

Analysis A:

The mean proportions of correct old/new responses to new words and words associated with target and non-target categories in the function and drawing groups is shown in Table 8.7. Analyses using t-tests showed that in both groups, the likelihood of old responses to old words was greater than the likelihood of old responses to new words ($t(14) > 6.97$, $p < 0.001$ in all cases; see Appendix C for details). The likelihood of a correct old judgement did not differ, however, according to target or non-target category status.

ANOVA incorporating the same factors as described in the foregoing paragraphs revealed an interaction between GP and CC ($F (1.4, 38.1) = 3. 96$, $p < 0.05$). Bonferroni corrected t-tests (adjusted $p = 0.017$) indicated that the likelihood of correct responses to new words and words associated with the target and the non-target categories did not differ across groups. The interaction probably reflects the slight advantage for 'target' and new words in the function group.

Group	Word Condition		
	Target	**New**	**Non-target**
Function	0.78 (.14)	0.90 (.11)	0.70 (.13)
Drawing	0.70 (.12)	0.83 (.07)	0.74 (.12)

Table 8.7: Mean proportions of correct responses in the Remember/Know recognition task to new words and words associated with the target and the non-target categories in the function and drawing groups. (S.D in brackets).

Table 8.8 shows the RTs associated with correct responses to new words and words associated with the target and the non-target categories in the function and drawing groups. RTs associated with 'target' misses, false alarms and 'non-target' false alarms are not shown because the mean numbers of trials (range in brackets) were 8 (0-18), 3 (0-25) and 9 (4-17), respectively in the function target designation group and 10 (0-22), 5 (0-18) and 9 (2-20), respectively in the drawing target designation group.

RTs to correct responses to new words and words associated with the target and the non-target categories in the function and drawing groups were submitted to ANOVA employing the factors of GP (function, drawing) and CC (target, new, non-target). The analysis revealed a main effect of CC (F(1.6, 44.7) = 42.86, p < 0.01). Bonferroni corrected t-tests (adjusted p = 0.017) revealed that in both groups the RTs to new words were faster compared to RTs to words associated witg the target category (function: t(29) = 5.15, p < .001; drawing: t(29) = 4.16, p < .001) and to words associated with the non-target category (function: t(29) = 6.22, p < .001; drawing: t(29) = 4.25, p < .001). RTs for words associated with the target and non-target categories did not differ.

Group	**Word Condition**		
	Target	**New**	**Non-target**
Function	1677 (385)	1268 (261)	1721 (341)
Drawing	1584 (314)	1354 (271)	1599 (313)

Table 8.8: RTs (ms) to correct responses in the Remember/Know recognition task to new words and words associated with the target and the non-target categories in the function and drawing groups. (S.D. in brackets).

Analysis B:

Tables 8.9 and 8.10 shows the mean proportions of Remember, Know and New responses to new words and words associated with the target and the non-target categories in the function and drawing groups, respectively. The probabilities of Remember, Know and New responses to new words and words associated with the target and the non-target categories in the function and drawing groups were subjected to ANOVA, employing the factors of GP (function, drawing), RS: response (Remember, Know) and CC (target, non-target). ANOVA of these data revealed a three way interaction involving GP, RS and CC (F(1,28) = 25.31, p < .01). Subsequent analysis for each group revealed RS x CC interactions (function: (F(1,14) = 19.00, p < .01); drawing: (F(1,14) = 6.99, p < .01). These reflect the fact that in the function group, the likelihood of 'Remember' responses was greater for words associated with the target category than for words associated with non-target category. In contrast, in the drawing group, participants made more 'Remember' responses to words associated with non-target category compared to words associated with target category. The reverse pattern characterises the Know responses.

Word Condition	**Responses**	**Proportion**
Target	*Remember*	0.70 (.17)
	Know	0.16 (.08)
	New	0.13 (.11)
New	*Remember*	0.02 (.02)
	Know	0.08 (.10)
	New	0.90 (.10)
Non-target	*Remember*	0.57 (.19)
	Know	0.26 (.15)
	New	0.17 (.09)

Table 8.9: Mean proportions of 'Remember', 'Know' and 'New' responses to new words and words associated with the target and the non-target categories for the function group. (S.D. in brackets).

Word condition	**Response**	**Proportion**
Target	*Remember*	0.58 (.15)
	Know	0.25 (.09)
	New	0.17 (.09)
New	*Remember*	0.05 (.03)
	Know	0.12 (.06)
	New	0.83 (.07)
Non-target	*Remember*	0.65 (.16)
	Know	0.19 (.10)
	New	0.16 (.08)

Table 8.10: Mean proportions of 'Remember', 'Know' and 'New' responses to new words and words associated with the target and the non-target categories for the drawing group. (S.D. in brackets).

Table 8.11 displays the reaction times associated with 'Remember' responses to words associated with the target and non-target categories in the function and drawing groups. As described in the foregoing paragraphs, the RTs associated with incorrect responses are not shown because the numbers of trials associated with them was low. The RTs to 'Know' responses to words associated with the target and non-target categories were also not analysed because there were not enough participants who contributed sufficient trials to these conditions.

The reaction times for Remember responses to words associated with the target and non-target categories in the function and drawing groups were submitted to ANOVA, employing the factors of GP (function, drawing) and CC (target, non-target). The analyses revealed a main effect of CC ($F(1,28) = 6.35, p < .01$), indicating that RTs associated with Remember responses to words associated with the target category were faster than those to words associated with the non-target category.

Group	Word Condition	RTs (ms)
Function	Target	1425 (290)
	Non-target	1529 (375)
Drawing	Target	1395 (221)
	Non-target	1416 (220)

Table 8.11: RTs (ms) for 'Remember' responses to new words and words associated with the target and the non-target categories in the function and drawing groups. (S.D. in brackets).

Analysis C:

Table 8.12 displays the mean proportion of corrected 'Know' responses to new words and words associated with the target and the non-target categories in the function and drawing groups. ANOVA employing the factors of GP (function, drawing) and CC (target, non-target) did not reveal main effect or interactions involving CC.

Group	Word Condition		
	Target	**New**	**Non-target**
Function	0.61 (.20)	0.08 (.11)	0.59 (.15)
Drawing	0.61 (.16)	0.13 (.07)	0.53 (.13)

Table 8.12: Mean proportions of corrected 'Know' responses to new words and words associated with the target and the non-target categories in the function and drawing groups. (S.D. in brackets).

8.4. Discussion

To recap, in the present experiment, participants engaged in an exclusion task prior to a subsequent retrieval task. Two paradigms were employed for the subsequent retrieval task. In the first, an old/new recognition judgement was employed, whereby participants were asked to distinguish between words that appeared in the study phase and words that were presented at test for the first time. In the second, the Remember/Know procedure (Tulving, 1985) was employed. In this procedure, after having studied a list of words, participants were instructed to make 'remember', 'know' or 'new' judgements for each word. Participants were required to press one key if they could remember the task in which the word was previously encoded (a Remember response). They were to press another key if they thought the word had been presented earlier but they could not remember its study task (a Know response), and to press another key if they thought the word had not been presented earlier. These two retrieval tasks were employed in an attempt to investigate the mechanisms responsible for selective retrieval.

The principal interest in Experiment Five is on the measures of correct responses to 'targets' and 'non-targets', as well as the times taken to respond in the subsequent retrieval tasks. A memory accuracy or RT advantage for words previously belonging to the target category would provide evidence in support of the view that control of recollection is exerted by processes that act directly on memory representations (target bias), by virtue of the fact that the subsequent accessibility of that information had been influenced.

The findings in the old/new recognition task do not fit the criteria supporting a target-bias account, since accuracy to words designated previously as targets and non-targets did not differ significantly. This was true for both target designation groups. The RTs associated with words previously designated as targets were also similar to non-targets, thereby providing no support for a target bias account.

The use of the Remember/Know procedure (Experiment 5b) provides other opportunity to assess the target bias account. A selective advantage for R or for K responses or equivalent overall recognition performance but different proportions of both R and K responses for words associated with the target and non-target categories would, in addition to supporting the target-bias account, also provide information about the way in which those representations were influenced.

The accuracy data in the Remember/Know task also provides no direct support for a target bias account. While the overall likelihood of correct 'old' judgments and Remember judgments was superior for 'targets' compared to 'non-targets' in the function target designation, there was if anything a tendency for the reverse to be true in the drawing designation condition. This reversal suggests that the easiest way to explain these data is in terms of better memory for words encoded in the function task, which were of course targets in the function designation group, and non-targets in the drawing designation group. This interpretation also draws some support from the overall pattern of exclusion task data shown in Table 8.5, which is consistent with the explanation that memory for words encoded in the function task was superior. Why this should be the case for this sample of participants when any such encoding advantages were negligible in Experiments Three and Four remains to be determined.

Critically, some support for the target bias account of the data is provided by the reaction time findings. Specifically, when the RTs for Remember responses were analysed, responses were quicker for words associated with the target than with the non-target category. This finding is broadly consistent with the view that the relative accessibility of words associated with the target and non-target categories was influenced by completion of the exclusion tasks. Inspection of the data in Table 8.10 shows that this effect is carried mainly by the function designation group, although the analysis did not reveal a group by condition interaction. The larger target/non-target RT disparity in the function group is arguably understandable, however, since the argument advanced earlier is that the extent to which recollection is prioritised increases along with the likelihood of target recollection. It follows from this that the degree of engagement of target bias mechanisms – if they are indeed responsible for selective recollection – should be greater in the function than the drawing target designation, hence any target/non-target disparities in accuracy or reaction times should also be more pronounced in the function in comparison to the drawing condition. The exclusion task performance in the function condition in Experiment 5b is also comparable to that in Experiment Three overall, which provided the key electrophysiological evidence that selective control of recollection was exerted in the exclusion task.

8.5 Concluding Remarks

In subsequent work it will be important to encourage higher levels of memory accuracy for targets than was achieved here in order to determine whether under these circumstances it is possible to observe costs on memory accuracy as well as on reaction times. This observation does not take away from the important observation, however, which is that the RT data provide some support for a target bias account of the mechanisms by which selective recollection may be accomplished in the exclusion task.

Chapter 9

9.1. Introduction

The study of strategic retrieval processing in episodic memory addressed in this thesis involves several issues: the relationship between retrieval orientation and retrieval effort (Chapters 4 and 5); the conditions under which selective control of recollection occurs (Chapters 6 and 7); the functional significance of ERP indices of retrieval orientation (Chapters 6-8). These issues are discussed below, alongside a summary of the principal experimental findings.

9.2. Summary and Discussion of Experimental Findings

Experiments One and Two

Recent developments in ERP studies of retrieval processing have seen a growing interest in the study of processes that are engaged prior to retrieval as well as those that are engaged in pursuit of retrieval when a retrieval cue is encountered. Investigating this form of retrieval process is important since it enables the identification of electrophysiological correlates of retrieval orientations; a cognitive state that is maintained tonically and determines the processing of a retrieval cue. According to Rugg and Wilding (2000) participants adopt different retrieval orientations that vary according to what kind of information is to be retrieved from episodic memory. One approach that has been employed to provide electrophysiological evidence to support the concept of retrieval orientation involves recording and analysing neural activity that is set in train by retrieval cues while restricting the contrasts to the ERPs evoked by new test items in tasks that vary in their retrieval demands. The logic behind this contrast is that it can reveal neural activity that indexes processes that are engaged independently of successful episodic retrieval (e.g. see Ranganath and Paller, 1999; Wilding, 1999; Ranganath and Paller, 2000; Rugg et al., 2000; Herron and Rugg, 2003a).

Contrasts between classes of new test items have been made in several recent ERP studies (see Chapter 1 for details) and the ERPs evoked by these items have varied according to the task demands. For example, in Ranganath and Paller (1999; 2000) and Rugg et al. (2000), the differences between the ERPs evoked by new test items were evident at left-anterior sites. The relative positivity was associated with the items in the more demanding of the two tasks, leading Rugg et al. (2000) to propose that the differences reflect processes related to retrieval effort.

Experiments One and Two were conducted to establish the functional significance of the differences between the ERPs evoked by new test items (focusing on the relationship between retrieval effort and retrieval orientation). These two processes are thought to form part of a retrieval attempt , and study of their relationship is important due to the fact that in the majority of the studies that have included contrasts between new test items, these two processes have been confounded.

Participants in Experiments One and Two saw words and were required to study them semantically or phonologically. In separate test blocks, they responded only to targets. These two experiments differed in the number of study-test blocks presented to participants; 6 for Experiment One and 12 for Experiment Two.

In Experiment One, the ERPs evoked by classes of correct rejections varied according to target designation. However, since effort (as defined by response accuracy) and orientation were confounded, it was not possible to draw strong conclusions regarding the functional significance of the differences evoked by the two classes of new test words.

Progress towards understanding the relationship between effort and orientation was achieved in Experiment Two, in which these two processes were systematically manipulated. The design permitted an analysis of the ways in which indices of orientation vary according to effort. Effort was manipulated by dividing participants into groups on the basis of their behavioural performance. The differences between the ERPs evoked by classes of new test items varied according to target designation only when the two retrieval tasks were not of equivalent difficulty. This pattern of findings was interpreted as support for the view that ERPs index orientations, and that changes in effort are manifest primarily as changes in activity in the generators typically engaged in service of task demands.

As far as retrieval effort is concerned, one aspect that warrants attention relates to which aspect of behavioural data to focus to upon when determining task difficulty in the context of retrieval orientation (Wilding and Sharpe, 2003). One way to assess the behavioural data in this regard is to focus only on the accuracy of judgments to new items, since these are the data that are most directly relevant to the critical ERP contrast. An alternative, however, is that difficulty, for new as well as for old judgments, is assessed in relation to the accuracy of judgments to old as well as to new test items. In two studies for example (Wilding, 1999 and Ranganath and Paller, 1999), there is no difference in task difficulty if it is assessed in terms of the probability of making correct rejections. In contrast, if task difficulty is assessed on the basis of the probability of making correct responses to old items or in terms of other discrimination measures, the conclusion is that one task is harder than the other (the voice retrieval task in the study of Wilding (1999) and the specific retrieval task in the study of Ranganath and Paller (1999)). There is no consensus as to which aspect of behavioural data to rely upon when determining task difficulty with respect to the processing of new test items. These concerns do not of course apply to Experiments Three and Four in this thesis, nor to the low relative difficulty group in Experiment Two, since in all cases accuracy did not vary according to target designation.

More generally, Mitchell and Hunt (1989) have highlighted the need for better ways to index task difficulty. They suggested that it is not optimal to use the measures of performance on the task you are interested in to measure the effort required on that task. They suggested instead the use of a dual-task interference paradigm in which a secondary task is presented along with a primary task. For example, in addition to performing an exclusion task, participants might be required to listen to background tones and count them. Differences in the accuracy of tone counting according to the primary task demands can then be used as the measure of effort engaged during completion of the primary task, hence how 'difficult' the task was. Such a design, however, may not be suitable for use with ERPs, as the background activity may increase the noise: signal ratio, which is undesirable. It is also difficult although not impossible to isolate activity related to the secondary task from the activity contributing to the task of interest.

Experiments Three and Four:

It has been suggested recently that retrieval orientations play a specific role in strategic retrieval processing, specifically that they enable selective access to only some kinds of information held in memory (Herron and Rugg, 2003a). This possibility was pursued in

Experiments Three and Four where attempts were made to link ERP indices of retrieval orientation with indices of recollection. The electrophysiological correlate of recollection is the left-parietal old/new effect, and the effect was observed for correctly classified target items but not for non-target items in Experiment Three. This suggests that recollection of information associated with non-targets occurred markedly less often than recollection of information associated with targets. This pattern of results was proposed to be due to the adoption of a retrieval strategy by participants which restricted recollection to target information only and which was adopted by participants because the likelihood of recollecting information about targets was sufficiently good to support such a strategy (Herron and Rugg, 2003b; Dzulkifli and Wilding, in press).

Experiment Four tested the hypothesis that restricting recollection to targets occurs more often when memory for targets is high than when it is low. The accuracy of task judgements was superior in Experiment Three than in Experiment Four and the left-parietal old/new effect was evident for both target and non-target words in the latter experiment. It therefore appears that participants adopted a retrieval strategy in which they recollected information about non-targets in Experiment Four but not in Experiment Three. The findings in Experiments Three and Four are consistent with those reported in several recent ERP experiments employing the exclusion task where non-target old/new effects have been smaller than target effects: (Herron and Rugg, 2003a; 2003b; Dywan et al., 1998 and Dywan et al., 2001).

The patterns of results in these studies and in Experiments Three and Four permit alternative conclusions: firstly, that the left-parietal old/new effect is associated with additional processing contingent on recovery of information from memory. According to this interpretation, information for studied items may have been recovered in both Experiments Three and Four, but only participants in Experiment Four attended to and employed this information for non-targets. This account would imply that the left-parietal old/new effect reflects attentional and/or control processes that act upon recollected information (Dywan et al., 1998). An alternative conclusion is also possible; that the left-parietal old/new effect indexes recovery of information from memory. According to this interpretation, participants were able to successfully suppress or inhibit recovery of source information deemed to be task irrelevant in Experiment Three.

Whichever conclusion is correct, these findings have implications for the PDP procedure, as one of its assumptions is that non-targets are correctly excluded on the basis of recollection (Jacoby, 1991). Jacoby proposed that non-targets are successfully excluded only when participants recollect contextual information that is diagnostic of the item's source, but the data reviewed and presented here suggests that at least under some circumstances this proposal is questionable.

Thus the findings in this thesis have important implications for one popular means of assessing the relative contributions that recollection and familiarity make to performance on tasks requiring explicit memory judgments. Do the data also have other implications for dual-process accounts of recognition memory? Inspection of the figures in Experiments 1-4 of this thesis in which ERP old/new effects are shown indicates that at least in some cases the ERPs at mid-frontal electrode locations were more positive-going for correct target and non-target judgments than for correct rejections (in particular, see Figures 6.3 and 7.2). This aspect of the electrical record has been identified as a possible index of familiarity, but the experiments in this thesis contain no experimental manipulations that permit this account to be tested, and as a result the analysis strategy employed in this thesis is not optimal for assessing changes across conditions at the critical locations for this putative index of familiarity. Levels of memory performance were also sufficiently high to preclude analysis of ERPs elicited by incorrect responses to targets and to non-targets (target misses and non-target false alarms), which are arguably response categories that might be more informative concerning the functional significance of the mid-frontal old/new effect (e.g. Wilding and Rugg, 1997). Hence the extent to which the data in this thesis can speak to questions about the accuracy or otherwise of dual-process accounts of recognition memory is somewhat limited.

Another important question is whether target accuracy is the sole factor influencing the nature of the retrieval strategy adopted by participants in the exclusion task. In the studies of Wilding and Sharpe (2004), a non-target left-parietal old/new effect was observed even when the accuracy of target judgements was high (> .70). In Wilding and Rugg (1997), target recognition accuracy was low (.58) and they reported a left-parietal old/new effect for non-target items, whereas in the study of Dywan et al. (1998) a left-parietal old/new effect was observed for targets only, although target accuracy was relatively poor (.58). These data suggest that target accuracy is not the only factor influencing the strategy adopted by participants.

One other factor that may influence the adoption of a specific strategy is the correspondence between targets and non-targets. In studies where target accuracy has been relatively high yet ERP old/new effects for non-targets have been obtained, targets and non-targets have been associated with what can be regarded as relatively similar kinds of information. For example, in the studies of Wilding and colleagues (Wilding and Rugg, 1997; Wilding and Sharpe, 2004), the target/non-target distinction was gender of study voice (male/female). In the studies of Cycowicz et al. (2001; 2003) the distinction was colour (red/green). It may be the case that for certain kinds of information – perhaps perceptual information bound to a stimulus – there is less opportunity to adopt a specific orientation that results in the selective processing of information associated with targets only. According to this account, therefore, the reduced effects for non-targets in other work, and in Experiments Three and Four, come about because the encoding operations associated with targets and non-targets were sufficiently distinct to support a strategy of processing targets relatively selectively. It remains to be seen whether this as well as other factors also influence the likelihood of the adoption of a strategy of prioritising recollection of information about targets only.

In short, the findings reported in Experiments Three and Four support the view that the likelihood of recollecting targets can influence the retrieval strategy that participants employ in optimising their performance in exclusion tasks. However, complex interactions between targets and non-targets are possible, and further work is required to identify and examine the various factors contributing to strategic retrieval processing.

ERP indices of retrieval orientation

The findings in Experiments Three and Four also address the question of the functional significance of ERP indices of retrieval orientation. One possibility is that the differences between the ERPs evoked by new words in Experiment Three reflect processes important for the control of recollection. Given the pattern of left-parietal ERP old/new effects in Experiments Three and Four, this account would have been supported had the indices of orientation in Experiment Three been reduced in Experiment Four. This is precisely what was found, and the data therefore suggest, in keeping with recent accounts (Herron and Rugg, 2003a), that orientations reflect processes that are engaged during selective retrieval processing. By this view, the absence of comparable differences between the ERPs evoked by new words in Experiment Four is explained by the fact that in both target designations participants attempted to recollect information about targets as well as non-targets. Hence, at least in terms of selective recollection, participants can be regarded as having adopted the same orientation.

Experiment Five

Experiment Five was conducted to investigate the mechanisms that are responsible for the selective control of information from memory. Drawing on the framework due to Anderson and Bjork (1994) it was assumed that if selective recollection is in fact due to processes that operate directly on memory representations (target bias processes in the terminology of Anderson and Bjork), then this should have long-lasting effects on the accessibility of information, and so could be revealed by assessing how the subsequent memorability of targets and non-targets was influenced by completion of an exclusion task.

Participants in Experiment Five initially completed one study-test cycle of an exclusion task followed by a second retrieval task. Two types of retrieval task were employed: old/new recognition memory and the Remember/Know procedure. Memory accuracy and RTs for ‘target’ and ‘non-target’ words did not differ overall in the old/new recognition task or the Remember/Know task. RTs for Remember judgements to ‘targets’ were, however, faster than Remember judgements to ‘non-targets’. This provides some support for the view that selective recollection is due to processes that operate directly on memory representations. The possibility that restricting recollection to specific classes of studied items occurs also due to processes that have their impact at a later processing stage cannot be ruled out at this point (Wilding, 1999).

9.3. Implications for models of retrieval processing

The models of retrieval processing discussed in Chapter 1 delineate processes that might be engaged when information is to be recovered from memory (Tulving, 1983; Burgess and Shallice, 1996; Schacter et al., 1998; Rugg and Wilding, 2000). How does the data in this thesis relate to the processes that have been proposed to support the control of memory retrieval? The fact that reliable item-related indices of retrieval orientation have been identified, the fact that these have been obtained when task difficulty has been held constant, and the fact that these item-related indices vary according to task, provides empirical support for the view that item-related processes independent of successful retrieval are engaged in response to a retrieval cue. These processes, termed focusing by Schacter et al. (1998) and cue-specification by Burgess and Shallice (1996), may be what the differences between the ERPs evoked by new items index. While the ERP data are consistent with this account, however, it remains a possibility that the differences between the ERPs evoked by new items in fact reflect processes that operate on the products of retrieval. That is, using the terminology introduced in Chapter 8, the differences between the ERPs may in fact index attention bias rather than cue bias mechanisms.

In this sense, then, the identification of the differences between the ERPs evoked by new items, and the data reviewed earlier suggesting that these differences are indices of orientation, is the precursor to subsequent work in which a more precise characterisation of these processes is obtained. It is this subsequent stage of analysis that will permit an assessment of the accuracy of different models of episodic retrieval.

It is worth noting, however, that Experiment 5 comprised an attempt to provide data germane to the question of the mechanisms responsible for the control of recollection indicated by the ERP old/new effects in Experiments 3 and 4. The RT data in Experiment 5b provide some support for a target bias account of the control of selective retrieval, as discussed previously (see page 208 in Chapter 8). Herron and Rugg (2003b) have suggested that target bias operations are likely due to the fact that operation of tonically maintained processes, hence the RT data from Experiment 5b provide some support for the view that selective retrieval does not necessarily come about because of cue-specification (bias) or focusing operations, but because of the operation of retrieval sets. If this is true, then an accurate model of memory retrieval must encapsulate explicitly the notion of sustained mnemonic processes, as discussed by Tulving (1983) and more recently at length by Rugg and Wilding (2000).

In subsequent experiments it will be important to determine whether the RT differences in Experiment 5b can be obtained for different kinds of information. It is also worth noting that the RT data, while providing support for a target bias account, do not rule out the possibility that other classes of bias mechanism are also involved in the control of selective retrieval. It is also in principle possible that the particular classes of bias mechanisms responsible for the control of retrieval vary according to the content of information that is to be retrieved as well as other aspects of task demands (Wilding, Herron and Fraser, in press).

In summary, the data in this thesis suggests that at best the models proposed by Burgess and Shallice (1996), and by Schacter et al. (1998) are incomplete. It remains to be seen whether subsequent ERP studies will help to shed further light on the ways in which retrieval processing in episodic memory is accomplished.

9.4. Haemodynamic indices of retrieval mode, retrieval orientation, retrieval effort and retrieval success.

The brain regions supporting episodic retrieval processing have been investigated in a number of studies employing haemodynamic methods. As has been described in Chapter 1, some support for the concept of retrieval mode has been inferred from the findings in studies employing PET (e.g. Tulving et al.,1994; Lepage et al, 2000; Kapur et al., 1995; Nyberg et al.,1995). Due the fact, however, that PET data comprise an averaged blood flow signal over an extended period of time, it is not possible to distinguish item-related from state-related activity. fMRI memory studies in which blocked designs have been employed suffer from a similar limitation and are not described below, despite the fact that claims about strategic retrieval processing have been inferred on the basis of data from blocked designs (e.g. Dobbins, Foley, Schacter and Wagner, 2002). Instead, the discussion below is restricted to designs in which only event-related (transient) data was acquired, or in which event-related as well as task-related (sustained) data was acquired.

There have been only a few attempts to separate transient (item-related) and sustained (state-related) processes in fMRI studies of episodic retrieval. Donaldson, Petersen, Ollinger and Buckner (2001) employed a combined blocked and event-related design in an attempt to dissociate state-related processes memory processes from item-related processes.

They contrasted the state-related activity obtained in a recognition memory task against a fixation baseline condition. Regions that showed sustained activity in the recognition task relative to fixation were restricted to frontal cortex and included left inferior and middle frontal gyrus and bilateral frontal operculum. The right prefrontal cortical activation reported previously in PET studies was not prominent in their findings, which might indicate that the PET data in fact indexes summed item-related activity rather than sustained activity. The involvement of right PFC in retrieval mode, however, has also been inferred on the basis of the ERP data, reviewed in Chapter 1. In three studies (Duzel et al., 1999; 2000; Morcom and Rugg, 2001; Herron and Wilding, 2004) activity at right-frontal and central scalp sites has been more positive-going in episodic retrieval tasks than in semantic retrieval tasks. The reasons for these disparities across different brain imaging modalities are not entirely clear, but in the first instance it will be important to obtain data from the same task pairs using the different imaging methods in paradigms that have precisely the same trial structures. Neither of these factors has been equated adequately to date.

Similar to the study of Donaldson et al. (2001), in the study of Velanova, Jacoby, Wheeler, McAvoy, Petersen and Buckner (2003) a combined task- and item-related fMRI design was employed in the attempt to identify brain regions supporting sustained and transient processes engaged during episodic retrieval. Participants completed two old/new recognition tasks, and in each the 'old' items had a different study history. In one task, the old items had been presented multiple times in old/new recognition memory study-test phases the day before scanning. In the other, the old items had been presented once in a deep encoding task (pleasantness judgments) immediately before the scanning session. The accuracy of old/new judgments was superior in the task where there had been multiple study presentations.

This design, therefore, confounds orientation and effort in much the same way as in some ERP studies in which contrasts between classes of correct rejections were made (see Chapter 1). What this means is that for either sustained or transient activations identified it is difficult to claim with any confidence whether they arise because of changes in effort, orientation, or a combination of the two. Thus although the authors identified several brain regions that may play a part in the control of retrieval, including several left prefrontal cortical regions as well as right fronto-polar cortex, the design of the experiment means that inferences about the functional significances of these activations are necessarily tentative.

In summary, the PET data provide equivocal evidence with respect to the question of whether retrieval mode is supported by the right-prefrontal cortex. The studies due to Donaldson et al. (2001) and Velanova et al. (2003) are both consistent with the view that sustained (mode and orientation) and transient (item-related) processes contribute during episodic retrieval, but a more precise characterisation than this awaits the outcome of further studies, and at least in the case of the Velanova et al. study, better control over critical experimental variables.

Information relevant to questions concerning episodic retrieval processing has also come from event-related fMRI studies of memory retrieval. These studies, by design, cannot provide indices of sustained retrieval processing, but in much the same way as inferences about the engagement of orientations have been made on the basis of differences between

ERPs evoked by correct rejections, similar inferences can be made on the basis of contrasts between patterns of brain activity in fMRI studies.

Ranganath, Johnson and D'Esposito (2003) employed the same tasks used previously by Ranganath and Paller (1999; 2000). They reported that activity in left PFC was greater during the processing of both old and new items in the specific than in the general retrieval task. On the basis of the assumption that effects common to both new and old items are more likely candidates of processes contributing to retrieval attempt than are effects that vary according to item type (Rugg and Henson, 2003), Ranganath and colleagues proposed that the activity in left PFC reflected monitoring and evaluation processes that are engaged during an attempt to retrieve information from memory. From the perspective of finding converging fMRI data that supports the concept of retrieval orientation, clearly this contrast fits the criterion, thus this fMRI data permits similar conclusions to that drawn on the basis of the ERP differences between correct rejections described in this thesis. Different brain regions have also been identified as forming part of retrieval orientations in other studies, and of particular note here is the work of Dobbins, Rice, Wagner and Schacter (2003). While they did not report data for new test items only, Dobbins et al. (2003) identified several brain regions that were engaged selectively according to retrieval task (source versus recency judgments) and which within each task were insensitive to the success or failure of task judgments. On the basis of this pattern of data, Dobbins et al. (2003) argued that these brain regions reflected item-related indices of retrieval orientation because their activity did not change according to item status or the accuracy of task judgments. In keeping with the logic outlined above, these data also provide general support for the concept of retrieval orientation (see also Dobbins et al., 2002), although it is difficult to assess how one would confidently equate effort on source versus recency discrimination tasks. In respect of this last point, it is reasonable to say that in fMRI studies of episodic retrieval to date there are few if any studies in which all factors other than task difficulty have been held constant, thus the haemodynamic data to date have little to say about the concept of retrieval effort and how it relates to the concepts of mode, orientation and success (see, for example, Buckner, Koutstaal, Schacter, Wagner and Rosen, 1998, although also see Simons, Gilbert, Owen, Fletcher and Burgess, 2005).

This brief summary emphasises the principal points of contact between the haemodynamic imaging literature and the ERP work in this thesis with respect to the concepts of retrieval mode, retrieval orientation and retrieval effort. Are there also inferences that can be made about the control of recollection in the exclusion task on the basis of fMRI data? The answer is at this stage no. The reason for this is that there is at present no consistent fMRI signal that can be considered functionally equivalent to the left-parietal ERP old/new effect. Hence there is no brain signature that will permit similar inferences to be made (for fMRI studies in which blood flow measures have been acquired during exclusion tasks, see Rugg, Henson and Robb, 2003; Henson, Shallice and Dolan, 1999). It is to be hoped that this situation will change relatively soon. This is of course not to say that there is not an extensive fMRI literature on the functional neuroanatomy of successful memory retrieval (for reviews, see Rugg and Henson, 2003; Fletcher and Henson, 2001; Simons and Spiers, 2003), but that at present the fMRI data does not speak directly to the issues discussed in this thesis with respect to the control of successful retrieval. The data in these brain imaging studies is relevant, however, to the question of the neural structures responsible for the scalp-recorded activity described in this thesis, and this literature is covered where appropriate in the following section.

9.5. The neural basis of ERP old/new effects and indices of retrieval orientation

In Chapter 2 it was emphasised that it is difficult to make inferences about the neural basis of scalp-recorded ERPs unless converging information from other brain imaging modalities as well as data from patients with selective brain damage is available. It is also important to note that none of the functional conclusions drawn in this thesis depend upon claims about the specific brain regions that are responsible for old/new effects and for indices of orientation. The question of the brain regions responsible for selective retrieval processing remains, none the less, an interesting one.

There are no strong conclusions that can be drawn about the neural basis of the left-parietal ERP old/new effect, although the data from patient studies (reviewed earlier) suggests that the effect depends upon the medial temporal lobes being intact (Smith and Halgren, 1989; Duzel et al., 2001; Rugg, Roberts, Potter, Pickles and Nagy, 1994; Tendolkar et al., 1999). The effect is unlikely to be a direct reflection of hippocampal or medial temporal lobe activity, however (Johnson, 1989; Rugg, 1995; Stapleton, Halgren and Moreno, 1987; Wood, McCarthy, Allison, Goff, Williamson and Spencer, 1982), and it has been suggested recently that left-parietal cortex is the likely brain region that generates this effect (Henson, Shallice and Dolan, 1999). This account is based principally on the finding that this region has been activated in several fMRI studies of episodic retrieval (e.g. Wheeler et al., 1997; Henson et al., 1999).

The right-frontal old/new effect is largest, as the name implies, over right-frontal scalp, and it has been proposed that the effect indexes activity in right prefrontal cortex. A wealth of evidence is available to support the view that pre-frontal cortex (PFC) is involved in retrieval monitoring and control processes (for example see Burgess and Shallice, 1996;

Stuss et al., 1994; Fletcher and Henson, 2001; Rugg and Henson, 2003), but localisation of the generators of the right-frontal old/new effect is likely going to involve recording from denser electrode arrays than have been used to date, as well as greater knowledge of the functional significance of the effect.

The results of several fMRI studies of memory retrieval, moreover, (e.g. Fletcher and Henson, 2001; Dobbins et al., 2003) have shown that sub-regions of right and left PFC play different roles during retrieval. Taken together these findings are consistent with the view that the functional integrity of the PFC is necessary for strategic retrieval processing. Some of the indices of orientation reported in this thesis may reflect directly activity in prefrontal cortex. For all of the indices of orientation, and also presumably for the selective control of recollection shown by the patterns of ERP old/new effects in Experiments Three and Four, it is reasonable to assume that even if they are not generated directly in PFC, they depend critically upon the functional integrity of this brain region. With the exception of the work of Ranganath and colleagues, however, there are no studies in which the same strategic retrieval tasks and stimuli have been employed using ERPs and fMRI, which is probably the logical first step to identifying the neural correlates of the differences between correct rejections observed in the ERP studies described in this thesis.

9.6. Concluding remarks

The present thesis employed episodic retrieval tasks in order to investigate the strategic control of retrieval in episodic memory. The use of ERPs here has enabled assessments of retrieval processing that would not have been possible on the basis of behavioural data alone. This claim holds for the inferences that have been made on the basis of the differences between the ERPs evoked by new items, and the inferences regarding strategic retrieval processing in the exclusion task. The findings in this study have addressed the relationship between retrieval effort and retrieval orientation, they have gone some way to establishing the validity of the concept of orientation, the functional significance of at least one index of orientation, and the conditions under which recollection of some information can be prioritised at the expense of other information.

The focus of the work presented in this thesis is in line with recent developments in brain imaging studies of episodic memory that have seen a shift towards consideration of control processes that are important for modulating what is retrieved from memory (Fletcher and Henson, 2001; Rugg and Henson, 2003). The work also helps to extend current understanding of the ways in which retrieval of information from episodic memory may be controlled. This is important, as memory impairments in aging (Logan, Sanders, Snyder, Morris and Buckner, 2002), in Alzheimer's disease (Grady, McIntosh, Beig, Keightley, Burian and Black, 2003) and following frontal brain damage (Stuss et al., 1994) may be due to the failure to engage such control processes.

REFERENCES

Aggleton, J. P. and Shaw, C. 1996. Amnesia and recognition memory: a reanalysis of psychometric data. *Neuropsychologia* 34, pp. 51-62.

Allan, K. and Rugg, M. 1998. Neural correlates of cued recall with and without retrieval of source memory. *Neuroreport* 9, pp. 3463-3466.

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

Anderson, M. C. 2003. Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language* 49, pp. 415-445.

Anderson, M. C. and Bjork, R. A. eds. 1994. *Inhibitory processes in attention, memory and language.* San Diego, California: Academic Press, pp. 265-325.

Atkinson, R. C. and Shiffrin, R. 1968. Human memory: A proposed system and its control processes. In: Spence, K.W. and Spence, J.T. eds. *The psychology of learning and motivation.* London: Academic Press.

Baddeley, A. D. and Hitch, G. 1974. Working memory. In: Bower, G.A. ed. *Recent Advances in Learning and Motivation.* Vol. 8. New York: Academic Press, pp. 47-90.

Berger, H. 1929. Ueber das Elektrenkephalogramm des Menschen. *Archiv fur Psychiatrie und Nervenkrankheiten* 87, pp. 527-570.

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

Brown, M. W. and Aggleton, J. P. 2001. Recognition memory: what are the roles of the perirhinal cortex and hippocampus? *Nature Neuroscience* 2, pp. 51-61.

Buckner, R. L. and Koutstaal, W. and Schacter, D. L. and Wagner, A. D. and Rosen, B. R. 1998. Functional anatomic study of episodic retrieval using fMRI: 1. Retrieval effort versus retrieval success. *Neuroimage* 7, pp. 151-162.

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

Chwilla, D. J. and Brown, C. M. and Hagoort, P. 1995. The N400 as a function of the level of processing. *Psychophysiology* 32, pp. 274-285.

Coles, M. G. H. and Rugg, M. 1995. Event-related potentials: an introduction. In: Rugg, M. and Coles, M.G.H. eds. *Electrophysiology of mind.* New York: Oxford University Press Inc., pp. 1-23.

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

Croft, R. J. and Barry, R. J. 1998. EOG correction: a new perspective. *Electroencephalography and Clinical Neurophysiology* 107, pp. 387-394.

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

Curran, T. and Hintzman, D. L. 1995. Violation of the independence assumption in process dissociation. *Journal of Experimental Psychology: Learning, Memory and Cognition* 21, pp. 531-547.

Curran, T. and Schacter, D. L. and Johnson, M. and Spinks, R. 2001. Brain potentials reflect behavioral differences in true and false recognition. *Journal of Cognitive Neuroscience.* 13, pp. 201-216.

Cycowicz, Y. M. and Friedman, D. 2003. Source memory for the color of pictures: event-related brain potentials (ERPs) reveal sensory-specific retrieval-related activity. *Psychophysiology* 40, pp. 455-464.

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

Dobbins, I. G. and Foley, H. and Schacter, D. L. and Wagner, A. D. 2002. Executive control during episodic retrieval: Multiple prefrontal processes subserve source memory. *Neuron* 35, pp. 989-996.

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

Dodson, C. S. and Johnson, M. K. 1993. Rate of false source attributions depends on how questions are asked. *American Journal of Psychology* 106, pp. 541-557.

Donaldson, D. I. and Allan, K. and Wilding, E. L. 2002. Fractionating retrieval from episodic memory using event-related potentials. In: Parker, A.E. and Wilding, E.L. and Bussey, T.J. eds. *The cognitive neuroscience of memory: Episodic encoding and retrieval.* Hove: Psychology Press, pp. 39-58.

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

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

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

Donchin, E. 1981. Suprise!...Suprise? *Psychophysiology* 18, pp. 493-513.

Donchin, E. and Coles, M. G. H. 1988. Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences* 11, pp. 355-372.

Donchin, E. and Ritter, W. and McCallum, W. C. 1978. Cognitive psychophysiology: The endogenous components of the ERP. In: Callaway, E. and Tueting, P. and Koslow, S.H. eds. *Event-Related Potentials in Man*. London: Academic Press, pp. 349-442.

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

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

Duzel, E. and Picton, T. W. and Cabeza, R. and Yonelinas, A. P. and Scheich, H. and Heinze, H. J. and Tulving, E. 2001. Comparing electrophysiological and hemodynamic measures of neural activation during memory retrieval. *Human Brain Mapping* 13, pp. 104-123.

Duzel, E. and Vargha-Khadem, F. and Heinze, H. J. and Mishkin, M. 2001. Brain activity evidence for recognition without recollection after early hippocampal damage. *Proceedings of the National Academy of Sciences, USA* 98, pp. 8101-8106.

Duzel, E. and Yonelinas, A. P. and Mangun, G. R. and Heinze, H. J. and 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, pp. 5973-5978.

Dywan, J. and Segalowitz, S. J. and Arsenault, A. 2002. Electrophysiological response during source memory decisions in older and younger adults. *Brain and Cognition* 49, pp. 322-340.

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

Dywan, J. and Segalowitz, S. J. and Webster, L. and Hendry, K. and Harding, J. 2001. Event-related potential evidence for age-related differences in attentional allocation during a source monitoring task. *Developmental Neuropsychology* 19, pp. 99-120.

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

Dzulkifli, M. A. and Wilding, E. L. in press. Electrophysiological indices of strategic episodic retrieval processing. *Neuropsychologia*.

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

Friedman, D. 1990. ERPs during continuous recognition memory for words. *Biological Psychology* 30, pp. 61-87.

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

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

Gardiner, J. M. and Java, R. I. 1993. Recognition memory and awareness: an experiential approach. *European Journal of Cognitive Psychology.* 5, pp. 337-346.

Grady, C. L. and McIntosh, A. R. and Beig, S. and Keightley, M. L. and Burian, H. and Black, S. 2003. Evidence from functional neuroimaging of a compensatory frontal netwrok in Alzheimer's disease. *Journal of Neuroscience* 23, pp. 986-993.

Graf, P. and Schacter, D. L. 1985. Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 11, pp. 501-518.

Greenhouse, G. W. and Geisser, S. 1959. On methods in the analysis of repeated measures designs. *Psychometrika* 49, pp. 95-112.

Henson, R. N. A. and Rylands, A. and Ross, E. and Vuilleumeir, P. and Rugg, M. D. 2004. The effect of repetition lag on electrophysiological and hemodynamic correlates of visual object priming. *NeuroImage* 21, pp. 1674-1689.

Henson, R. N. A. and Shallice, T. and Dolan, R. J. 1999. Right prefrontal cortex and episodic memory retrieval: a fMRI test of the monitoring hypothesis. *Brain* 122, pp. 1367-1381.

Herron, J. E. and Quayle, A. H. and Rugg, M. D. 2003. Probability effects on event-related potential correlates of recognition memory. *Cognitive Brain Research* 16, pp. 66-73.

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

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

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

Hornberger, M. and Morcom, A. M. and Rugg, M. D. 2004. Neural correlates of retrieval orientation: Effects of Study-Test similarity. *Journal of Cognitive Neuroscience* 16, pp. 1196-1210.

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

Jacoby, L. L. and Dallas, M. 1981. On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General* 3, pp. 306-340.

Jacoby, L. L. and Kelley, C. 1992. Unconscious influences of memory: Dissociations and automaticity. In: Milner, A.D. and Rugg, M.D. eds. *The Neuropsychology of Consciousness*. London: Academic Press, pp. 201-233.

Jacoby, L. L. and Kelley, C. M. and Dywan, J. 1989. Memory attributions. In: Roediger, H.L. and Craik, F.M. eds. *Varieties of Memory and Consciousness*. Hillsdale, New Jersey: Erlbaum, pp. 391-422.

Jacoby, L. L. and Toth, J. P. and Yonelinas, A. P. 1993. Separating conscious and unconscious influences of memory: Measuring recollection. *Journal of Experimental Psychology: General* 122, pp. 139-154.

Jasper, H. A. 1958. The ten-twenty system of the international federation. *Electroencephalography and Clinical Neurophysiology* 10, pp. 371-375.

Johannsen, M. and Mecklinger, A. 2003. The late posterior negativity in ERP studies of episodic memory: action monitoring and retrieval of attribute conjunctions. *Biological Psychology* 64, pp. 91-117.

Johansson, M. and Stenberg, G. and Lindberg, M. and Rosen, I. 2002. Memory for perceived and imagined pictures - an event-related potential study. *Neuropsychologia* 40, pp. 986-1002.

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

Johnson, M. K. and Hashtroudi, S. and Lindsay, D. S. 1993. Source monitoring. *Psychological Bulletin* 114, pp. 3-28.

Johnson, M. K. and Kounios, J. and Nolde, S. F. 1996. Electrophysiological brain activity and memory source monitoring. *NeuroReport* 8, pp. 1317-1320.

Johnson, M. K. and Raye, C. L. 1981. Reality monitoring. *Psychological Review* 88, pp. 67-85.

Johnson, R. 1989. Auditory and visual P300s in temporal lobectomy patients: Evidence for modality dependent generators. *Psychophysiology* 26, pp. 633-650.

Johnson, R. and Pfefferbaum, A. and Kopell, B. S. 1985. P300 and long-term memory: Latency predicts recognition performance. *Psychophysiology* 22, pp. 497-507.

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

Kapur, S. and Craik, F. I. M. and Jones, C. and Brown, G. M. and Houle, S. and Tulving, E. 1995. Functional role of the prefrontal cortex in retrieval of memories: a PET study. *Neuroreport* 6, pp. 1880-1884.

Kelley, C. M. and Jacoby, L. L. and Hollingshead, A. 1989. Direct vs. indirect tests of memory for source: Judgements of modality. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 15, pp. 1101-1108.

Kiloh, J. G. and Osselton, J. W. 1961. *Clinical Electroencephalography*. London: Butterworths.

Koriat, A. and Goldsmith, M. 1996. Monitoring and control operations in the strategic regulation of memory accuracy. *Psychological Review* 103, pp. 490-517.

Kucera, H. and Francis, W. N. 1967. *Computational analysis of present-day American English*. RI: Brown University Press.

Kutas, M. and Hillyard, S. A. 1980. Reading senseless sentences: brain potentials reflect semantic incongruity. *Science* 207, pp. 203-205.

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

Lins, O. G. and Picton, T. W. and Berg, P. and Scherg, M. 1993. Ocular artifacts in EEG and event-related potentials. 1. Scalp Topography. *Brain Topography* 6, pp. 51-63.

Logan, J. M. and Sanders, A. L. and Snyder, A. Z. and Morris, J. C. and Buckner, R. L. 2002. Under-Recruitment and Nonselective Recruitment: Dissociable Neural Mechanisms Associated with Aging. *Neuron* 33, pp. 827-840.

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

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

McClelland, J. L. and McNaughton, B. L. and O'Reilly, R. C. 1995. Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review* 102, pp. 419-457.

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

Mecklinger, A. and von Cramon, D. Y. and Matthes-von Cramon, G. 1998. Event-related potential evidence for a specific recognition memory deficit in adult survivors of cerebral hypoxia. *Brain* 121, pp. 1919-1935.

Metcalfe, J. 1993. Novelty Monitoring, Metacognition, and Control in a Composite Holographic Associative Recall Model: Implications for Korsakoff Amnesia. *Psychological Review* 100, pp. 3-22.

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

Morcom, A. M. and Rugg, M. D. 2002. Getting ready to remember: the neural correlates of task set during recognition memory. *NeuroReport* 13, pp. 149-153.

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

Naatanen, R. 1982. Processing negativity: An evoked-potential reflection of selective attention. *Psychological Bulletin* 92, pp. 605-640.

Naatanen, R. and Picton, T. W. 1987. The N1 wave of the human electric and magnetic response to sound: A review and an analysis of the component structure. *Psychophysiology* 24, pp. 375-425.

Nessler, D. and Mecklinger, A. 2003. ERP correlates of true and false recognition after diferent retention delays: stimulus and response related processes. *Psychophysiology* 40, pp. 146-159.

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

Neville, H. J. and Kutas, M. and Chesney, G. and Schmidt, A. L. 1986. Event-related brain potentials during initial encoding and recognition memory of congruous and incongruous words. *Journal of Memory and Language* 25, pp. 75-92.

Norman, D. A. and Shallice, T. 1980. Attention to action: Willed and automatic control of behaviour.San Diego: Center for Human Information Processing, University of California.

Norman, D. A. and Shallice, T. 1986. Attention to action: Willed and automatic control of behaviour. In: Davidson, R.J. and Schwartz, G.E. and Shapiro, D. eds. *Consciousness and self regulation.* Vol. 4. New York: Plenum Press, pp. 1-18.

Nunez, P. L. 1981. *Electric fields of the brain: The neurophysics of EEG.* New York: Oxford University Press.

Nunez, P. L. 1990. Physical principles and neurophysiological mechanisms underlying event-related potentials. In: Rohrbaugh, J.W. and Parasuraman, R. and Johnson, R. eds. *Event-Related Brain Potentials: Basic Issues and Applications.* Oxford: Oxford University Press, pp. 19-36.

Nyberg, L. and Tulving, E. and Habib, R. and Nilsson, L. G. and Kapur, S. and Houle, S. and Cabeza, R. and McIntosh, A. R. 1995. Functional brain maps of retrieval mode and recovery of episodic information. *NeuroReport* 7, pp. 249-252.

Paller, K. A. and Kutas, M. 1992. Brain potentials during retrieval provide neurophysiological support for the distinction between conscious recollection and priming. *Journal of Cognitive Neuroscience.* 4, pp. 375-391.

Paller, K. A. and Kutas, M. and McIsaac, H. K. 1995. Monitoring conscious recollection via the electrical activity of the brain. *Psychological Science* 6, pp. 107-111.

Picton, T. W. and Bentin, S. and Berg, P. and Donchin, E. and Hillyard, S. A. and Johnson, S. A. and Johnson, R. and Miller, G. R. and Ritter, W. and Ruchkin, D. S. and Rugg, M. and Taylor, M. J. 2000. Guidelines for using human event-related potentials to study cognition: recording standards and publication criteria. *Psychophysiology* 37, pp. 127-152.

Picton, T. W. and Lins, O. G. and Scherg, M. 1995. The recording and analysis of event-related potentials. In: Boller, F. and Grafman, J. eds. *Handbook of Neuropsychology, Volume 10.* Vol. 9. Elsevier, pp. 429-499.

Rajaram, S. and Roediger, H. L. 1993. Direct comparison of four implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 19, pp. 765-776.

Ranganath, C. and Johnson, M. K. and D'Esposito, M. 2000. Left anterior prefrontal activation increases with demands to recall specific perceptual information. *Journal of Neuroscience* 20: RC108, pp. 1-6.

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

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

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

Rugg, M. and Allan, K. 2000. Event-related potential studies of memory. In: E.Tulving and Craik, F.I.M. eds. *The Oxfrd Handbook of Memory.* London: Oxford University Press, pp. 521-534.

Rugg, M. D. 1992. Event-related potentials in clinical neuropsychology. In: Crawford, J.R. and Parker, D.M. and McKinlay, W.W. eds. *A Handbook of Neuropsychological Assessment.* Hove: Erlbaum, pp. 393-411.

Rugg, M. D. 1998. Converging approaches to electrophysiological and haemodynamic investigations of memory. *Human Brain Mapping* 6, pp. 394-398.

Rugg, M. D. 1998. Functional Neuroimaging in Cognitive Neuroscience. In: Brown, C.M. and Hagoort, P. eds. *The Neurocognition of Language.* Oxford: Oxford University Press, pp. 15-36.

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

Rugg, M. D. and Brovedani, P. and Doyle, M. C. 1992. Modulation of event-related potentials by word repetition in a task with inconsistent mapping between repetition and response. *Electroencephalography and Clinical Neurophysiology* 84, pp. 521-531.

Rugg, M. D. and Doyle, M. C. 1992. Event-related potentials and recognition memory for low- and high-frequency words. *Journal of Cognitive Neuroscience* 4, pp. 69-79.

Rugg, M. D. and Furda, J. and Lorist, M. 1988. The effects of task on the modulation of event-related potentials by word repetition. *Psychophysiology* 25, pp. 55-63.

Rugg, M. D. and Henson, R. N. A. 2003. Episodic memory retrieval: an (event-related) functional neuroimaging perspective. In: Parker, A.E. and Wilding, E.L. and Bussey, T.J. eds. *The Cognitive Neuroscience of Memory: Episodic encoding and retrieval.* Hove: Psychology Press, pp. 5-38.

Rugg, M. D. and Henson, R. N. A. and Robb, W. G. K. 2003. Neural correlates of retrieval processing in the prefrontal cortex during recognition and exclusion tasks. *Neuropsychologia* 41, pp. 40-52.

Rugg, M. D. and Roberts, R. C. and Potter, D. D. and Pickles, C. D. and Nagy, M. E. 1991. Event-related potentials related to recognition memory. Effects of unilateral temporal lobectomy and temporal lobe epilepsy. *Brain* 114, pp. 2313-2332.

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

Rugg, M. D. and Schloerscheidt, A. M. and Mark, R. E. 1998. An electrophysiological comparison of two indices of recollection. *Journal of Memory and Language* 39, pp. 47-69.

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

Sanquist, T. F. and Rohrbaugh, J. W. and Syndulko, K. and Lindsley, D. B. 1980. Electrocortical signs of levels of processing: Perceptual analysis and recognition memory. *Psychophysiology* 17, pp. 568-576.

Schacter, D. L. 1987. Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 13, pp. 501-518.

Schacter, D. L. and Norman, K. A. and Koutstaal, W. 1998. The cognitive neuroscience of constructive memory. *Annual review of Psychology* 49, pp. 289-318.

Scherg, M. 1990. Fundamentals of dipole source potential analysis. In: Grandori, F. and Hoke, M. and Romani, G.L. eds. *Auditory Evoked Magnetic fields and Electric Potentials: Advances in Audiology.* Vol. 6. Basel: Karger, pp. 40-69.

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

Semon, R. S. 1904. *The mneme*. London: Allen and Unwin.

Semon, R. S. 1921. *Die mneme als erhaltendes prinzip im wechsel des organishchen gesechehens*. Berlin: William Engelman.

Senkfor, A. J. and C., V. P. 1998. Who said what: An event-related potential investigation of source and item memory. *Journal of Experimental Psychology: Learning, Memory and Cognition* 24, pp. 1005-1025.

Shallice, T. and Warrington, E. K. 1970. Independent functioning of verbal memory stores: A neuropsychological study. *Quarterly Journal of Experimental Psychology* 22, pp. 261-273.

Sharbrough, F. and Chatrian, G. E. and Lesser, R. P. and Luders, H. and Nuwer, M. and Picton, T. W. 1991. AEEGS Guidelines for Standard Electrode Position Nomenclature. *Journal of Clinical Neurophysiology* 8, pp. 200-202.

Shimamura, A. P. 1994. Memory and frontal lobe function. In: Gazzaniga, M.S. ed. *The Cognitive Neurosciences*. Cambridge, Massachusetts: MIT Press, pp. 803-813.

Simons, J. S. and Gilbert, S. J. and Owen, A. M. and Fletcher, P. C. and Burgess, P. W. 2005. Distinct roles for lateral and medial anterior prefrontal cortex in contextual recollection. *Journal of Neurophysiology*.

Simons, J. S. and Spiers, H. J. 2003. Prefrontal and medial temporal lobe interactions in long-term memory. *Nature reviews: neuroscience* 4, pp. 637-648.

Smith, M. E. 1993. Neurophysiological manifestations of recollective experiênce during recognition memory judgements. *Journal of Cognitive Neuroscience* 5, pp. 1-13.

Smith, M. E. and Guster, K. 1993. Decomposition of recognition memory event-related potentials yields target, repetition, and retrieval effects. *Electroencephalography and Clinical Neurophysiology* 86, pp. 335-343.

Smith, M. E. and Halgren, E. 1989. Dissociation of recognition memory components following temporal lobe lesions. *Journal of Experimental Psychology: Learning, Memory and Cognition* 15, pp. 50-60.

Spencer, K. and Abad, E. V. and Donchin, E. 2000. On the search for the neurophysiological manifestation of recollective experience. *Psychophysiology* 37, pp. 494-506.

Squire, L. R. 1992. Declarative and non-declarative memory: multiple brain systems supporting learning and memory. *Journal of Cognitive Neuroscience.* 4, pp. 232-243.

Squire, L. R. and Knowlton, B. J. 1994. Memory, hippocampus, and brain systems. In: Gazzaniga, M.S. ed. *The Cognitive Neurosciences*. Cambridge, Massachusetts: MIT Press, pp. 825-837.

Squire, L. R. and Zola-Morgan, M. 1991. The medial temporal lobe memory system. *Science* 253, pp. 1380-1386.

Stapleton, J. M. and Halgren, E. and Moreno, K. A. 1987. Endogenous potentials after anterior temporal lobectomy. *Neuropsychologia* 67, pp. 549-557.

Stuss, D. T. and Eskes, G. A. and Foster, J. K. 1994. Experimental neuropsychological studies of frontal lobe functions. In: Boller, F. and Grafman, J. eds. *Handbook of Neuropsychology, Volume 10*. Vol. 9. New York: Elsevier, pp. 149-183.

Sutton, S. and Braren, M. and Zubin, J. and John, E. R. 1965. Evoked potential correlates of stimulus uncertainty. *Science* 150, pp. 1187-1188.

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

Trott, C. T. and Friedman, D. and Ritter, W. and Fabiani, M. 1997. Item and source memory: differential age effects revealed by event-related potentials. *Neuroreport* 8, pp. 3373-3378.

Tsivilis, D. and Otten, L. and Rugg, M. D. 2001. Context effects on the neural correlates of recognition memory: an electrophysiological study. *Neuron* 31, pp. 1-20.

Tulving, E. 1972. Episodic and semantic memory. In: Tulving, E. and Donaldson, W. eds. *Organization of Memory*. New York: Academic Press, pp. 381-403.

Tulving, E. 1983. *Elements of Episodic Memory*. Oxford: Oxford University Press.

Tulving, E. 1985. How many memory systems are there? *American Psychologist* 40, pp. 385-398.

Tulving, E. 1986. What kind of hypothesis is the distinction between episodic and semantic memory ? *Journal of Experimental Psychology: Learning, Memory, and Cognition* 12, pp. 307-311.

Tulving, E. 1993. What is episodic memory? *Current Perspectives in Psychological Science* 2, pp. 67-70.

Tulving, E. 1993a. Human memory. In: Andersen, P. and Hvalby, O. and Paulsen, O. and Hokfelt, B. eds. *Memory Concepts - 1993. Basic and Clinical Aspects*. New York: Elsevier, pp. 27-45.

Tulving, E. and Kapur, S. and Craik, F. I. M. and Moscovitch, M. and Houle, S. 1994. Hemispheric encoding/retrieval asymmetry in episodic memory: Positron emission tomography findings. *Proceedings of the National Academy of Science* 91, pp. 2016-2020.

Ullsperger, M. and Mecklinger, A. and Muller, U. 2000. An electrophysiological test of directed forgetting: The role of retrieval inhibition. *Journal of Cognitive Neuroscience* 12, pp. 924-940.

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

Van Petten, C. and Kutas, M. and Kluender, R. and Mitchiner, M. and McIsaac, H. 1991. Fractionating the word repetition effect with event-related potentials. *Journal of Cognitive Neuroscience* 3, pp. 129-150.

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

Velanova, K. and Jacoby, L. L. and Wheeler, M. E. and McAvoy, M. P. and Petersen, S. E. and Buckner, R. L. 2003. Functional-anatomic correlates of sustained and transient processing components engaged during controlled retrieval. *Journal of Neuroscience* 23, pp. 8460-8470.

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

Wagner, A. D. and Desmond, J. E. and Glover, G. H. and Gabrieli, J. D. 1998. Prefrontal cortex and recognition memory; Functional-MRI evidence for context-dependent retrieval processes. *Brain* 121, pp. 1985-2002.

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

Whittlesea, B. W. A. 1993. Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 19, pp. 1235-1253.

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

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

Wilding, E. L. and Fraser, C. S. and Herron, J. E. in press. Indexing strategic retrieval of colour information with event-related potentials. *Cognitive Brain Research.*

Wilding, E. L. and Nobre, A. C. 2001. Task-switching and memory-retrieval processing: Electrophysiological evidence. *NeuroReport* 12, pp. 3613-3617.

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

Wilding, E. L. and Rugg, M. D. 1997. Event-related potentials and the recognition memory exclusion task. *Neuropsychologia* 35, pp. 119-128.

Wilding, E. L. and Sharpe, H. L. 2003. Episodic memory encoding and retrieval: Recent insights from event-related potentials. In: Zani, A. and Mado-Proverbio, A. eds. *The cognitive electrophysiology of mind and brain*. San Diego: Academic Press, pp. 169-196.

Wilding, E. L. and Sharpe, H. L. 2004. The influence of response-time demands on electrophysiological correlates of successful episodic retrieval. *Cognitive Brain Research* 18, pp. 185-195.

Wood, C. C. 1987. Generators of event-related potentials. In: Halliday, A.M. and Butler, S.M. and Paul, R. eds. *A Textbook of Clinical Neurophysiology*. New York: Wiley, pp. 535-567.

Wood, C. C. and McCarthy, G. and Allison, T. and Goff, W. R. and Williamson, P. D. and Spencer, D. D. 1982. Endogenous event-related potentials following temporal lobe excisions in humans. *Society for Neuroscience Abstracts* 8, p. 976.

Wood, J. N. and Grafman, J. 2003. Human prefrontal cortex: processing and representational perspectives. *Nature reviews: neuroscience* 4, pp. 139-147.

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

Yonelinas, A. P. 1998. Recollection and familiarity in recognition memory: Convergence of remember/know, process dissociation and ROC data. *Neuropsychology* 12, pp. 323-329.

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

Yonelinas, A. P. and Jacoby, L. L. 1994. Dissociations of processes in recognition memory: Effects of interference and of response speed. *Canadian Journal of Experimental Psychology* 48, pp. 516-534.

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

Yovel, G. and 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, pp. 789-800.

Zola-Morgan, S. and Squire, L. R. 1993. The neuroanatomy of amnesia. *Annual Review of Neuroscience* 16, pp. 547-563.

APPENDIX A

Experiment 1:

Analysis of ERP old/new effects

Figures 10.1 and 10.2 show the ERP old/new effects that were obtained in the phonological and semantic target designation tasks, respectively. In both target designation tasks, the ERPs evoked by targets and non-targets are more positive-going than those evoked by correct rejections from about 300-500 ms at posterior sites and in the semantic target designation task at frontal sites. The enhanced positivity evoked by targets in the semantic designation remains until the end of the recording epoch at parietal sites. Common to both target designation tasks is relatively greater positivity evoked by new words in comparison to either type of old words, onsetting at about 650 ms. This modulation is larger over the right than the left hemisphere. Also evident in both target designations is the late posterior negativity, which is somewhat more pronounced for the phonological target designation.

The ERP old/new effects were subjected to a series of global analyses incorporating data from the same array of electrode locations that were employed for the analyses of the ERPs evoked by new words (see Chapter 4). The analyses were completed over three post-stimulus time-windows: 300-500, 500-800 and 800-1100 ms. The first two time windows were selected on the basis of previous findings in ERP recognition memory and source memory studies (Rugg and Allan, 2000), while the third time window was to capture the differences evident later in the recording epoch. The data were submitted to ANOVA with factors of TK (phonological, semantic), CC (target, new, non-target), HM (left, right), AP dimension (anterior, posterior) and ST (4 levels). The mean numbers of trials (range in brackets) contributing to averaged ERPs associated with targets and non-targets in the phonological target designation task were 35 (18-48) and 46 (29-56), respectively. The corresponding values for the semantic target designation task were 46 (23-55) and 44 (19-56). As stated in chapter 4, the mean numbers of trials for new items were 44 (24-56) and 46 (23-57) for the phonological and semantic designations, respectively.

In the analysis over each of the three time windows, interactions involving TK and CC were obtained. Therefore the follow-up analyses were completed for all possible paired contrasts of the ERPs evoked by the three word conditions, separated according to target designation. The outcomes of the analyses are described below, separated according to epoch, along with the results of the follow-up analyses.

300-500 ms

The initial analysis over the 300-500 ms time window revealed a main effect of CC ($F(1.9, 38.9) = 6.54, p < .01$), a CC x AP ($F(1.9, 37.4) = 3.88$ $p < .05$), a CC x ST ($F(3.7, 74.7) = 4.83, p < .01$) and a TK x CC ($F(2.0, 39.4) = 3.68, p < .05$) interaction. For the phonological designation, the only reliable effect in this epoch – the CC x HM interaction for the target vs. non-target contrast (see Table 10.1) - reflects the fact that the relative positivity for targets in comparison to non-targets is larger over the right than the left hemisphere.

For the semantic target designation task (see Table 10.2), the CC x AP x ST interaction revealed by the target vs. new contrast reflects the fact that the relatively greater positivity for targets is largest at superior pre-frontal sites. For non-targets, the three-way interaction between CC, HM and ST reflects the fact that the relatively greater positivity for non-targets than for new words is largest at left superior sites. The contrast between the two categories of old words revealed a three-way interaction involving CC, AP and ST which reflects the fact that at superior pre-frontal sites, the ERPs evoked by targets are more positive-going than those evoked by non-targets.

500-800 ms

The initial analysis revealed interactions between CC and HM (F(1.9, 37.2) = 7.27, $p < .01$), CC, AP and HM (F(1.7, 34.8) = 9.14, $p < .01$), as well as CC, AP and ST (F(3.3, 66.1) = 6.38, $p < .01$). Three interactions involving target designation were also significant: TK x CC x HM (F(2.0, 39.3) = 20.88, $p < .01$), TK x CC x AP x HM (F(1.4, 28.1) = 3.84, $p < .05$) and TK x CC x HM x ST (F(3.7, 73.3) = 3.38, $p < .01$). The follow-up analysis at anterior sites for the four-way interaction revealed by the target vs. new contrast in the phonological target designation task (see Table 10.3) revealed no reliable effects involving CC, despite the apparent greater positivity (see Figure 10.1). Follow-up analysis at posterior sites revealed an interaction between CC and HM (F(1,20) = 7.45, $p < .01$) and a CC x HM x ST interaction (F(2.3, 46.1) = 5.01, $p < .01$), indicating that the largest differences between conditions are at right hemisphere superior and mid-lateral sites, where the ERPs evoked by new words are more positive-going. For the non-target vs. new contrast, the follow-up analysis at anterior sites revealed a main effect of CC (F(1,20) = 4.94, $p < .05$), as well as CC x HM (F(1,20) = 8.17, $p < .01$) and CC x ST (F2.2, 43.3) = 5.33, $p < .01$) interactions. The reasons for these interactions are: 1, the relatively greater positivity for new rather than non-target words, which is largest over the right hemisphere, and 2, the minimal differences between the conditions at sites FP1, FP2, O1 and O2. The follow-up analysis at posterior sites revealed a CC x HM interaction (F(1,20) = 56.68, $p < .01$) and a CC x HM x ST interaction (2.9, 58.4) = 11.07, $p < .01$), reflecting the fact that the mean amplitudes for new words are more positive-going than those for non-targets over the right hemisphere, particularly at P6, while over the left hemisphere the ERPs evoked by these two classes of test words differ minimally. The contrasts involving the two categories of old words revealed a three-way interaction involving CC, HM and ST, reflecting the fact that the relatively greater positivity for targets is for the most part restricted to right hemisphere sites, where it is most pronounced at superior and mid-lateral locations.

For the semantic target designation task (see Table 10.4), the contrasts involving new words revealed four-way interactions between CC, AP, HM and ST. The follow-up analysis at anterior sites for targets revealed an interaction between CC and ST (F(2.2, 43.4) = 7.95, $p < .01$), reflecting the fact that the relatively greater positivity for targets than for new words is larger at superior than at mid-lateral and inferior sites. The follow-up analysis at posterior sites for targets revealed a main effect of CC (F(1,20) = 6.26, $p < .05$), as well as CC x HM (F(1,20) = 41.49, $p < .01$) and CC x HM x ST interactions (F(2.6, 51.1) = 7.05, $p < .01$), reflecting the fact that the relatively greater positivity for targets is largest at P5. The follow-up analysis for non-targets revealed a significant effect only at posterior sites. The CC x HM x ST interaction (F(2.2, 43.2) = 6.46, $p < .01$) reflects the fact that the relatively greater positivity is associated with new rather than non-target words at all sites over the right hemisphere as well as at T5, while at left hemisphere mid-lateral and superior sites the greater relative positivity is associated with non-targets. Finally, the CC x AP x ST interaction revealed by the target vs. non-target contrast indicates that the relatively greater positivity for targets is largest at left hemisphere posterior sites.

<u>800-1100 ms</u>

The initial analysis revealed a CC x ST interaction (F(3.9, 77.3) = 3.77, $p < .01$), and two three-way interactions involving CC: CC x AP x HM (F(1.9, 38.8) = 13.91, $p < .01$) and CC x AP x ST (F(2.8, 56.2) = 6.19, $p < .01$). Two interactions involving TK were also significant: TK x CC x HM (F(1.9, 38.2) = 10.80, $p < .01$) and TK x CC x HM x ST (F(4.7, 93.2) = 3.68, $p < .01$). For the phonological target designation task (see Table 10.5), the follow-up analysis for the four-way interaction revealed by the target vs. new contrast revealed significant interactions involving CC at posterior sites only: CC x HM (F(1,20) = 6.69, $p < .01$), CC x ST (F(1.7, 33.9) = 3.47, $p < .05$) and CC x HM x ST (F(2.4, 48.9) = 3.42, $p < .05$), reflecting the fact that at left posterior sites, particularly P5, the greater relative positivity is associated with targets, while over the right hemisphere, the reverse is true.

The non-target vs. new contrast revealed two three-way interactions (CC x AP x HM, CC x AP x ST) reflecting the fact that the relatively greater positivity for new words has more of a hemisphere asymmetry at posterior than at anterior sites, and the positivity is most pronounced at anterior superior sites. The target vs. non-target contrast revealed a three-way interaction involving CC, HM and ST, reflecting the fact that the mean amplitudes for targets are more positive-going than those for non-targets at all sites over the right hemisphere, whereas at left inferior sites the mean amplitudes for non-targets rather than targets are more positive-going.

For the semantic target designation task (see Table 10.6), the target vs. new contrast revealed three three-way interactions (CC x AP x ST, CC x HM x ST, CC x AP x HM) and the reasons for these interactions are the relatively focal positivities for old words at left posterior scalp sites, while the effects being larger at superior than at inferior sites. The non-target vs. new contrast also revealed two three-way interactions: CC x AP x HM and CC x AP x ST, reflecting the fact that the greater positivity for new words is pronounced at right hemisphere posterior locations, particularly at superior sites. The target vs. non-target contrast revealed a CC x AP x HM interaction, reflecting the fact that the relatively greater positivity for targets is largest at left posterior sites.

Analyses at P5

The ERP old/new effects were also subjected to a specific analysis involving the data obtained from P5 over the 500-800 ms time window. This analysis was implemented in order to determine the relationship between the ERP signature of recollection – the left-parietal ERP old/new effect for target and for non-target words. This analysis was motivated in part by the findings in Experiments Three and Four, and are included here for completeness, whilst acknowledging that the response confound makes conclusions somewhat tentative. The combination of location and time window corresponds to that over which parietal ERP old/new effects are typically largest (Rugg & Allan, 2000).

The initial analysis included the factors of TK (phonological, semantic), CC (target, new, non-target) and ST. The analysis revealed a main effect of CC ($F(1.9, 38.5) = 6.47$, $p < .01$) and an interaction between TK and CC ($F(1.6, 32.8) = 6.93$, $p < .01$). Consistent with the analysis strategy described above, follow-up analyses were completed for all possible paired comparisons of the ERPs evoked by correct judgements to targets, non-targets and to new test words, separated according to target designation. Reliable effects involving CC were obtained in the analyses for targets for the semantic target designation task only (new words: CC $(1,20) = 20.24$, $p < .01$; non-targets: CC ($F(1,20) = 15.78$, $p < .01$), reflecting the relatively greater positivity for targets than for non-targets and for new words.

Additional analyses were also completed over the 600-800 ms and 800-1100 ms epochs. The analysis over these time windows included the data from C6 and Pz, respectively.

These two sites were chosen since they represent the sites over which the enhanced negativity for old words relative to new words was evident in Experiment 3 (see Figures 10.1 and Figure 10.2 and Chapter 4). The data were submitted to ANOVA with the same factors described above.

The initial analysis over the 600-800 ms time window revealed a main effect of CC ($F(2.0, 39.1) = 14.92$, $p < .01$) and an interaction between TK and CC ($F(1.9, 38.3) = 3.54$, $p < .05$). This analysis was followed-up by all possible paired contrasts of the ERPs evoked by the three word conditions, separated according to target designation. For the phonological target designation, main effects of CC were revealed by the contrasts involving new words (targets: ($F(1, 20) = 10.12$, $p < .01$; non-targets: $F(1,20) = 30.60$, $p < .01$) and old words ($F(1, 20) = 7.58$, $p < .01$). This reflects the fact that the relatively greater positivity is associated with new words. Greater positivity is also associated with targets than with non-targets. For the semantic target designation task, a main effect of CC was only revealed by the non-target vs. new contrast (($F(1,20) = 5.63$, $p < .05$). This reflects the fact that the mean amplitudes for new words are more positive-going than those for non-target words.

The initial analysis over the 800-1100 ms time window at Pz revealed a main effect of CC ($F(1.9, 37.8) = 9.16$, $p < .01$) only. Follow-up analyses (collapsed across the factor of target designation) revealed main effects of CC for the contrasts involving new words only (targets: $F(1,20) = 6.21$, $p < .05$; non-targets: $F(1,20) = 16.81$, $p < .01$), reflecting the relatively greater positivity for new than for old words.

No detailed discussion of these outcomes is included here. The prominence of the large relative positivity for new words from 600 ms onwards that is particularly prominent in the phonological designation condition may be related to the response-time demands of the task (see Wilding and Sharpe, 2004, where the same response time demands were imposed in Experiment One).

FIGURE 10.1: ERP old/new effects in the phonological target designation task. Electrode montage as in Figure 4.1 (Chapter 4).

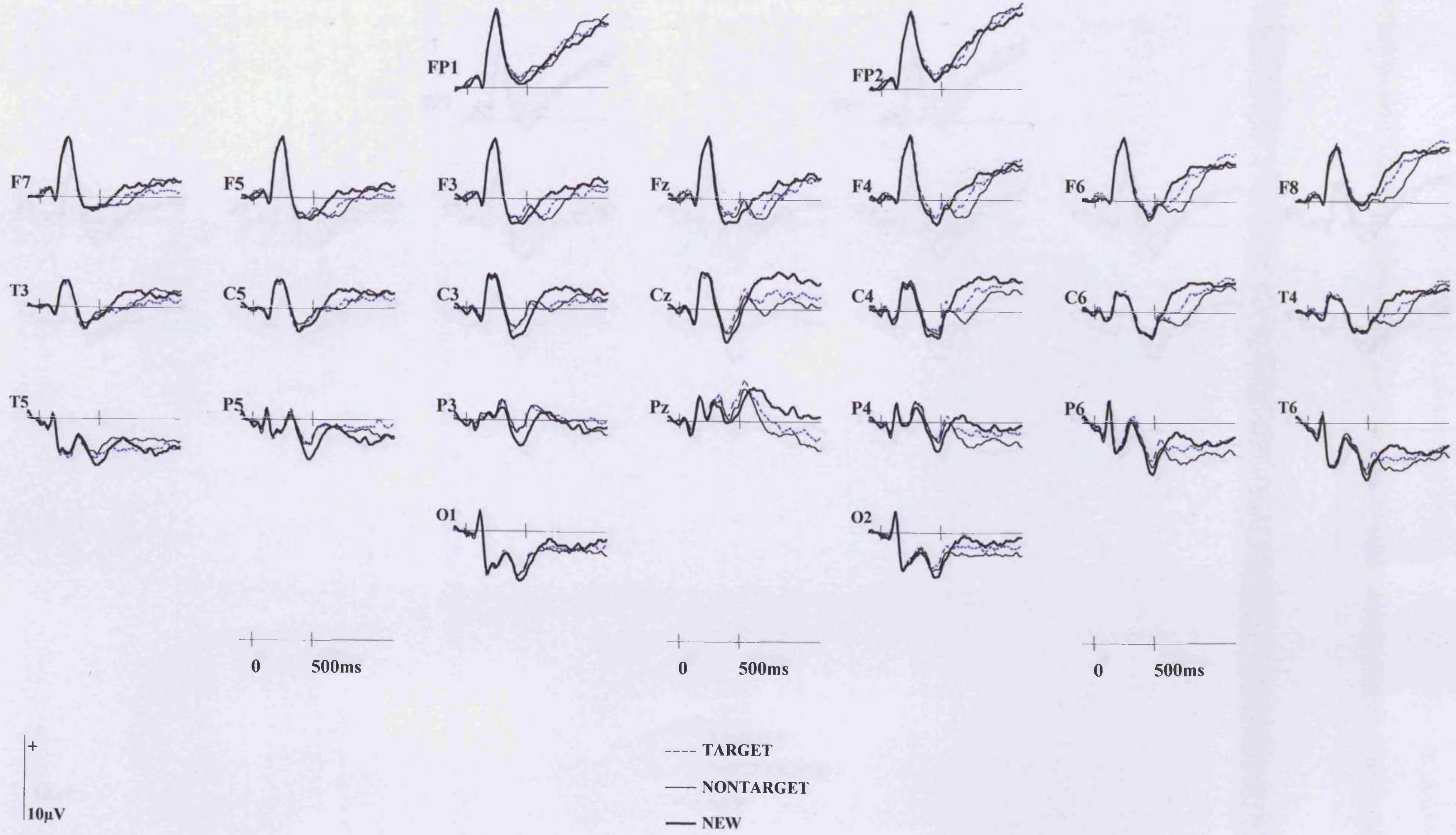


FIGURE 10.2: ERP old/new effects in the semantic target designation task. Electrode montage as in Figure 4.1 (Chapter 4).

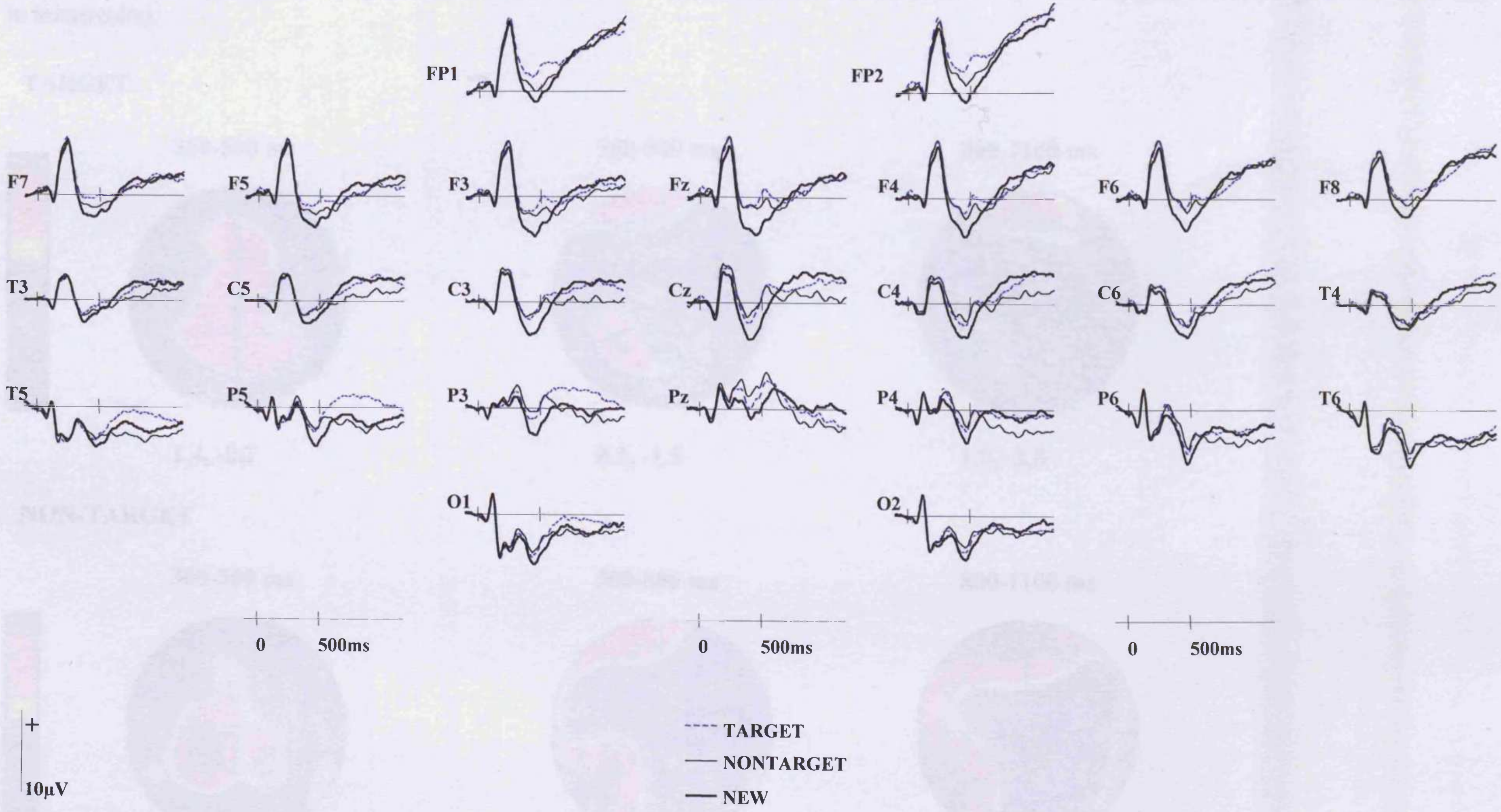


FIGURE 10.3: Scalp distributions of the ERP old/new effects evoked by targets and non-targets in the phonological target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

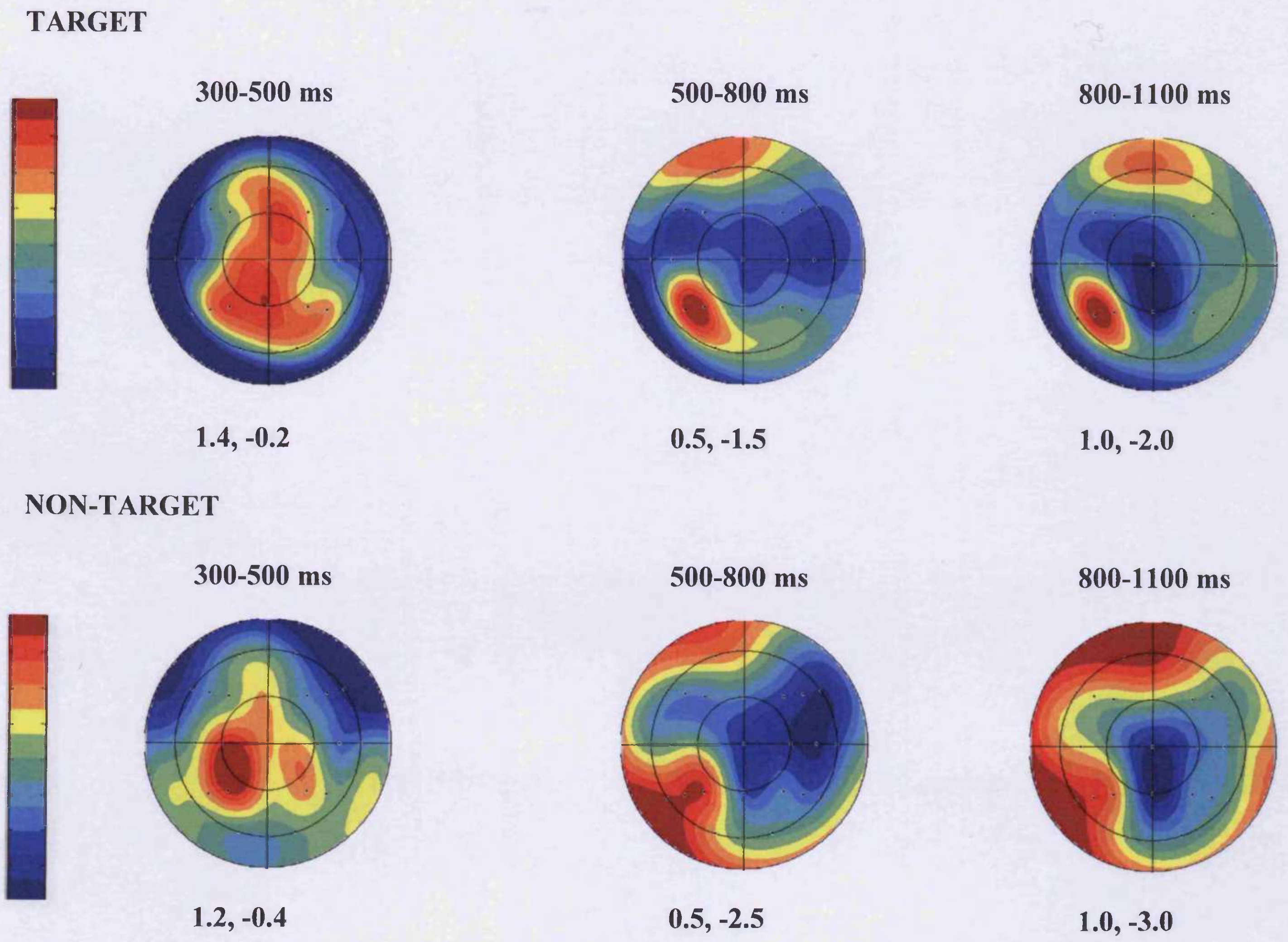


FIGURE 10.4: Scalp distributions of the ERP old/new effects evoked by targets and non-targets in the semantic target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

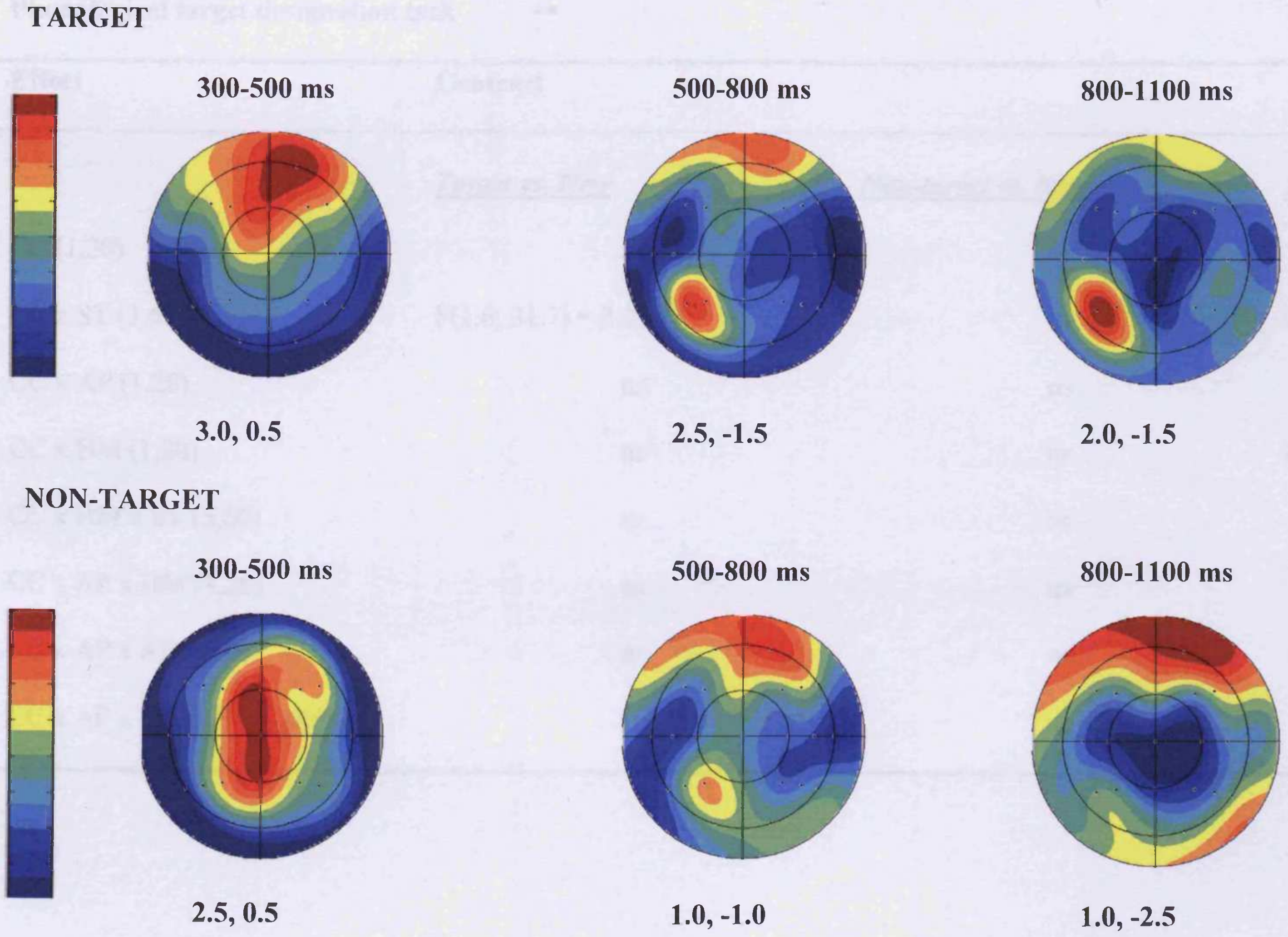


TABLE 10.1: The outcomes of follow-up analyses for ERP old/new effects in the phonological target designation task over the 300-500 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

300-500 ms
Phonological target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,20)	ns	ns	ns
CC x ST (3,60)	F(1.6, 31.7) = 3.25 *	ns	ns
CC x AP (1,20)	ns	ns	ns
CC x HM (1,20)	ns	ns	F(1,20) = 4.75 **
CC x HM x ST (3,60)	ns	ns	ns
CC x AP x HM (1,20)	ns	ns	ns
CC x AP x ST (3,60)	ns	ns	ns
CC x AP x HM x ST (3,60)	ns	ns	ns

TABLE 10.2: The outcomes of follow-up analyses for ERP old/new effects in the semantic target designation task over the 300-500 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

300-500 ms
Semantic target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,20)	F(1,20) = 23.24 ***	F(1,20) = 11.88 ***	ns
CC x ST (3,60)	F(2.4, 48.9) = 4.94 ***	F(2.4, 48.8) = 5.91 ***	F(2.3, 46.4) = 4.65 ***
CC x AP (1,20)	F(1,20) = 21.83 ***	ns	F(1,20) = 4.68 **
CC x HM (1,20)	ns	ns	ns
CC x HM x ST (3,60)	ns	F(2.4, 47.7) = 3.33 **	ns
CC x AP x HM (1,20)	ns	ns	ns
CC x AP x ST (3,60)	F(2.0, 40.9) = 4.75 ***	ns	F(1.9, 38.2) = 3.70 **
CC x AP x HM x ST (3,60)	F(2.7, 54.7) = 2.56 *	F(2.3, 45.7) = 2.57 *	ns

TABLE 10.3: The outcomes of follow-up analyses for ERP old/new effects in the phonological target designation task over the 500-800 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

500-800 ms
Phonological target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,20)	ns	F(1,20) = 4.22 **	ns
CC x ST (3,60)	ns	ns	ns
CC x AP (1,20)	ns	ns	ns
CC x HM (1,20)	F(1,20) = 3.26 *	F(1,20) = 33.51 ***	F(1,20) = 14.75 ***
CC x HM x ST (3,60)	ns	F(2.8, 55.1) = 3.79 ***	F(2.4, 47.0) = 4.76 ***
CC x AP x HM (1,20)	ns	F(1,20) = 8.38 ***	ns
CC x AP x ST (3,60)	F(2.4, 47.4) = 4.94 ***	F(2.2, 44.1) = 5.51 ***	ns
CC x AP x HM x ST (3,60)	F(2.6, 51.7) = 3.81 **	F(2.2, 43.3) = 3.56 **	ns

TABLE 10.4: The outcomes of follow-up analyses for ERP old/new effects in the semantic target designation task over the 500-800 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1^{st} column).

500-800 ms
Semantic target designation task

Effect	**Contrast**		
	Target vs. New	*Non-target vs. New*	*Target vs. Non-target*
CC (1,20)	F(1,20) = 4.44 **	ns	ns
CC x ST (3,60)	F(2.4, 47.1) = 3.88 **	ns	ns
CC x AP (1,20)	ns	ns	ns
CC x HM (1,20)	F(1,20) = 7.72 ***	ns	F(1,20) = 13.14 ***
CC x HM x ST (3,60)	F(2.6, 52.9) = 3.86 ***	F(2.4, 47.8) = 2.35 *	ns
CC x AP x HM (1,20)	F(1,20) = 16.48 ***	F(1,20) = 5.74 **	F(1,20) = 5.08 **
CC x AP x ST (3,60)	F(2.1, 41.4) = 6.88 ***	ns	F(2.3, 46.7) = 4.09 ***
CC x AP x HM x ST (3,60)	F(2.8, 55.2) = 3.09 **	F(2.3, 46.7) = 3.89 **	ns

TABLE 10.5: The outcomes of follow-up analyses for ERP old/new effects in the phonological target designation task over the 800-1100 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

800-1100 ms
Phonological target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,20)	ns	ns	ns
CC x ST (3,60)	ns	ns	ns
CC x AP (1,20)	ns	ns	ns
CC x HM (1,20)	ns	F(1,20) = 10.28 ***	F(1,20) = 10.45 ***
CC x HM x ST (3,60)	ns	ns	F(2.6, 52.4) = 3.89 ***
CC x AP x HM (1,20)	F(1,20) = 7.29 ***	F(1,20) = 10.10 ***	ns
CC x AP x ST (3,60)	F(1.8, 36.9) = 5.15 ***	F(1.9, 38.5) = 8.25 ***	ns
CC x AP x HM x ST (3,60)	F(2.8, 55.2) = 4.02 ***	ns	ns

TABLE 10.6: The outcomes of follow-up analyses for ERP old/new effects in the semantic target designation task over the 800-1100 ms epoch. Key: * $p < .1$, ** $p < .05$, *** $p < .01$, **** $p < .001$, ns = non-significant, full df in brackets (1st column).

800-1100 ms
Semantic target designation task

Effect	**Contrast**		
	Target vs. New	*Non-target vs. New*	*Target vs. Non-target*
CC (1,20)	ns	ns	F(1,20) = 4.11 *
CC x ST (3,60)	ns	F(2.1, 41.2) = 6.66 ***	F(1.9, 38.0) = 6.89 ***
CC x AP (1,20)	F(1,20) = 3.22 *	ns	F(1,20) = 12.21 ***
CC x HM (1,20)	F(1,20) = 3.87 *	ns	F(1,20) = 6.33 **
CC x HM x ST (3,60)	F(2.4, 47.6) = 3.45 **	ns	ns
CC x AP x HM (120)	F(1,20) = 16.05 ***	F(1,20) = 5.26 **	F(1,20) = 4.34 **
CC x AP x ST (3,60)	F(2.0, 40.6) = 3.98 **	F(2.5, 49.3) = 3.13 **	ns
CC x AP x HM x ST (3,60)	ns	ns	ns

APPENDIX B

Experiment 2:

Analysis of ERP old/new effects

Figures 11.1-11.6 show the ERP old/new effects that were obtained in the phonological and semantic target designation tasks for all participants, the low and the high relative difficulty groups, respectively. Common to both groups is the greater relative negativity associated with correctly identified targets and non-targets than with correctly identified new words. This relative negativity onsets approximately from 650 ms and is evident at the majority of the scalp locations, with a tendency to be most pronounced at central and posterior electrode locations and somewhat larger over the right hemisphere. The ERPs evoked by targets are markedly more positive-going than those evoked by correct rejections from about 500 ms in the semantic target designation task for the high relative difficulty group. The effect remains until the end of the recording epoch and is evident principally over the left hemisphere at posterior locations.

The ERP old/new effects were subjected to a series of global analyses incorporating data from the same array of electrode locations that were employed for the analyses of the ERPs evoked by new words (see Chapter 5). The analyses were completed over four post-stimulus time-windows: 300-500, 500-800, 800-1100 ms and 1100-1400 ms. The data were submitted to ANOVA with factors of GP (low, high), TK (phonological, semantic), CC (target, new, non-target), HM (left, right), AP dimension (anterior, posterior) and ST (4 levels). The mean numbers of trials (range in brackets) contributing to averaged ERPs associated with targets and non-targets in the phonological target designation task for the low relative difficulty group were 40

(22-55) and 45 (26-53), respectively. The corresponding values for the semantic target designation task were 43 (31-56) and 44 (16-56). For the high relative difficulty group, the mean numbers of trials for targets and non-targets in the phonological target designation task were 34 (22-48) and 46 (28-57) and for the semantic target designation task the corresponding values were 41 (19-58) and 44 (23-58). As stated in Chapter 5, the mean numbers of trials for new words in the high relative difficulty group were 44 (20-59) and 47(31-58) for the semantic and phonological target designations, respectively while for the low relative difficuty group, the corresponding values were 48 (25-59) and 47 (30-58).

The preliminary between-participants analysis over each time window did not reveal any significant effects involving group. Therefore, subsequent analyses for every time window were completed by collapsing data across this factor and comprised all possible paired contrasts of the three word conditions, separated according to TK for the 500-800 ms and 800-1100 ms time windows. For the analyses over the 300-500 ms and 1100-1400 ms time windows, no reliable effects involving TK were obtained. Thus, data were analysed for all possible paired contrasts of targets, new and non-target words, collapsing across the factor of TK. The outcomes of the analyses are described below, separated according to epoch.

300-500 ms

The initial analysis over the 300-500 ms time window revealed a main effect of CC ($F(2.0, 67.4) = 26.44$, $p < .01$), a CC x HM ($F(1.9, 63.4) = 4.02$, $p < .05$) and a CC x ST ($F(3.0, 103.6) = 11.23$, $p < .01$) interaction. Follow-up analysis (see Table 11.1) only revealed significant effects involving CC for the contrasts involving new words.

The CC x ST and the CC x HM interactions reflect the fact that the mean amplitudes for both types of old words are more positive-going than those for new words with the effects for targets being larger at superior than at inferior sites and for non-targets being larger over the left than over the right hemisphere.

500-800 ms

The initial analysis revealed a main effect of CC ($F(1.7, 57.8) = 13.43$, $p < .01$), an interaction between CC and AP ($F(1.5, 52.5) = 7.67$, $p < .01$), CC and HM ($F(1.5, 52.2) = 6.47$, $p < .01$), and CC and ST ($F(2.9, 98.8) = 3.05$, $p < .05$) as well as three-way interaction involving CC, AP and HM ($F(1.5, 51.8) = 5.86$, $p < .01$). Two interactions involving target designation were also significant: TK x CC ($F(1.8, 61.7) = 3.80$, $p < .05$), TK x CC x AP x ST ($F(4.4, 151.1) = 2.66$, $p < .05$). For the phonological target designation task (see Table 11.2), the targets vs. new contrast revealed a three-way interaction involving CC, AP and ST, reflecting the fact that the relatively greater positivity for new words rather than targets is largest at superior anterior sites. The non-target vs. new contrast revealed two two-way interactions (CC x AP, CC x HM) which reflect the fact that the relatively greater positivity for new in comparison to non-target words is larger over the left than the right hemisphere and greater at anterior than at posterior sites. The contrasts involving the two categories of old words revealed a three-way interaction between CC, AP and ST, reflecting the fact that the relatively greater positivity for targets is largest overall at the O1 and O2 sites.

For the semantic target designation task (see Table 11.3), the target vs. new contrast revealed a four-way interaction involving CC, AP, HM and ST. The follow-up analysis only revealed significant effects involving CC at posterior sites: CC (F(1,17) = 9.66, p < .01), CC x HM (F(1,17) = 15.97, p < .01), CC, HM and ST (F(2.2, 37.5) = 5.59, p < .01). These reflect the fact that the relatively greater positivity associated with targets than with new words is largest at P5. For non-targets, the CC x AP x HM interaction indicates the relatively greater positivity associated with new rather than non-target words, with the effects being largest at right anterior sites. The target vs. non-target contrast revealed a CC x AP x HM interaction, indicating that the relatively greater positivity for targets than for non-targets is largest at left posterior sites.

<u>800-1100 ms</u>

The initial analysis revealed a main effect of CC (F(1.8, 60.6) = 13.12, p < .01), a CC x ST interaction (F(3.2, 108.6) = 4.23, p < .01), a CC x AP x HM interaction (F(1.4, 48.5) = 12.69, p < .01) and a CC x AP x HM x ST interaction (F(4.9, 168.0) = 3.33, p < .01). Three interactions involving TK were also significant: TK x CC (F(1.9, 63.7) = 3.56, p < .05), TK x CC x HM (F(2.0, 67.0) = 3.81, p < .05) and TK x CC x ST (F(4.5, 151.6) = 2.87, p < .05).

For the phonological target designation task (see Table 11.4), the target vs. new contrast revealed a three-way interaction involving CC, AP and HM, reflecting the fact that the relatively greater positivity for new words rather than targets is largest at left anterior sites. The non-target vs. new contrast also revealed the same interaction, indicating that the mean amplitudes for new words are more positive-going than those for non-targets and largest at right posterior sites. The follow-up analysis at anterior sites for the target vs. non-target contrast revealed an interaction between CC and HM (F(1,17) = 8.99, p < .01), which was moderated by a three-way interaction involving

CC, HM and ST (F(2.0, 34.5) = 6.26, p < .01), reflecting the fact that over right inferior sites, the positivity is associated with targets whereas over left superior sites, the positivity is associated with non-targets. The follow-up analysis at posterior sites revealed an interaction between CC and ST (F(2.1, 35.0) = 3.62, p < .05), reflecting the fact that the enhanced positivity for targets compared to non-targets is larger at superior than at inferior sites.

For the semantic target designation task (see Table 11.5), the follow-up analysis at anterior sites for the target vs. new contrast revealed an interaction between CC and HM (F(1,17) = 5.13, p < .05), reflecting the fact that over the left hemisphere, the positivity is associated with new words while over the right hemisphere, the positivity is associated with targets. The follow-up analysis at posterior sites also revealed a CC x HM interaction (F(1,17) = 6.50, p < .05) reflecting the fact that the relatively greater positivity for targets than for new words is larger over the left than the right hemisphere. The non-target vs. new contrast revealed a three-way interaction involving CC, AP and HM, reflecting the fact that the relatively greater positivity associated with new words in comparison to non-targets is largest at right posterior sites. The target vs. non-target contrast revealed two two way-interactions involving CC: CC x AP and CC x ST, reflecting the fact that the relatively greater positivity is associated with targets than non-targets with the effect being larger at posterior than anterior sites and greater at superior than at mid-lateral and inferior sites.

1100-1400 ms

The initial analysis over the 1100-1400 ms time window revealed a main effect of CC (F(2.0, 67.1) = 11.95, p < .01), a CC x HM (F(1.5, 52.3) = 9.23, p < .01), a CC x ST

(F(3.7, 125.7) = 8.76, p < .01), a CC x AP (F(2.0, 66.3) = 4.58, p < .01) interaction, and three three-way interactions: CC x AP x HM (F(1.5, 51.1) = 15.93, p < .01), CC x AP x ST (F(4.2, 142.3) = 3.66, p < .05), and CC x HM x ST (F(4.1, 139.5) = 2.93, p < .05). The four-way interaction involving CC, AP, HM and ST was also reliable (F(4.6, 154.9) = 2.55, p < .05). For the contrasts involving new words (see Table 11.6), the CC x AP x HM interaction was reliable for both types of old word and for non-targets, the CC, AP and ST interaction was also significant. The reason for these interactions is that the mean amplitudes for targets are more positive-going than those for new words at posterior and right anterior sites, while at left anterior sites, the mean amplitudes for new words show an enhanced positivity. For non-targets, the positivity associated with new words is largest at right superior posterior sites. The follow-up analysis at anterior sites for the contrast involving the two categories of old words revealed a CC x HM interaction (F(1,17) = 8.87, p < .01) as well as an interaction between CC and ST (F(1.9, 31.5) = 14.51, p < .01), which was moderated by a CC x HM x ST interaction (F(1.8, 31.1) = 4.57, p < .05), reflecting the fact that over left inferior sites, the mean amplitudes for targets are more positive-going than those for non-targets, while over right inferior sites, the positivity is associated with non-targets. The follow-up analysis at posterior sites revealed a main effect of CC (F(1,17) = 33.66, p < .01) and a CC x ST interaction (F(2.3, 39.0) = 13.71, p < .01), reflecting the fact that the relatively greater positivity for targets than for non-targets is larger at superior than at inferior sites.

Analysis at P5

The ERP old/new effects were also subjected to a specific analysis involving the data obtained from P5 over the 500-800 ms time window. This analysis was implemented for the same reason described in Chapter 6.

The initial between-participants analysis included the factors of GP (high, low), TK (phonological, semantic), CC (target, new, non-target) and site. The analysis revealed a main effect of CC ($F(1.7, 59.3) = 7.76, p < .01$) and an interaction between TK and CC ($F(1.8, 61.9) = 8.08, p < .01$). Consistent with the analysis strategy described above, follow-up analyses were completed by collapsing data across the factor of GP and comprised all possible paired comparisons of the ERPs evoked by correct judgements to targets, non-targets and to new test words, separated according to target designation.

Reliable effects involving CC were obtained in the analyses for the semantic target designation task only: mirroring the results reported in Appendix A. Main effects of CC were obtained from the target vs. new contrast ($F(1,17) = 29.74, p < .01$) and from the contrast involving targets and non-targets ($F(1,17) = 25.07, p < .01$). The reason for this is the fact that the relatively greater positivity is associated with targets than with new words and with targets rather than with non-targets.

An additional analysis was also completed over the 600-800 ms and 800-1400 ms epoch. The reasons for conducting this analysis, as well as the factors and the sites included, are the same as described in Appendix A and in Chapter 6.

The initial analysis over the 600-800 ms time window revealed a main effect of GP ($F(1, 34) = 6.54, p < .01$), and a main effect of CC ($F(1.6, 54.4) = 45.48, p < .01$). Follow-up analysis was completed for each group (collapsed across the factor of TK) and comprised all possible paired contrasts of the ERPs evoked by the three word conditions. For the high relative difficulty group, the contrasts involving new words revealed main effects of CC for both targets ($F(1,17) = 16.77, p < .01$) and non-targets ($F(1,17) = 64.04, p < .01$), reflecting the fact that the mean amplitudes for new words are more positive-going than those for both types of old word. The target vs. non-target contrast also revealed a main effect of CC ($F(1,17) = 12.46, p < .01$), reflecting the relatively greater positivity for targets than for non-targets. For the low relative difficulty group, the contrast involving new words also revealed a main effect of CC in each case (target: $F(1, 17) = 13.90, p < .01$); non-target: $F(1, 17) = 24.51, p < .01$), reflecting the relative positivity for new words rather than both type of old word. The mean amplitudes for targets are also more positive-going than those for non-targets, as revealed by the main effect of CC in the target vs. non-target contrast ($F(1,17) = 6.01, p < .05$).

For the same reason detailed in Appendix A, an additional analysis was completed over the 800-1400 ms time window involving the data from Pz. The initial analysis revealed only a main effect of CC ($F(1.9, 66.2) = 31.93, p < .01$). Follow-up analysis (collapsed across the factors of GP and TK) revealed a main effect of CC for the contrasts involving new words (targets: $F(1,17) = 6.74, p < .01$; non-targets: $F(1,17) = 47.16, p < .01$), reflecting the fact that the mean amplitudes for new words are more positive-going than those for either type of old words. The target vs. non-target contrast also revealed a main effect of CC ($F(1,17) = 42.03$, $p < .01$), reflecting the relatively greater positivity for targets than for non-targets.

In summary, these findings are broadly comparable to those from Experiment One, and in the semantic target designation condition in both experiments provide some support for the proposal that when target accuracy is high participants prioritise recollection of target information. These studies, however, confound target accuracy with the content of the target/non-target distinction (see Chapter 4 and Herron and Rugg, 2003a), so in and of themselves are not as conclusive as the findings in Experiments Three and Four. This is of course also the case because of the response confound for the contrasts involving targets, non-targets and new words.

FIGURE 11.1: ERP old/new effects in the phonological target designation task for 36 participants. Electrode montage as in Figure 4.1 (Chapter 4).

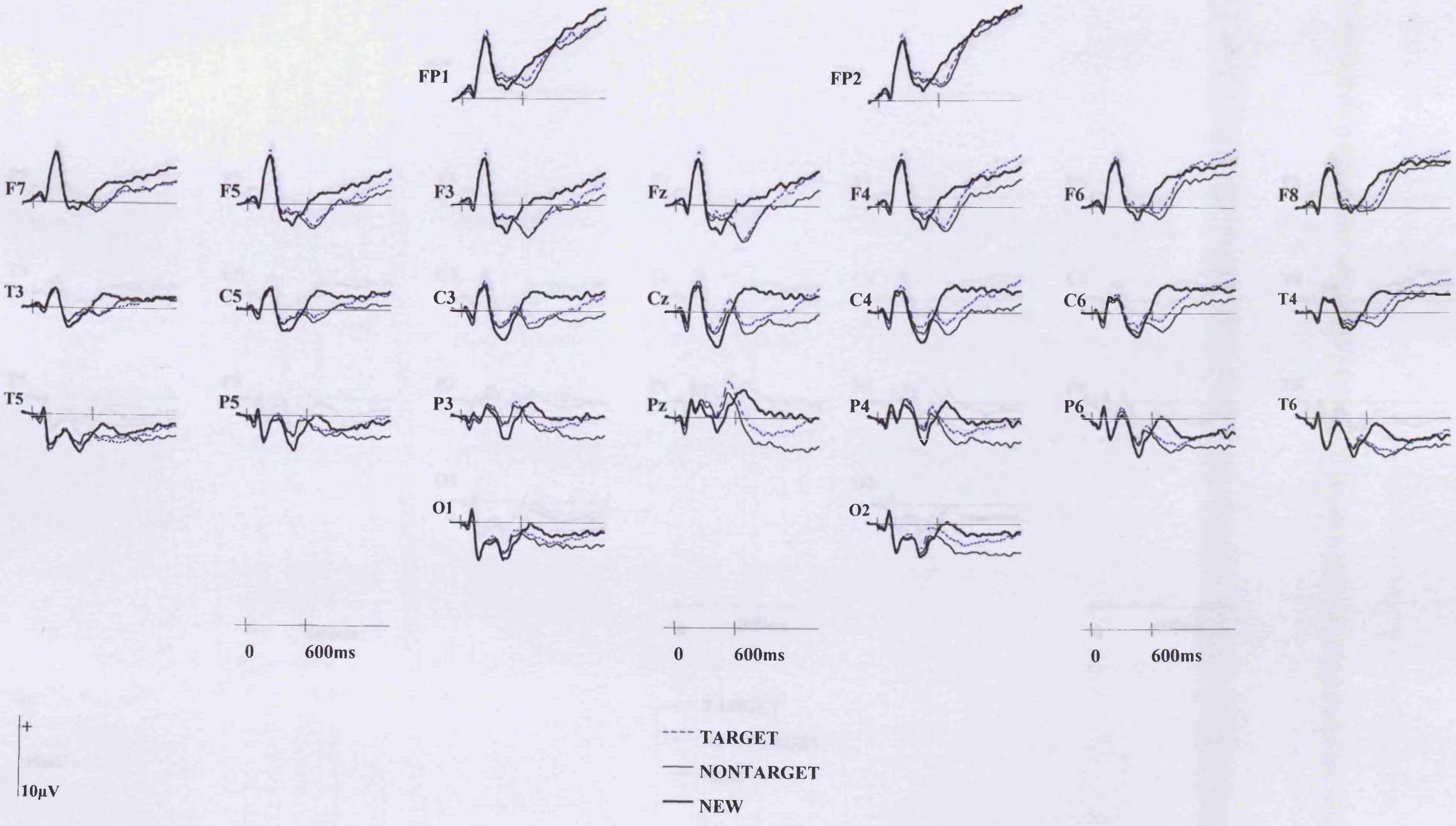


FIGURE 11.2: ERP old/new effects in the semantic target designation task for 36 participants. Electrode montage as in Figure 4.1 (Chapter 4).

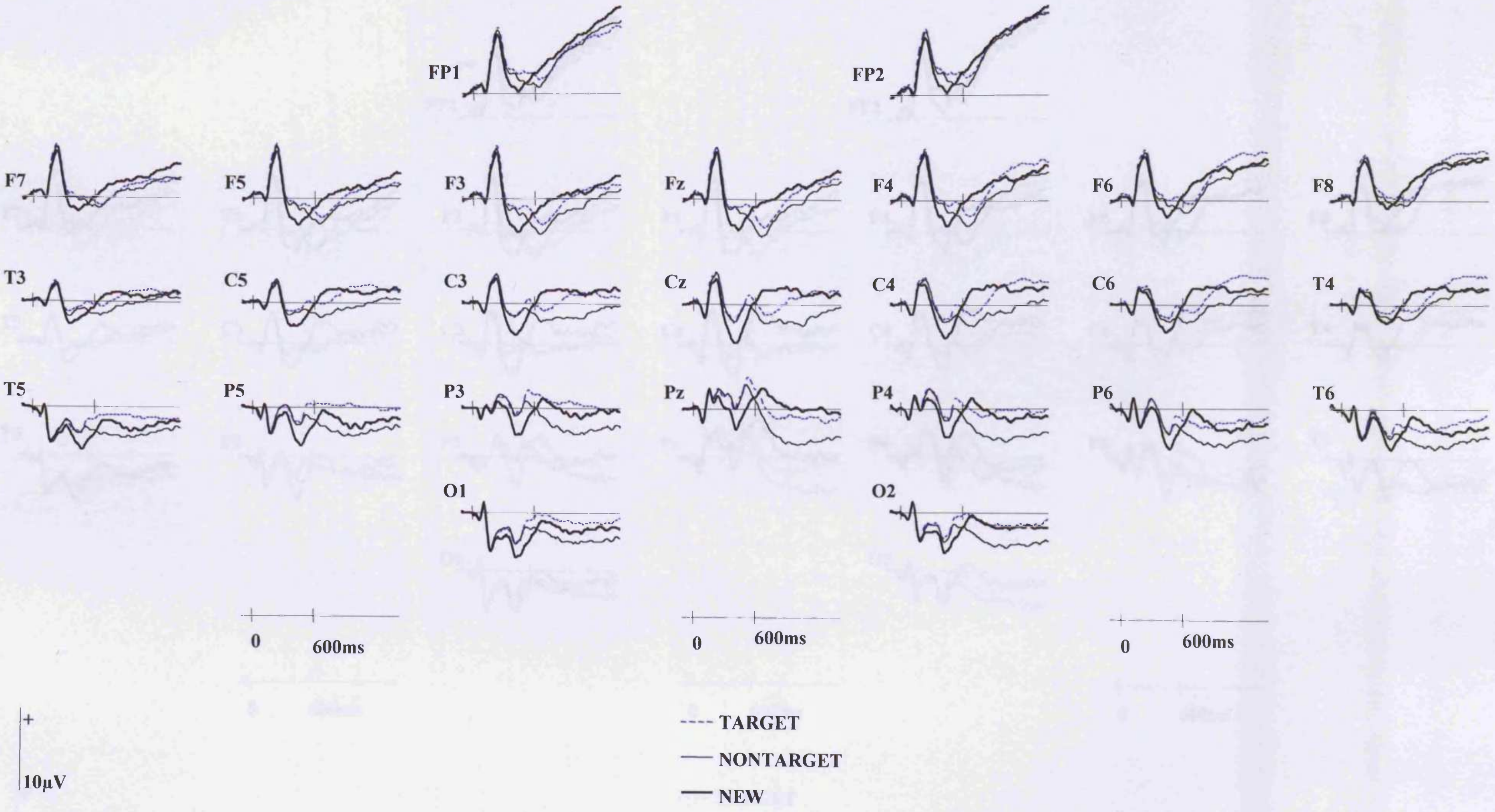


FIGURE 11.3: ERP old/new effects in the phonological target designation task for the low relative difficulty group. Electrode montage as in Figure 4.1 (Chapter 4).

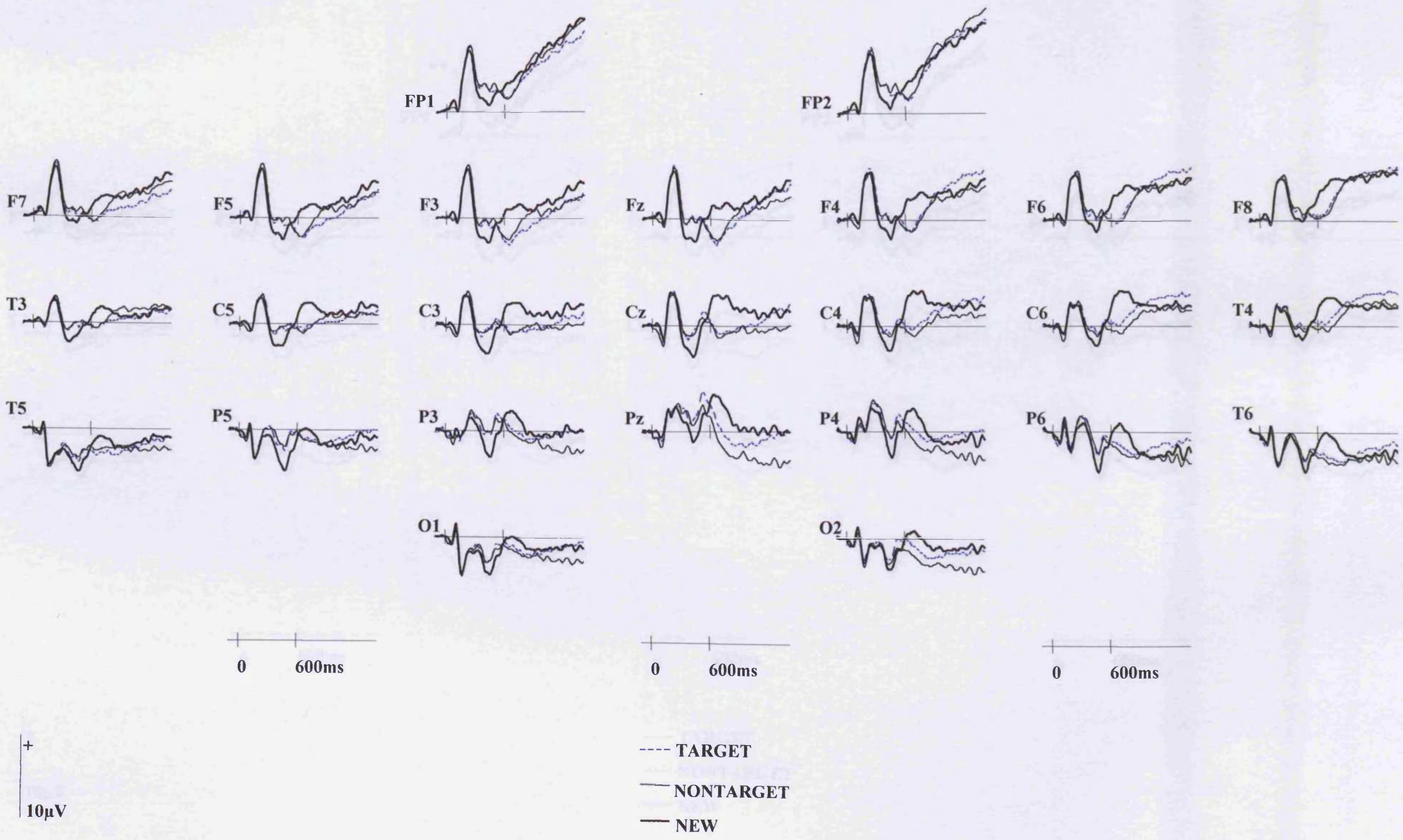


FIGURE 11.4: ERP old/new effects in the semantic target designation task for the low relative difficulty group. Electrode montage as in Figure 4.1 (Chapter 4).

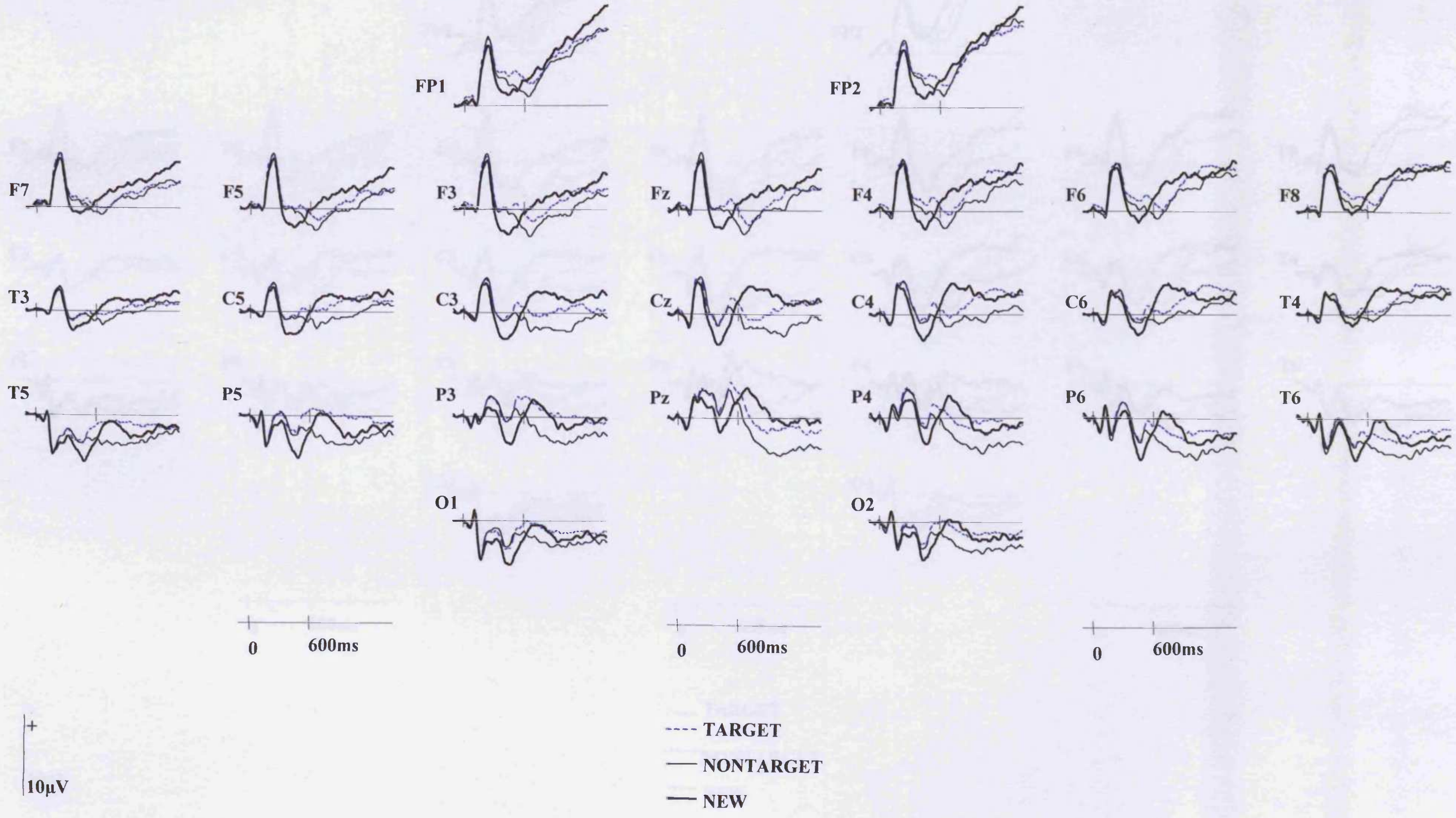


FIGURE 11.5: ERP old/new effects in the phonological target designation task for the high relative difficulty group. Electrode montage as in Figure 4.1 (Chapter 4).

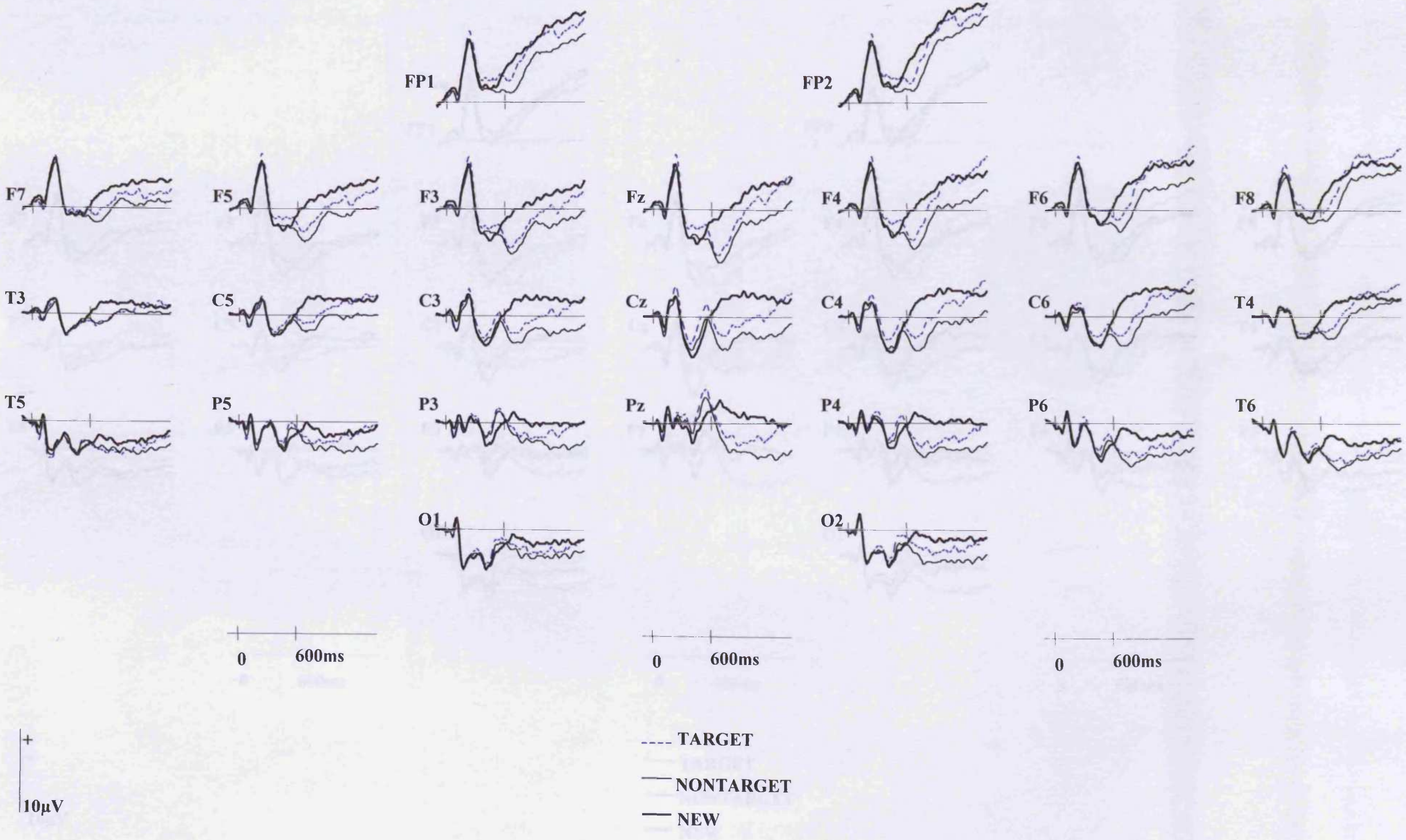


FIGURE 11.6: ERP old/new effects in the semantic target designation task for the high relative difficulty group. Electrode montage as in Figure 4.1 (Chapter 4).

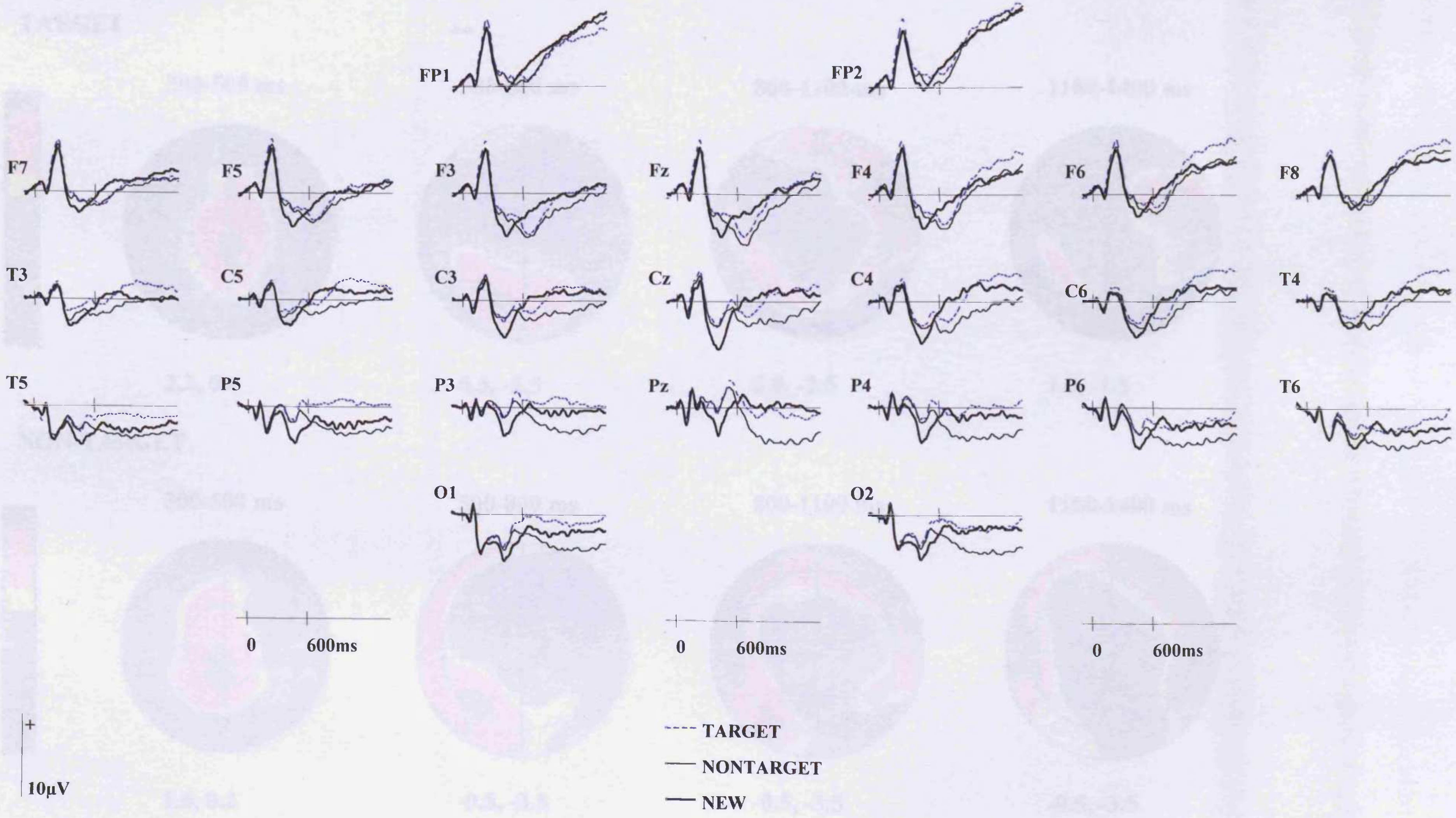


FIGURE 11.7: Scalp distributions of the ERP old/new effects evoked by targets and non-targets in the phonological target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

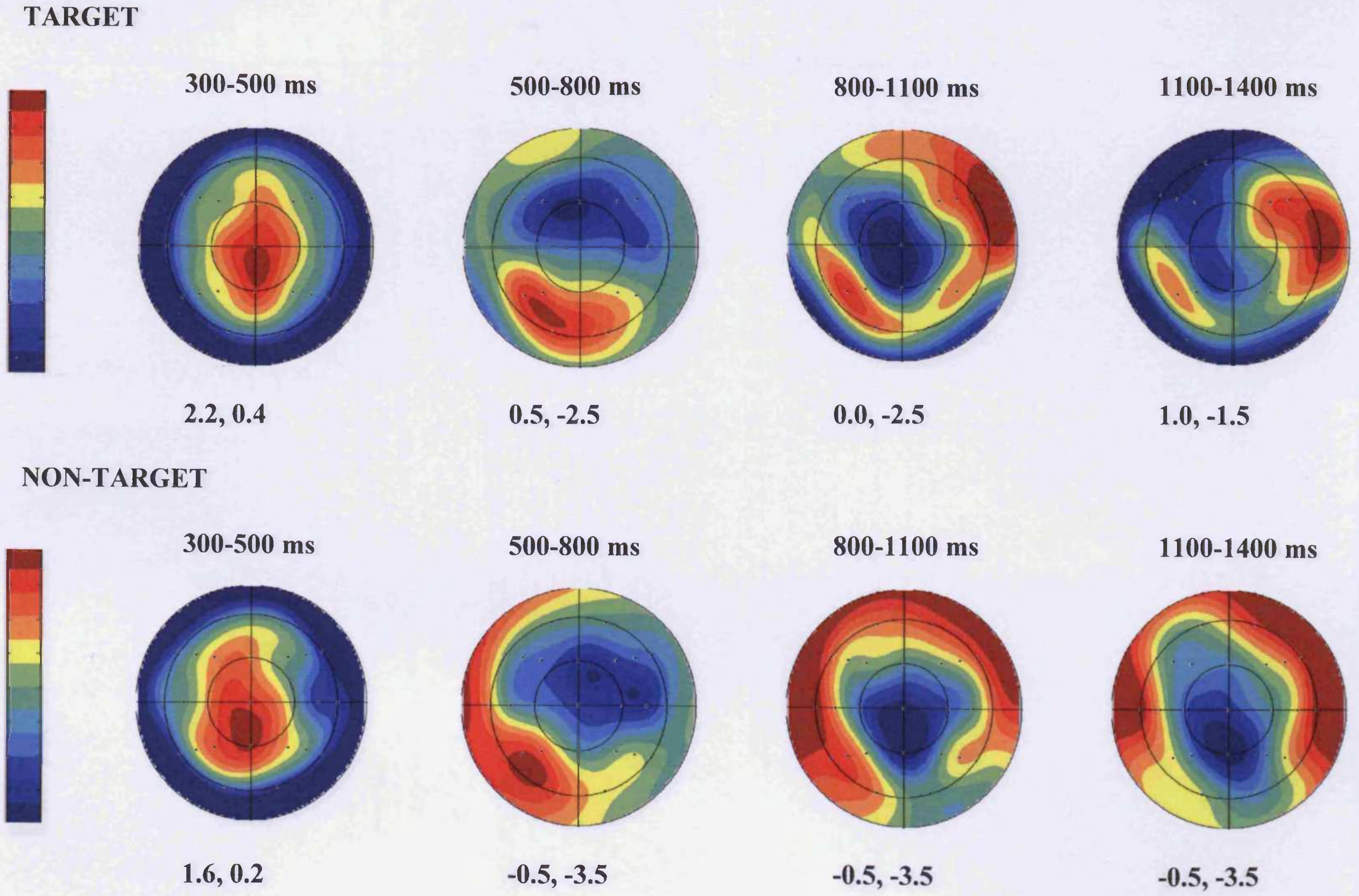


FIGURE 11.8: Scalp distributions of the ERP old/new effects evoked by targets and non-targets in the semantic target designation task. The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets. Each map is proportionately scaled between the maxima (dark red) and minima (dark blue) of the depicted effect (range below each map in microvolts).

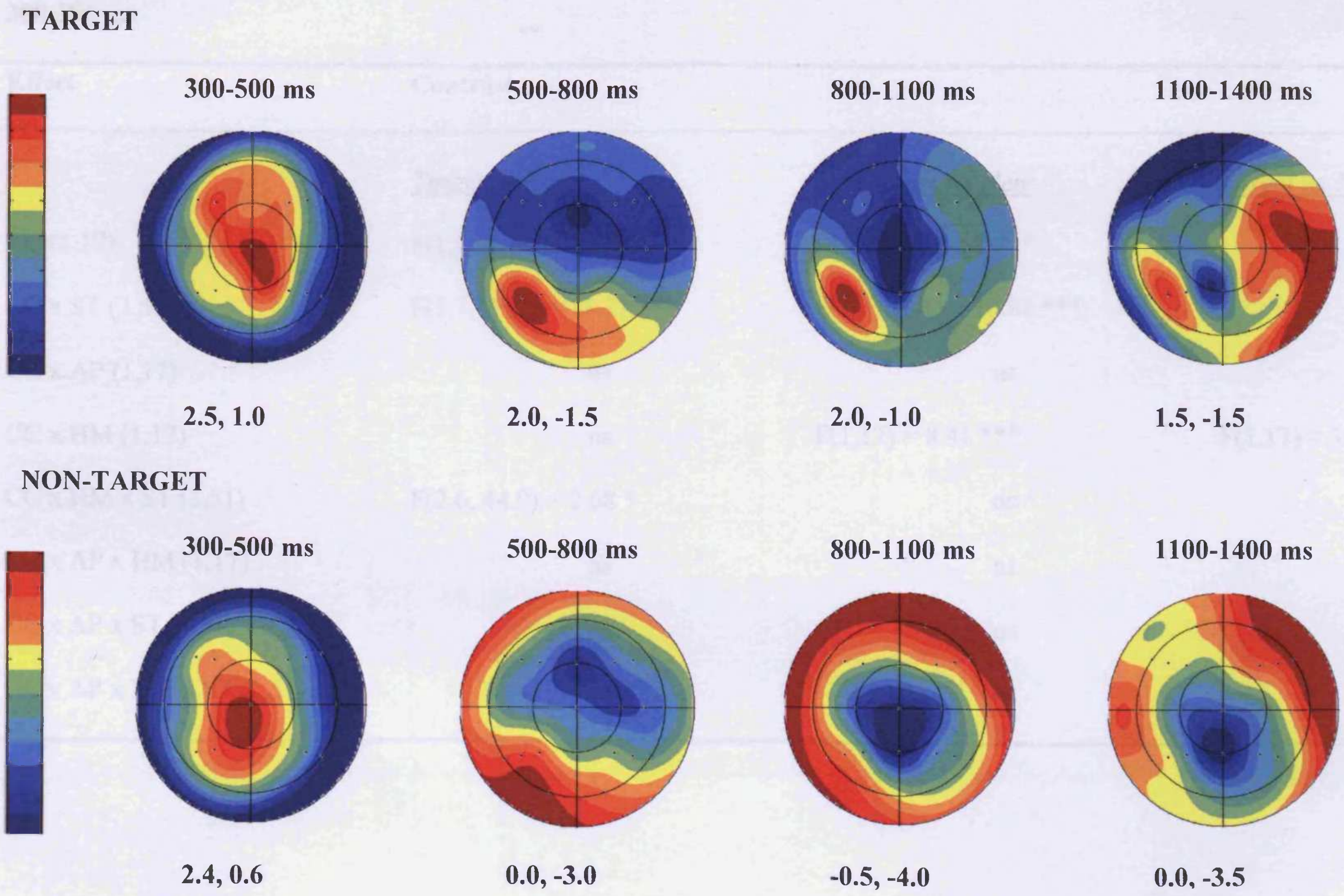


TABLE 11.1: The outcomes of follow-up analyses for ERP old/new effects over the 300-500 ms epoch . Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

300-500 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 42.70 ***	F(1,17) = 26.58 ***	ns
CC x ST (3,51)	F(1.7, 29.3) = 14.21 ***	F(1.8, 31.4) = 18.81 ***	ns
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	ns	F(1,17) = 8.41 ***	F(1,17) = 3.85 *
CC x HM x ST (3,51)	F(2.6, 44.0) = 2.68 *	ns	ns
CC x AP x HM (1,17)	ns	ns	ns
CC x AP x ST (3,51)	ns	ns	ns
CC x AP x HM x ST (3,51)	ns	ns	ns

TABLE 11.2: The outcomes of follow-up analyses for ERP old/new effects in the phonological target designation task over the 500-800 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1^{st} column).

500-800 ms
Phonological target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	F(1,17) = 5.74 **	F(1,17) = 13.64 ***	ns
CC x ST (3,51)	ns	ns	ns
CC x AP (1,17)	F(1,17) = 8.72 ***	F(1,17) = 7.55 ***	ns
CC x HM (1,17)	ns	F(1,17) = 7.88 ***	ns
CC x HM x ST (3,51)	ns	ns	ns
CC x AP x HM (1,17)	ns	ns	ns
CC x AP x ST (3,51)	F(2.3, 39.0) = 5.41 ***	ns	F(2.2, 36.8) = 4.14 **
CC x AP x HM x ST (3,51)	F(2.5, 41.8) = 2.55 *	ns	ns

TABLE 11.3: The outcomes of follow-up analyses for ERP old/new effects in the semantic target designation task over the 500-800 ms epoch. Key: * $p < .1$, ** $p < .05$, *** $p < .01$, **** $p < .001$, ns = non-significant, full df in brackets (1st column).

500-800 ms
Semantic target designation task

Effect	**Contrast**		
	Target vs. New	*Non-target vs. New*	*Target vs. Non-target*
CC (1,17)	ns	F(1,17) = 11.02 ***	F(1,17) = 15.78 ***
CC x ST (3,51)	ns	F(2.2, 37.9) = 4.93 ***	ns
CC x AP (1,17)	F(1,17) = 21.64 ***	ns	F(1,17) = 8.18 ***
CC x HM (1,17)	F(1,17) = 4.96 **	F(1,17) = 5.99 **	ns
CC x HM x ST (3,51)	ns	ns	ns
CC x AP x HM (1,17)	F(1,17) = 14.03 ***	F(1,17) = 6.34 **	F(1,17) = 5.73 **
CC x AP x ST (3,51)	ns	ns	ns
CC x AP x HM x ST (3,51)	F(1.8, 31.0) = 3.95 **	ns	ns

TABLE 11.4: The outcomes of follow-up analyses for ERP old/new effects in the phonological target designation task over the 800-1100 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

800-1100 ms
Phonological target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	ns	F(1,17) = 9.77 ***	ns
CC x ST (3,51)	ns	F(1.7, 28.2) = 3.41 **	ns
CC x AP (1,17)	ns	ns	ns
CC x HM (1,17)	F(1,17) = 4.88 **	ns	F(1,17) = 7.29 ***
CC x HM x ST (3,51)	ns	ns	ns
CC x AP x HM (1,17)	F(1,17) = 7.99 ***	F(1,17) = 5.80 **	ns
CC x AP x ST (3,51)	F(2.3, 39.2) = 2.75 *	F(2.2, 37.5) = 3.01 *	ns
CC x AP x HM x ST (3,51)	ns	ns	F(2.7, 45.2) = 4.98 ***

TABLE 11.5: The outcomes of follow-up analyses for ERP old/new effects in the semantic target designation task over the 800-1100 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

800-1100 ms
Semantic target designation task

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	ns	F(1,17) = 16.08 ***	F(1,17) = 37.30 ***
CC x ST (3,51)	ns	F(1.9, 32.7) = 6.24 ***	F(1.8, 31.1) = 9.81 ***
CC x AP (1,17)	F(1,17) = 5.04 **	ns	F(1,17) = 16.49 ***
CC x HM (1,17)	ns	ns	ns
CC x HM x ST (3,51)	ns	ns	ns
CC x AP x HM (1,17)	F(1,17) = 13.69 ***	F(1,17) = 10.15 ***	ns
CC x AP x ST (3,51)	ns	ns	ns
CC x AP x HM x ST (3,51)	F(1.8, 30.0) = 3.68 **	ns	ns

TABLE 11.6: The outcomes of follow-up analyses for ERP old/new effects over the 1100-1400 ms epoch. Key: * p < .1, ** p < .05, *** p < .01, **** p < .001, ns = non-significant, full df in brackets (1st column).

1100-1400 ms

Effect	**Contrast**		
	Target vs. New	***Non-target vs. New***	***Target vs. Non-target***
CC (1,17)	ns	F(1,17) = 16.78 ***	F(1,17) = 16.29 ***
CC x ST (3,51)	F(1.6, 27.7) = 4.28 **	F(1.9, 32.0) = 7.25 ***	F(1.8, 30.9) = 16.10 ***
CC x AP (1,17)	ns	ns	F(1,17) = 8.44 ***
CC x HM (1,17)	F(1,17) = 11.84 ***	F(1,17) = 4.76 **	F(1,17) = 9.71 ***
CC x HM x ST (3,51)	ns	ns	F(2.5, 42.0) = 2.56 *
CC x AP x HM (1,17)	F(1,17) = 23.58 ***	F(1,17) = 26.05 ***	F(1,17) = 3.75 *
CC x AP x ST (3,51)	F(2.6, 44.5) = 2.81 *	F(2.4, 41.5) = 3.19 **	F(2.3, 38.6) = 9.91 ***
CC x AP x HM x ST (3,51)	F(2.5, 42.7) = 2.90 *	ns	F(2.1, 35.1) = 4.11 **

APPENDIX C: The outcomes of t-tests for the behavioural data in Experiments One, Three, Four and Five.

Experiment	**Target Designation**	**Contrast**	
One	Phonological	Target vs. new	0.68 vs. 0.06; $t(20) = 18.95$, $p < .001$
		Target vs. non-target	0.68 vs. 0.08; $t(20) = 17.19$, $p < .001$
	Semantic	Target vs. new	0.89 vs. 0.03; $t(20) = 43.14$, $p < .001$
		Target vs. non-target	0.89 vs. 0.13; $t(20) = 31.56$, $p < .001$
Three	Function	Target vs. new	0.83 vs. 0.01; $t(17) = 36.96$, $p < .001$
		Target vs. non-target	0.83 vs. 0.11; $t(17) = 19.13$, $p < .001$
	Drawing	Target vs. new	0.81 vs. 0.02; $t(17) = 23.87$, $p < .001$
		Target vs. non-target	0.81 vs. 0.10; $t(17) = 15.61$, $p < .001$
Four	Function	Target vs. new	0.69 vs. 0.11; $t(17) = 11.18$, $p < .001$
		Target vs. non-target	0.69 vs. 0.18; $t(17) = 7.95$, $p < .001$
	Drawing	Target vs. new	0.65 vs. 0.06; $t(17) = 13.51$, $p < .001$
		Target vs. non-target	0.65 vs. 0.20; $t(17) = 6.41$, $p < .001$
Five (a) exclusion	Function	Target vs. new	0.77 vs. 0.05; $t(5) = 18.35$, $p < .001$
		Target vs. non-target	0.77 vs. 0.15; $t(5) = 15.25$, $p < .001$
	Drawing	Target vs. new	0.72 vs. 0.08; $t(5) = 8.60$, $p < .001$
		Target vs. non-target	0.72 vs. 0.18; $t(5) = 5.55$, $p < .001$
Five (a) old/new recognition task	Function	Old vs. new (Target)	0.86 vs. 0.15; $t(5) = 13.10$, $p < .001$
		Old vs. new (Non-target)	0.86 vs. 0.14; $t(5) = 23.02$, $p < .001$
	Drawing	Old vs. new (Target)	0.78 vs. 0.17; $t(5) = 6.99$, $p < .001$
		Old vs. new (Non-target)	0.78 vs. 0.16; $t(5) = 8.86$, $p < .001$
Five (b) exclusion	Function	Target vs. new	0.79 vs. 0.07; $t(14) = 11.84$, $p < .001$
		Target vs. non-target	0.79 vs. 0.16; $t(14) = 7.57$, $p < .001$
	Drawing	Target vs. new	0.69 vs. 0.09; $t(14) = 11.26$, $p < .001$
		Target vs. non-target	0.69 vs. 0.22; $t(14) = 7.82$, $p < .001$
Five (b) R/K procedure	Function	Old vs. new (Target)	0.78 vs. 0.10; $t(14) = 15.35$, $p < .001$
		Old vs. new (Non-target)	0.78 vs. 0.30; $t(14) = 6.97$, $p < .001$
	Drawing	Old vs. new (Target)	0.70 vs. 0.17; $t(14) = 14.30$, $p < .001$
		Old vs. new (Non-target)	0.70 vs. 0.26; $t(14) = 7.44$, $p < .001$

APPENDIX D: The outcome of t-tests for the behavioural data in Experiment Two for all participants, the high relative difficulty group and the low-relative difficulty group in the two target designation tasks.

Target Designation Task	**All participants**	**High relative difficulty group**	**Low relative difficulty group**
Phonological			
Target vs. new	0.71 vs. 0.01; $t(35) = 29.98$, $p < .001$	0.62 vs. 0.02; $t(17) = 18.99$, $p < .001$	0.80 vs. 0.01; $t(17) = 50.88$, $p < .001$
Target vs. non-target	0.71 vs. 0.09; $t(35) = 24.63$, $p < .001$	0.62 vs. 0.08; $t(17) = 15.24$,$p < .001$	0.80 vs. 0.11; $t(17) = 26.32$, $p < .001$
Semantic			
Target vs. new	0.85 vs. 0.01; $t(35) = 60.22$, $p <.001$	0.86 vs. 0.01; $t(17) = 51.35$, $p < .001$	0.83 vs. 0.01; $t(17) = 36.66$, $p < .001$
Target vs. non-target	0.85 vs. 0.11; $t(35) = 32.72$, $p <.001$	0.86 vs. 0.08; $t(17) = 29.46$, $p < .001$	0.83 vs. 0.14; $t(17) = 20.16$, $p < .001$