AN EXAMINATION OF TASK AND RESPONSE INFLUENCES ON EVENT-RELATED POTENTIAL (ERP) CORRELATES OF RECOLLECTION AND FAMILIARITY

by

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Submitted in partial fulfilment of the requirements
for the degree of Doctor of Philosophy

at

Dalhousie University
Halifax, Nova Scotia
September 2010

DALHOUSIE UNIVERSITY

DEPARTMENT OF PSYCHOLOGY

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Dated: September 9, 2010

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DALHOUSIE UNIVERSITY

DATE: 9 September 2010

AUTHOR: Kenneth Troy Harker

TITLE: AN EXAMINATION OF TASK AND RESPONSE INFLUENCES ON EVENT-RELATED POTENTIAL (ERP) CORRELATES OF RECOLLECTION AND FAMILIARITY

DEPARTMENT OR SCHOOL: Department of Psychology

DEGREE: Ph.D. CONVOCATION: October YEAR: 2010

DEDICATION PAGE

To my family.

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ABSTRACT

Cognitive Event-Related Potential (ERP) recordings have been used to study the neurophysiological correlates of recognition memory. Previous ERP research has demonstrated that on tasks of recognition memory, Old items elicit ERP responses that are more positive in electrical amplitude than the ERP responses elicited by New items, commonly referred to as ERP Old/New positivity effects. ERP Old/New positivity effects have been used to make inferences about cognitive processes mediating recognition memory, such as the early frontal Old/New positivity effect that has been associated with familiarity and the late parietal Old/New positivity effect that has been associated with recollection. These effects have been demonstrated different types of stimuli and on different types of recognition memory tasks. However, a systematic comparison of ERP Old/New positivity effects across different recognition memory tasks is lacking, particularly with respect to Remote Long-term memory. This thesis asked how ERP Old/New positivity effects differ between tasks of Short-term, Recent Long-term, and Remote Long-term memory tasks for faces. Experiment 1 simulated the condition of limited overt communication skills by analyzing the brain responses to memory stimuli, regardless of the overt behavioural response from healthy, "honest" participants. Experiment 2 examined the ERP responses of healthy participants instructed to feign a memory impairment. ERP Old/New positivity effects similar to those described in the experimental ERP literature were observed on the Short-term and Remote Long-term memory tasks in both Experiments 1 and 2. However, response accuracy was lower than expected on the Recent Long-term task resulting in weak ERP results. A comparison of the ERP Old/New responses between the Honest Response (Experiment 1) and the Simulated Memory Malingering (Experiment 2) groups found that despite differing overt behavioural responses, the ERP Old/New responses remained similar. The results demonstrate a similar electrophysiological mechanism mediating Short-term, Recent Long-term, and Remote Long-term recognition memory ERP responses, despite the different neuroanatomical substrates that have been proposed these different types of memory. Although an improved measure of Recent Long-term memory is needed, the results of this thesis are promising and demonstrate that ERP recordings could provide an objective instrument for measuring recognition memory functioning in clinical settings.

LIST OF ABBREVIATIONS USED

CVLT-II = California Verbal Learning Test 2^{nd} Edition

db = decibels

DMT = Digit Memory Test

df = Degrees of freedom

EEG = Electroencephalogram

e.g. = exampli gratia (for example)

EOG = Electrooculogram

ERMF = Event-related magnetic field

ERP = Cognitive event-related potential

Hz = Hertz

HR = Honest Response

i.e. = id est (that is)

kΩ = Kilo-ohms

LC = Left Central

LF = Left Frontal

LP = Left Parietal

LT = Left Temporal

ms = Milliseconds

n = number of participants

NEPSY = Developmental Neuropsychological Assessment

p = probability

RM-ANOVA = Repeated measures analysis of variance

RC = Right Central

RF = Right Frontal

RP = Right Parietal

RT = Right Temporal

s.e.m. = Standard error of the mean

SMM = Simulated Memory Malingering

TOMM = Test of Memory Malingering

μV = Microvolts

WMS-III = Wechsler Memory Scales 3rd Edition

WRMT = Warrington Recognition Memory Tests

ACKNOWLEDGEMENTS

This research was made possible through Graduate Research Scholarships to K. Troy Harker through the Killam Trust Foundation, the National Research and Engineering Council of Canada, and the Nova Scotia Health Research Foundation.

A special thanks to Jennifer and Brayden for assistance with manuscript formatting and editing.

CHAPTER 1 INTRODUCTION

Memory is a fascinating cognitive phenomenon that represents a cornerstone of human experience. Modal models of memory typically posit three different stages of memory processing including a sensory registration stage, a short-term memory stage, and a long-term stage. The sensory registration stage occurs during the initial perception of incoming sensory information from the environment. During the sensory registration stage incoming sensory-perceptual information is stored briefly by primary sensory regions of the brain (e.g., 100 ms for visual information). The short-term and long-term memory stages are post-perceptual stages of memory processing. It is the latter two stages of memory processing that pertain to what is commonly thought of as "memory" and are the focus of this thesis.

1.1. Types of Memory

1.1.1 Short-term Memory

The short-term memory stage is a temporary memory system that has been referred to by various names including immediate memory, primary memory, working-memory, and short-term memory. There are both multi-component and unitary theories of short-term memory (Jonides et al., 2008). Multi-modal theories such as Baddely's multi-component model (Repovs & Baddeley, 2006) make an explicit distinction between short-term and long-term memory systems. For example, Baddeley's model consists of three storage buffers, that are independent of long-term memory, and a central executive that is responsible for short-term memory processing. These buffers consist of a phonological loop for auditory and verbal information; a visual-spatial sketchpad for visual/object and spatial information; and an episodic buffer that is a combined store of information from long-term memory and the visual and phonological buffers. The central executive is responsible for orchestrating the processing of information within and between these different buffers. Neuropsychological and functional imaging evidence have implicated frontal-parietal networks as the neuroanatomical substrates of short-term memory (Jonides et al., 2008).

Unitary models of short-term memory differ from multi-component models in that short-term memory is dependent upon the matching of memory traces for features of recently experienced events or information with internal and/or external cues (Jonides et al., 2008; Nairne, 2002; Ranganath & Blumenfeld, 2005). As such, short-term memory processing would rely on the same neural mechanisms and structures as long-term memory. Despite the differences between multi-component and unitary models with respect to the storage of short-term memory, these theories are generally in agreement that short-term memory represents (a) the cognitive processing of information that is in the current focus attention, (b) is limited in its capacity, (c) is of brief duration (i.e., 2-5 seconds), and (d) is susceptible to interference effects (Jonides et al., 2008). In this thesis, the term short-term memory refers to temporary storage (2-5 seconds) of limited amounts of information (approximately 4 items of visual information) that is in the current focus of attention.

1.1.2 Long-term Memory

The long-term memory system represents a relatively durable and stable system for storing information over periods of minutes to years. It is generally recognized as an integrated multicomponent system with several subdivisions. According to Tulving's model of long-term memory organization (Tulving, 2000), the broadest division in long-term memory is between procedural and cognitive memories. Procedural memory collectively describes memory systems for actions or "doing something," such as habit memory, non-declarative memory, or implicit memory, and is thought to depend in part upon subcortical structures including the basal ganglia and cerebellum. In contrast, cognitive memory collectively refers to long-term memory processes that are declarative or explicit. Declarative memory can be expressed by "thinking about something" and can be further divided into semantic and episodic systems. The semantic memory system is for general knowledge and facts. The episodic memory system stores personally experienced events. According to Tulving, there is a hierarchical relationship between semantic and episodic memory, with episodic memory viewed as a specialized extension of the semantic memory system. As a result, most experimental and clinical memory tests engage aspects of both the semantic and episodic memory systems in humans (Tulving, 2002).

Distinctions in long-term declarative memory can also be made with respect to how recently the information was acquired. For example, learning new information relies heavily on brain structures in the medial temporal lobes and hippocampal formation (Squire & Zola, 1998; Tulving & Markowitsch, 1998). However, there is some debate as to the specific roles these structures play in acquiring episodic versus semantic memories (Mishkin, Vargha-Khadem, & Gadian, 1998). Recently acquired long-term memory is what is typically evaluated by most experimental and clinical tests of long-term memory. This thesis refers to this type of long-term memory as Recent Long-term memory.

Over time information stored in the Recent Long-term memory system is transferred and consolidated into Remote Long-term memory stores (Squire, Stark, &

Clark, 2004). These stores are distributed throughout the cortex in a modality specific pattern. Memory results from re-activating portions of the neural activity patterns that occurred during the initial experience of an event. Recall of information from Remote Long-term memory stores can occur independently of the hippocampal/medial temporal lobe system and is thought to depend on brain regions in the frontal, lateral temporal, and occipital cortices (Bayley, Gold, Hopkins, & Squire, 2005). In healthy individuals, distinctions between Recent Long-term memory and Remote Long-term memory are not readily apparent and typically rely on the assumption that with the passage of time declarative long-term memory is more likely to be dependent upon the Remote Long-term memory system. Evidence from fMRI suggests that the process of consolidation can begin within twenty-four hours after new learning (Takashima et al., 2009). Neuropsychological studies of patients with damage to medial temporal lobe / hippocampal brain regions suggest that the consolidation process may continue for several months to years (Parkin & Leng, 1993). For the purposes of this thesis, Remote Long-term memory was distinguished from Recent Long-term memory by the “age” of the memory being tested. Remote Long-term memory was defined as memory that had been acquired for at least one month prior to the study.

Memory has also been defined on the basis of how it is retrieved and expressed. For example, memory retrieval that is stimulated by internal cues is referred to as free recall. Memory retrieval that is stimulated by external cues or prompts is referred to as recognition memory. A further distinction in recognition memory has been made on the basis how confident one is in their memory. For example, dual-process recognition memory models posit two different processes that contribute to recognition memory, namely familiarity and recollection (Yonelinas, 2001). Familiarity has been commonly defined as the "feeling" of having previously encountered a stimulus, but being unable to remember any of the contextual information associated with the stimulus. Recollection has been commonly defined as the explicit recognition of a stimulus or certainty of having encountered it before. Face recognition is commonly used to illustrate the differences between these two concepts. Familiarity, for example, refers to the experience of encountering someone that you recognize as having seen before but for whom you are unable to recall any of the details about who they are or how you know them. In contrast recollection refers to the experience of encountering someone in which not only do you recognize who the individual is, but can easily recall the details surrounding your relationship and interactions with that individual. Of particular interest to this thesis is the processing of visual memory using faces as stimuli (discussed in more detail below). It is important to note that while the interpretation of the results of this thesis will use these theoretical models of recognition memory, the tasks were not designed to specifically test dual-process versus single process models of recognition memory.

1.2 Measuring Memory

1.2.1 Clinical Tests of Visual Recognition Memory

Memory problems are one of the most common impairments associated with brain injury and neuropathology generally (Bond, 1979b; McAllister, 1992b) and have a detrimental impact on quality of life (Tate & Broe, 1999b). Clinical neuropsychology is concerned with the assessment and treatment of behavioural expressions of brain dysfunction, including memory processes related to encoding, storage, and retrieval of information (Lezak, Howieson, & Loring, 2004). Most traditional clinical neuropsychological tests of memory have been developed on the basis of the modal model of memory described above (see Types of Memory) with an emphasis on measures of new learning and recent long-term memory for auditory, visual, verbal, and non-verbal information (Lezak et al., 2004). Clinical neuropsychology tests of non-verbal visual memory frequently use faces as stimuli (Benton, 1994). Faces have been used in both experimental and clinical studies of memory. Some advantages of face memory tests are their ecological validity, and the ability of neuropsychological tests to differentiate between defective perceptual processing of face stimuli from impaired memory processing (Benton, 1994). Individuals engage in face recognition on a daily basis in their social interactions with others; thus using face memory tests has an ecological validity not shared by other types of stimuli. Faces are also more convenient than other types of stimuli for comparing Recent and Remote Long-term recognition memory. Famous faces are commonly used for assessing Remote Long-term memory. The memory “age” for a famous face is easier to independently verify than other types of autobiographical information stored in Remote Long-term memory. Clinical tests of memory for faces all rely on recognition memory test paradigms. In the case of new learning (i.e., Recent Long-term memory), recognition memory tests for faces typically involve a study phase in which participants are presented with a set of faces that they are to study (Old faces) for subsequent memory testing. During the test phase the Old faces must be discriminated from the New faces (faces that were not part of the study set). Clinical recognition memory tests have used both forced-choice alternative paradigms (e.g. Warrington, 1984) and yes/no (e.g. Wechsler, 1997) recognition paradigms. Forced-choice alternative formats require a participant to identify the Old face from one or more simultaneously presented new faces whereas yes/no recognition involves identifying Old faces from New faces in a series of individually presented faces.

1.3 Neuroimaging and Neuropsychology

1.3.1 Structural Neuroimaging Techniques

During the last several decades, advances have been made in technology that allow for imaging of brain structure and function. For example, computed axial tomography (CAT) and magnetic resonance imaging (MRI) are non-invasive techniques that are commonly used to produce relatively high quality two or three-dimensional images of brain tissues and structure. CAT images are derived from a series of x-rays that slice through the brain at various angles and are dependent upon the density of the tissue being imaged. MRI images are derived changes in the electromagnetic energy of protons in brain tissues, when they are exposed to an external magnetic field and can have a resolution accuracy measured in submillimeters. CAT scans do not produce as detailed an image of brain structures as MRI images. However, both of these methods provide detailed images of damaged or abnormal brain structures that may result from aneurysms, bleeds, infarcts, tumors, or neurodegenerative disorders. The primary disadvantage of structural imaging methods is that they do not provide any detailed measure of cognitive brain function, like memory. Other disadvantages are that the imaging equipment for both MRI and CT scanners is expensive. In addition there are health risks associated with radiation exposure during CT scans.

1.3.2 Functional Neuroimaging Techniques

Based on knowledge gained from the study of brain-behaviour relationships, and the correlation of damaged brain structures with behavioural performance on tests of cognitive functioning, including memory tests, an early role of clinical neuropsychology was to use cognitive deficit measurement as a means for localizing brain dysfunction. However, with improvements in localization of structural brain damage through neuroimaging techniques, the emphasis of clinical neuropsychological assessment has evolved from that of localizing brain damage to that of neurocognitive evaluation (Benton, 1994).

Over the past several decades interest in the use of functional neuroimaging to assist in neurocognitive evaluation has been increasing. Because clinical neuropsychological tests examine brain-behaviour relationships by measuring a behavioural response, these tests are also limited by the quality of the behavioural response. The validity of a neuropsychological assessment is dependent upon an examinee's sensory/motor proficiency, in addition to cooperation, alertness, adequate motivation and effort (Lezak et al., 2004). When these conditions are compromised or considered inadequate, the validity of the neuropsychological test results is questionable or indeed lost. During the past decade research to assess, monitor, and possibly ameliorate communication skills and motivation / effort deficiencies has increased substantially. In particular, functional neuroimaging has been proposed as a tool for studying cognition independent of behavioural responses. Functional neuroimaging has emerged as a potential technique for evaluating cognitive function when an individual's behavioural responses are compromised.

Several brain-imaging techniques have been developed to measure brain function. Functional imaging techniques generally fall into two different categories – those based on hemodynamic measures of brain activity and those based on electromagnetic measures. For example, functional magnetic resonance imaging (fMRI) is a hemodynamic measure of brain activity based upon the same principles as MRI. However fMRI scans are tuned to protons of the hemoglobin proteins found in the blood supply. As a result, fMRI images represent changes in blood flow that fluctuate with neural activity (Raichle, 1994). The advantages of fMRI include good spatial resolution for localizing activity in the brain and its low level of invasiveness. The disadvantages of this measure include the operating and equipment costs and poor temporal resolution of brain activity. For example, fMRI scans generally represent brain activity that has been averaged over a period of several seconds.

Positron emission tomography (PET) and single photon emission computed tomography (SPECT) imaging are also hemodynamic based measures of brain activity. These methods rely on the injection of a radioactive tracer into the blood stream. PET and SPECT scanners detect the concentration of the radioactive tracers as they circulate through the brain. The primary advantage of PET and SPECT is that tracers can be used to target various molecules and compounds in the brain and can provide images of localized brain activity with good spatial resolution. The disadvantages of these methods for studying brain function include (a) the cost of equipment, tracer, and operation materials, (b) a higher level of procedural invasiveness, (c) limited time windows for studying brain activity (determined by the half-life of the tracer being used), and (d) the need to average brain activity over periods of several seconds to minutes (Luck, 2005).

Electromagnetic-based measures of brain function such as micro-electrode recordings, sensory evoked potentials (EP), cognitive event-related potential recordings (ERP), and event-related magnetic field recordings (ERMF) are all direct measures of the electromagnetic fields generated by neural activity. Neurons in the brain communicate via electrochemical reactions that produce an electrical signal. Recording electrodes can record the electrical or magnetic fields that are generated by brain electrical responses associated with sensory or cognitive events. The temporal resolution of these electromagnetic-based measures of brain activity is in the range of milliseconds and superior to hemodynamic measures of brain activity (Luck, 2005).

Micro-electrode recordings use electrodes that are placed directly into the brain. As such, micro-electrode recordings have the advantage of highly accurate spatial and temporal localization of brain activity. However, because electrode placement requires a craniotomy this method is highly invasive and not well-suited for the general study of brain-behaviour relationships, such as memory in humans. This method has typically been restricted to the study of brain activity in animals and some neurosurgical populations with irretractable seizures, tumors, or movement disorders (Engel, Moll, Fried, & Ojemann, 2005).

ERMF recordings use electrodes placed on the head to record magnetic fields that accompany brain electrical activity. Like other electromagnetic measures of brain function, ERMF are temporally accurate to the millisecond. In addition they are less invasive than microelectrode recordings. The weaknesses of ERMF include the expense of equipment and poor spatial localization relative to hemodynamic and micro-electrode techniques.

EP and ERP recordings use electrodes placed on the head to record electrical potentials that are associated with sensory (i.e., EP recordings) or cognitive stimuli (i.e., cognitive ERP). The advantages of this technique are temporal accuracy (accurate to the millisecond) compared to hemodynamic techniques (Luck, 2005) and a low level of invasiveness. In addition, the cost of the equipment and materials required for ERP recordings is relatively inexpensive compared to other hemodynamic and electromagnetic functional imaging techniques. The primary disadvantage of ERP recordings is poor localization of the source(s) of the signal being recorded in the brain, skull and skin. As the signal travels, it must pass through various biological materials with differing electrical conductive properties. The electrical signal must travel between its brain source and the recording electrode. As a result, brain electrical signals do not travel in a direct path between the source of activity and the recording electrode. Electrodes placed on the head thus record a summation of all electric potential fields generated during the time of interest. There are many different combinations of sources of brain activity that could produce the same "waveform" recorded at the head. Thus a given electrode could be recording brain activity from brain sources that are both near and far from the recording electrode. Trying to determine the source of the electrical activity that comprises a given ERP component recorded from the head is difficult – an issue commonly referred to as the inverse solution problem. However, in spite of its poor spatial resolution, the temporal accuracy of ERP recordings is well-suited to studying human cognitive processes that occur relatively quickly, such as memory. The low level of invasiveness and relative inexpense of ERP recording equipment compared to other functional imaging techniques is favorable for widespread use in experimental and clinical settings.

1.4 Recognition Memory Event-Related Potentials

1.4.1 ERP Old/New Positivity Effects

ERP recordings offer a neuroimaging alternative to standard neuropsychology tests. ERP recordings are made from electrodes placed at different locations on the head. Each electrode detects changes in the distribution and orientation of electromagnetic fields that are thought to originate in the (massed) electrical activity of the brain. The fluctuation of activity as a function of time is derived by averaging several trials of discrete time epochs of EEG following a cognitive event. Using a signal averaging process, ERP recordings can produce an electrical waveform (signal) associated with the cognitive processing of a class of stimuli (Picton et al., 2000). The summation of electrical activity recorded at each electrode is sensitive to different sources, hence structures, in the brain. By comparing the signals from different electrodes, one can create a map of the activity of the brain as it is distributed across the head, albeit one that has little value for localizing the source of the brain activity. That is, ERP recordings provide reliable insight about the type of processing, but not necessarily about the neural source of that processing.

ERP recordings provide a temporal record of *current* brain activity during a cognitive event. Electrical signals occurring within the first few hundred ms after the presentation of a stimulus tend to represent basic sensory-perceptual processing, whereas later occurring electrical signals tend to be associated with cognitive functioning, such as memory (Key, Dove, & Maguire, 2005). Components within the ERP waveform are typically defined with respect to the polarity, timing, and topographical location on the head (electrode site where the amplitude of the signal is at maximum) (Picton et al., 2000).

Components have been labeled either by theoretical function (e.g., Mismatch Negativity), by the order in which peaks and troughs in the ERP response appear, or by the length of time following the presentation of a stimulus that a component appears. For example, using the ordering of peaks and troughs naming system P1, P2, P3 would refer to the first three components with a positive deflection in the electrical signal (regardless of the time they appear). Using the peak timing naming system N100, N200, N400 would refer to negative going deflections at 100 milliseconds (ms), 200 ms, and 400 ms following the presentation of a stimulus. In this thesis, the functional descriptions of the components of interest are used together with the latency windows in which the components of interest were observed. That is, the peak order system is *not* used.

ERP recordings have been well established in the experimental cognitive neuroscience literature as a reliable brain imaging technique to study cognitive processing, including recognition memory (for review see, Rugg & Allan, 2000a). Of particular interest to this thesis are ERP components associated with visual recognition memory for faces. The experimental literature of ERP studies of recognition memory is vast for both verbal and non-verbal information. The majority of these studies have shown that the ERP responses to Old items are more positive in amplitude than ERP responses to New items; these differences are commonly referred to as Old/New positivity effects (Friedman & Johnson, 2000; Mecklinger, 2000; Rugg & Allan, 2000b). Two of these Old/New positivity effects are of particular interest to this thesis: the early frontal Old/New positivity effect and the later parietal Old/New positivity effect. The first Old/New positivity effect typically appears ~250-500 ms post-stimulus, has a fronto-central distribution (Rugg et al., 1998), and is thought to be associated with a sense of familiarity for a stimulus (e.g., Mecklinger, 2000; Schloerscheidt & Rugg, 2004). The second effect occurs later between 400-1000 ms, has a central-parietal distribution, and is associated with recollection (Rugg, 1995).

1.4.2 ERP Old/New Positivity Effects for Faces

Experimental studies of recognition memory for faces have also shown these early frontal and late parietal ERP Old/New positivity effects. ERP Old/New positivity effects for faces have been observed using paradigms of short-term memory (Barrett, Rugg, & Perrett, 1988; Schweinberger, Pfutze, & Sommer, 1995), recent long-term memory (Guillem, Bicu, & Debruille, 2001; Joyce & Kutas, 2005; Paller, Bozic, Ranganath, Grabowecky, & Yamada, 1999; Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000; Paller et al., 2003), and remote long-term memory (Eimer, 2000; Nessler, Mecklinger, & Penney, 2005; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002). For example, in the short-term memory paradigm used by Barret et al. (1988), the authors examined ERP responses associated with correct match / mismatch judgments for pairs of famous and novel faces. Regardless of the type of face (famous or novel), participants' ERP responses showed early Old/New differences over frontal head regions and late Old/New differences over posterior parietal regions.

Similar results have been observed in ERP responses on recent long-term recognition memory tasks for faces. For example, Paller et al. (2003) had participants study a series of faces for which additional (and fictional) biographical information was included. During a subsequent yes / no recognition test requiring participants to discriminate between the newly learned faces and novel faces, ERP Old/New differences were observed between 300 to 600 ms. These differences reflected an early left frontal

Old/New positivity effect that was followed by a later (but overlapping in time) left posterior Old/New positivity effect, similar to ERP studies using non-face stimuli.

ERP studies of remote memory for faces have typically compared the ERP responses for famous faces (such as well-known politicians, movie stars, musicians, and other celebrities) with ERP responses for non-famous novel faces. Late parietal ERP Old/New differences have consistently been observed between famous and novel non-famous faces (Barrett et al., 1988; Eimer, 2000; Nessler et al., 2005; Schweinberger et al., 2002). However, the early ERP Old/New positivity effect has been more varied. For example, in contrast to the typical early ERP Old/New response (described above), Eimer (2000) found that ERP responses to famous faces were more *negative* in amplitude than the ERP responses to new faces during the time window of the early ERP Old/New response.

Overall, faces appear to show a similar pattern of ERP recognition memory Old/New responses as do non-face stimuli, both with respect to their topographical distribution and timing. Direct evidence for this notion has been provided by Schweinberger et al. (2002). These authors made direct comparisons between the ERP responses for famous and non-famous faces and names. They found that the late parietal ERP Old/New positivity effect was similar in head topography between the famous faces and the names of famous people, consistent with the notion of having similar neuroanatomical sources. Based on the experimental memory literature, faces appear to elicit ERP Old/New positivity effects that are consistent with those elicited by non-face stimuli during the late parietal Old/New window; however, there is some variability with respect to Old/New differences during the early frontal window.

1.5 Applications of Cognitive ERP to Clinical Neuropsychology

Traditional clinical neuropsychological memory tests are likely to remain the most simple and economical means of assessing recognition memory. However, as discussed previously, there are at least two occasions when the potential to directly measure ERP responses could be of benefit. One case is when an individual is unable to communicate behaviourally either by verbal response or physical gestures. The second case is when an in individual's overt responses are suspected to be biased by secondary gain, commonly referred to as malingering. Each of these instances is discussed in more detail below.

1.5.1 Impaired Communication Skills

For many individuals who sustain a severe brain injury, the capacity for both verbal and non-verbal communication is impaired. Yet for some, such an impairment would underestimate their cognitive potential. This can result in a poor estimate of neurocognitive functioning which in turn can have negative consequences for subsequent treatment and rehabilitation planning (Connolly, Mate-Kole, & Joyce, 1999b). For this reason, research into alternative methods of cognitive assessment is important. A relatively recent approach to overcoming compromised sensory or motor skills when assessing cognitive functioning has been to use functional brain imaging (Owen et al., 2006). Typically, only structural brain imaging has been used in the clinical setting as a diagnostic tool to assess brain structure and physiology. Even at present, the use of functional brain imaging to assess cognitive function is not a widespread or standard practice in the clinical setting.

Accumulating evidence from cognitive ERP studies has demonstrated this methodology to be of clinical value, especially in neurological populations with compromised communication skills. For example, Connolly and colleagues describe the case of severely brain injured patient with aphasia, impaired motor skills, and no evidence of overt goal-directed behaviour (Connolly et al., 1999b); in fact, a patient in a vegetative state. This patient was "untestable" with traditional neuropsychological tests. However, when given tests of language comprehension with simultaneous ERP recordings, the patient generated ERP responses associated with comprehension that were comparable to the typical ERP response observed in healthy individuals. For this case, the results of these cognitive ERP tests provided the basis for determining the appropriate level of rehabilitation care. The patient eventually recovered sufficiently to leave the hospital under his own control. This case underscores the need for more accurate measures of cognitive functioning in individuals with compromised communication skills.

Connolly and colleagues have sought to address this issue by combining cognitive ERP recordings with standardized neuropsychological tests that have been adapted for computer presentation (Connolly, 2000). This approach allows for the assessment of cognitive functioning through the direct observation of brain activity by recording ERP during the administration of a neuropsychological test. Previous neuropsychological test adaptations have emphasized tests of speech and language skills (for review see, Connolly & D'Arcy, 2000), and have included the Vocabulary and Similarities subtests from the Wechsler intelligence scales (e.g., WISC-III, WAIS-III, WAIS-R NI) (Connolly, Major, Allen, & D'Arcy, 1999a; Connolly, Marchand, Major, & D'Arcy, 2006), the

Peabody Picture Vocabulary Test – Revised (PPVT-R) (Connolly, Byrne, & Dywan, 1995), the Token Test (D'Arcy & Connolly, 1999), and the Psycholinguistic Assessment of Language Processing in Aphasia (D'Arcy, Connolly, & Eskes, 2000). Adaptations have also been made to address auditory attention and working memory skills (Lefebvre, Marchand, Eskes, & Connolly, 2005), and visual working memory (Harker & Connolly, 2007). In the Harker and Connolly (2007) study, early frontal and late parietal ERP Old/New positivity effects similar to those reported in the experimental literature were observed on a clinical visual recognition memory task. The ERP responses in the Harker and Connolly study were derived from trials averaged on the basis of stimulus type (Old versus New) regardless of behavioral accuracy. Importantly, the behaviourally uncorrected category-based ERP responses did not significantly differ from the accuracy corrected ERP responses. This finding highlights the relationship between neurophysiological responses measured by ERP and the cognitive processes that mediate recognition memory. This thesis represents a continuation of this series of studies aimed at understanding what ERP recordings can offer to clinical assessment of cognitive functioning.

1.5.2 Neurocognitive Malingering

Functional brain imaging also has the potential to assess motivation, particularly the issue of neurocognitive malingering. With respect to clinical neuropsychological assessment, neurocognitive malingering has been defined as “the volitional exaggeration or fabrication of cognitive dysfunction for the purpose of obtaining substantial material gain, or avoiding or escaping formal duty or responsibility” (Slick, Sherman, & Iverson, 1999, p. 552).

Impaired memory functioning is a common (Bond, 1979a; McAllister, 1992a) and disabling (Tate & Broe, 1999a) result of brain injury and other neuropathological processes. A neuropsychological assessment is important for determining the level of cognitive functioning (including memory) following brain injury. The validity of any neuropsychological test is dependent upon a number of factors including the examinee's level of alertness, willingness to cooperate, motivation, effort, and importantly, sufficient sensory and motor skills to attend and appropriately respond to test stimuli (Lezak et al., 2004). Experiment 1 sought to address the possibility of assessing memory in individuals with limited overt communication skills through the use of cognitive ERP recordings (using category-based analyses to mimic the condition of impaired communication). Experiment 2 concerned itself with the issue of motivation and effort during neuropsychological testing. In particular, the focus was on using cognitive ERP to assess memory in the presence of suspect motivation and effort during neuropsychological test performance. In other words, the focus was on using cognitive ERP to assess memory in individuals who are able to respond to test items, but whose responses attempt to exaggerate a memory impairment beyond what they may have actually suffered as a consequence of their injury.

In cases of mild to moderate brain injury where physical findings may be limited and where there is the potential for primary gain, memory complaints can be susceptible to neurocognitive malingering (Schmand et al., 1998). Base rates of neurocognitive malingering have been recently estimated between 8 to 39 percent with the highest rates estimated for clinical contexts with greater possibility of primary gain (for example, mild head injury, personal injury, disability) (Mittenberg, Patton, Canyock, & Condit, 2002).

The potential economic costs associated with neurocognitive malingering have been estimated to be in the billions of dollars (Gouvier, Lees-Haley, & Hayes Hammer, 2003). Up until the last two decades, the detection of neurocognitive malingering was often left to the clinical judgment of the neuropsychologist. Although the superiority of quantitative measures over pure clinical judgment for detecting neurocognitive malingering was demonstrated more than 30 years ago (Heaton, Smith, Lehman, & Vogt, 1978), it is only within the last 15 years that research efforts to develop such methods have intensified (for examples, Boone, 2007; Hall & Poirier, 2000; Horton & Hartlage, 2003; Morgan & Sweet, 2009; Rogers, 1997).

Test-based approaches to measuring effort and detecting neurocognitive malingering have typically involved examining patterns of performance on established neuropsychological tests and/or performance on specialized tests of symptom validity. Overall, forced-choice alternative recognition format tests have been shown to be one of the best formats for measuring symptom validity (Vickery, Berry, Inman, Harris, & Orey, 2001). For example, one of the first published measures that was designed to specifically assess neurocognitive malingering using the forced-choice alternative format is the Digit Memory Test (Hiscock & Hiscock, 1989b). The Digit Memory Test contains delays of 5, 10, and 15 seconds with no intervening stimuli between study and test, and uses highly discriminable foils (i.e., each foil differs from the target by at least two digits, including the first and last digits). During a trial of the Digit Memory Test a subject is presented with a 5-digit number that they are told they will have to memorize and subsequently identify after a brief delay. Individuals are told that even though it may be hard to remember during longer delays, they should try their best to remember. Tests such as the

Digit Memory Test are an example of short-term recognition memory tasks, relying on the ability to retain items in immediate short-term memory for the present moment (memory with a capacity in the range of seconds to minutes). However, the general population is unaware that even individuals with documented moderate to severe brain injuries can achieve accuracy greater than 95% on this task (Prigatano & Amin, 1993; Prigatano, Smason, Lamb, & Bortz, 1997). Hence an individual who achieves accuracy below this level, in the absence of evidence to suggest a severe brain injury, neurodegenerative disorder, or extremely low intellectual functioning, may be suspected of neurocognitive malingering. A more recently developed measure of symptom validity is the pictorial Test of Memory Malingering (Tombaugh, 1996). The TOMM involves two separate learning trials for the same 50 line drawings of common objects, each followed by a forced-choice alternative recognition memory test. At face value, this test appears similar to established tests of recognition memory such as the Warrington Recognition Memory Test (WRMT) given the high number of intervening stimuli and the increased length of time between study and test. The TOMM differs from established tests of recognition memory in that learning the stimuli is facilitated by the provision of corrective feedback during recognition memory testing. The TOMM has a cut-off criterion of 90% accuracy, similar to tests such as the Digit Memory Test, which has been demonstrated as an indicator of possible neurocognitive malingering (Rees, Tombaugh, Gansler, & Moczynski, 1998; Tombaugh, 1997). Another recently developed symptom validity test that is commonly used in forensic neuropsychological assessments is the visual Word Memory Test (Green, 2003b) and its short form, the Medical Symptom Validity Test (Green, 2003a). This computer-presented test involves learning of paired associates with memory being tested through free recall and recognition memory tests. It also has high face validity as a memory test and has demonstrated high sensitivity to neurocognitive malingering (Rees et al., 1998; Tombaugh, 1997).

Symptom validity tests that do not contain a forced-choice alternative component are less common, but typically, they too consist of easy short-term memory paradigms with instructions that make the test appear more difficult than it really is. For example, in the Rey 15-item task (Rey, 1964) an individual is briefly shown a 3 X 5 array of 15 “different” characters (i.e., numbers and letters) for 10 seconds. Following a 10 to 15 second delay the individual is asked to reproduce the items. However, the 15 items can be easily chunked into 3 different concepts, and recall of less than 3 rows of the array is considered to be the criterion for suspecting neurocognitive malingering (Bernard & Fowler, 1990).

One of the main differences between tests developed for the sole purpose of symptom validity testing (e.g., the Digit Memory Test) and established neuropsychological tests is sensitivity to unfeigned cognitive impairment. For example, the Digit Memory Test is sensitive to neurocognitive malingering, but has low sensitivity to recent long-term memory impairment as even individuals with severe brain damage can perform with high accuracy (e.g., > 90%) on it (Prigatano & Amin, 1993). On the other hand, established tests of neuropsychological function have been designed as valid measure of cognitive functions, such as memory, but have also been studied as tools for detecting neurocognitive malingering (e.g., the California Verbal Learning and Memory Test – II (CLVT-II) (Coleman, Rapport, Millis, Ricker, & Farchione, 1998); the Warrington’s Recognition Memory Tests (WRMT) (Millis, 1994a). The CVLT-II assesses auditory verbal learning and memory for a list of words presented over several trials. It includes measures of free-recall, cued recall, and recognition memory. As is often the case with established tests used to detect symptom validity, both of these tests contain a forced-choice alternative recognition memory component. Test publishers and clinicians typically claim that the advantage of this approach is that these types of tests are less recognizable as a measure of symptom validity and thus more likely to detect neurocognitive malingering in more sophisticated individuals. This latter type of validity measurement is referred to as 'embedded' as opposed to the stand alone symptom validity measures (Boone, 2007).

The underlying premise for measures of symptom validity is that individuals who are exaggerating their cognitive symptoms will overestimate the difficulty of the task and perform at a level below chance or at a level below the cut-off score criterion that has been established for the task, often determined by the performance of severely brain damaged or dementia populations. Thus, a score that is significantly below chance or the cut-off criterion suggests poor effort.

Unfortunately, test-based detection of neurocognitive malingering is susceptible to the effects of coaching (i.e., providing an individual information about the nature of malingering tests, and strategies to avoid detection) to varying degrees (Coleman et al., 1998; DenBoer & Hall, 2007; Dunn, Shear, Howe, & Ris, 2003; Russeler, Brett, Klaue, Sailer, & Munte, 2008; Suhr & Gunstad, 2000). For example, Suhr and Gunstad (2000) compared two groups of healthy individuals that were instructed to feign a memory impairment. One group was provided with coaching and the other was not. Individuals who were coached performed worse than the control participants, but better than noncoached malingering participants. DenBoer and Hall (2007) found similar patterns of performance on the TOMM. This issue is especially problematic for neuropsychological assessments when the examinee is in litigation with respect to their injury and/or there is the potential for primary gain associated with the injury (Victor & Abeles, 2004). For example, in a survey of trial lawyers conducted by Essig and colleagues, 75% of the respondents reported preparing their clients for an assessment by spending time (mode of 15-60 minutes) covering information about the tests the psychologists use and how to respond (Essig, Mittenberg, Petersen, Strauman, & Cooper, 2001). Further complicating the issue of coaching is the finding that as many as 48% of the legal profession view coaching as an ethical means of 'best practice' in protecting the interests of their clients (Wetter & Corrigan, 1995). Thus at present, the influence of coaching for neuropsychological assessments poses a potential threat to the validity of any neuropsychological examination, particularly in a forensic context.

Another recent approach to improve the assessment of neurocognitive malingering has focused on the use of cognitive ERP recordings (Ellwanger, Tenhula, Rosenfeld, & Sweet, 1999b; Tardif, Barry, Fox, & Johnstone, 2000; Tardif, Barry, & Johnstone, 2002; Vagnini, Berry, Clark, & Jiang, 2008). This approach is based on the same premises described in the previous chapter for using cognitive ERP to assess cognitive functioning. Given that the behavioural responses are more difficult to interpret when coached neurocognitive malingering is suspected, the use of ERP Old/New brain responses could provide a useful and complimentary tool for studying memory in the context of poor effort.

As with the assessment of normal responding participants, well-described ERP effects from the experimental literature provide a theoretical foundation with which to evaluate ERP responses observed in individuals feigning cognitive impairment. For example, Ellwanger and colleagues (1999) examined the ERP responses from individuals asked to feign a cognitive impairment on a modified Digit Memory Test. The modified test used stimuli of 3 digits in length and employed a matching paradigm similar to the Short-term Memory task used in this thesis (i.e., match vs. mismatch of two stimuli presented in succession). However, the task differed from the Short-term memory task in that the probability of a mismatch was greater than the probability of a match. In the Short-term Memory task the probabilities of matched and mismatched stimuli were equal. Ellwanger and colleagues described the Old/New differences they found in the ERP responses in terms of the well-studied oddball P300 ERP response. In brief, this response occurs to low probability (i.e., oddball) stimuli and has been associated with attention, novelty detection, and memory updating processes (for a recent review see Polich, 2007). However, because of the oddball nature of the paradigm used, the ERP responses obtained in the Ellwanger study do not directly index neural processing associated with recognition memory. This is because unlike the oddball P300 response, typical Old/New recognition memory effects (Friedman & Johnson, 2000; Mecklinger, 2000; Rugg & Curran, 2007) can be obtained from paradigms with equal numbers of Old and New stimuli. The rationale behind the oddball paradigm (i.e., a lower proportion of Old stimuli to New stimuli during recognition testing) is that 'Old' items will only be processed as an 'oddball' if they are first recognized as Old. In other words, recognition memory is inferred from the presence of the oddball P300 response. However, the use of an oddball paradigm would thus result in the confounding of ERP responses for recognition memory with ERP responses for novelty detection.

In the studies by Tardif and colleagues (2000, 2002), ERP responses were obtained while participants were administered an established neuropsychological measure of recognition memory, the Warrington Recognition Memory Test – Words. They showed both early frontal and late parietal ERP Old/New positivity effects. Their studies showed no statistical differences in the late parietal ERP Old/New responses between a group of healthy, honest performing participants and a group of healthy participants that had been instructed to feign a memory impairment. However, they found that the malingering group displayed a larger early frontal ERP Old/New positivity effect than the honest performing control group.

In a more recent study, ERP responses to an experimental paradigm of visual recognition memory for line drawings of everyday objects (using a study-test paradigm similar to the Recent Long-term task in the current experiment) and behavioural responses to the TOMM were compared for healthy individuals, individuals malingering a memory impairment, and individuals who had sustained traumatic brain injury (Vagnini et al., 2008). In contrast to the above studies, Vagnini and colleagues failed to find any significant differences between ERP responses to Old and New items from a group of healthy participants asked to feign a memory impairment on the visual recognition memory task. Vagnini and colleagues interpreted the absence of Old/New positivity effects in the malingering group as a marker of neurocognitive malingering. In other words, feigning a memory reduces the magnitude of ERP Old/New positivity effects. However, an overall comparison of the ERP responses recorded from the midline regions of the head in the Vagnini study did not significantly differentiate between the malingering group and a group of individuals with documented brain injury. The results of the Vagnini study imply that one can fake an ERP response, just as they might an overt behavioural response, to resemble the ERP responses elicited in individuals with documented brain injury. In other words, this result suggests that one could "recognize" an item on a recognition memory test and subsequently conceal the electrophysiological response that was associated with the recognition memory processing. However, such an interpretation would be highly inconsistent with vast literature describing ERP Old/New positivity effects, as well as cognitive ERP responses in general. Although the reason for the findings in the Vagnini study are unclear, a strong possibility lies in their use of correct-response trials for generating the average ERP waveforms compared between the different groups. The problem is that a "correct" response by participants in the malingering group is impossible to interpret as it may represent an honest "correct" response, or an item that was initially incorrectly identified by the participant but inadvertently responded to as "correct" in an attempt to feign a memory impairment (i.e., an Old item initially and incorrectly recognized as New). As a result, Old and New ERP waveforms derived from correct-response trials in Malingering participants cannot be assumed to be a homogenous response and become problematic to interpret compared to Old and New waveforms from the correct-response trials of Honest responding participants.

To date no one has systematically compared Old/New ERP effects from tasks of short-term recognition memory, recent long-term recognition memory, or remote long-term recognition memory in individuals asked to feign a cognitive impairment.

Characterizing the ERP responses on these different types of tasks in individuals malingering a cognitive impairment is important for understanding how ERP responses may contribute to differentiating between memory impairment and neurocognitive malingering. It will also be important for providing a better understanding of the ERP responses that might be used as clinical indicators of neurocognitive malingering, especially given some of the discrepancies in the existing literature.

1.6 Thesis Overview

In brief, there are several outstanding issues to be addressed for understanding the potential contributions of ERP recordings to the assessment of memory functioning. The majority of ERP studies of recognition memory have studied Recent Long-term memory, with fewer studies of Short-term and Remote Long-term recognition memory. Typically, Remote Long-term recognition memory has been studied using famous faces, given the convenience of being able to independently verify the approximate “age” of the memory based upon the time period when the “celebrity” status of the famous face was at its peak. However, a criticism of this approach is that the famous faces used in any given study are not necessarily personally relevant to the participants. Memory for famous faces will be dependent upon one’s media exposure to the famous face depicted. An examination of the recognition memory ERP correlates of personally relevant faces would provide a more useful comparison for recognition memory ERP responses from tasks of Short-term and Recent Long-term memory. Personally relevant faces would provide a more consistent measure of Remote Long-term memory and a better standard for which to compare ERP Old/New responses from tasks of Short-term memory and Recent Long-term memory which are typically used in clinical neuropsychological assessments.

However, to date the few studies that have compared recognition memory ERP responses to faces between measures of Remote Long-term memory and new learning have used famous faces. In addition, no studies have systematically compared ERP Old/New responses to personally relevant faces with ERP Old/New responses to faces on tasks of Short-term and Recent Long-term memory.

Because brain damage can be associated with many potential types of memory impairments and because different types of impairment are thought to be associated with different regions of the brain, a comparison of ERP responses to processes associated with familiarity and recollection across different types of memory tasks will be important for understanding the ERP correlates of recognition memory. For example, while the late parietal Old/New ERP response (recollection) has been shown to be selective to Old items (Joyce & Kutas, 2005) on recognition memory tasks, the early frontal Old/New ERP response (familiarity) is influenced by the similarity of the Old and New items during recognition testing. As such, false recognition of New test items as being Old has also been shown to generate the early Old/New ERP response associated with familiarity (Nessler, Mecklinger, & Penney, 2001). Exploring the ERP responses associated with familiarity and recollection on different types of recognition memory tasks will be important for understanding the contribution of ERP responses to the assessment of memory functioning.

1.6.1 Objectives

For the experiments conducted in this thesis, the early frontal (250 to 500 ms) and late parietal (400 to 1000 ms) Old/New recognition memory ERP responses, which are more positive to Old items than to New items, were compared on three different tasks of visual recognition memory. The overall objective was to explore and compare the electrical brain activity associated with recognition memory for faces on tasks of Short-term memory, Recent Long-term memory, and Remote Long-term memory.

In Experiment 1 (Chapter 2), the goal was to explore the ERP Old/New recognition memory effects for familiarity and recollection independently of behavioural responses to mimic the condition when motor or verbal responses are unavailable. This was accomplished by comparing ERP responses Old faces with the ERP responses to New faces regardless of the behavioural response provided on the three different tasks of recognition memory. Behavioural responses to Old and New faces were also compared to provide behavioural measures of memory performance on the memory tasks. The second purpose of Experiment 1 was to provide a control group for Experiment 2. Thus in Experiment 1, participants were normal healthy adults responding normally to test items. As a result, Experiment 1 has been labeled as the Honest Response experiment. It was generally expected that participants would demonstrate high rates of accuracy in their behavioural performances on all three of the memory tasks. ERP responses were also expected to differentiate between Old and New faces on each task independently of the behavioural responses. The ERP Old/New differences were expected to be consistent with Old/New ERP recognition effects described in the experimental ERP recognition memory literature. Furthermore it was expected that the ERP analysis would complement the behavioural analysis. A summary of the hypotheses for Experiment 1 is provided in Table 1.

Table 1 Summary of hypotheses for Experiment 1. Shaded areas represent the expected distribution of ERP Old/New positivity effects, with darker shading to show ERP regions where the effects were expected to be at maximum.

Task	**Behavioural**	**ERP Time Window**	**ERP Old/New Results**		**Putative Cognitive Component**
Short-term	Total Correct > 90% (90/100)	Early Frontal Old/New Window (~250 to 500 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (~400 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Recent Long-term	Total Correct > 90% (90/100)	Early Frontal Old/New Window (~250 to 500 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (~400 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Remote Long-term	Total Correct > 90% (65/72)	Early Frontal Old/New Window (~250 to 500 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (~400 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	

(ERP event-related potential; LF Left Frontal; LC Left Central; LT Left Temporal; LP Left Parietal; RF Right Frontal; RC Right Central; RT Right Temporal; RP Right parietal)

Experiment 2 (Chapter 3) sought to explore examine recognition memory ERP Old/New positivity effects in participants who were instructed to feign a memory impairment. This study used the same tasks as those used for Experiment 1, but this time participants were provided with a financial incentive to feign a memory impairment. In this experiment, behavioural accuracy rates were expected to be low, reflecting participants' efforts at neurocognitive malingering. In contrast however, ERP Old/New memory effects, specifically the late Old/New positivity effect associated with recollection, were expected to still be present in the ERP responses of the participants. That is, participants would not be able to inhibit their ERP responses, though they would be able to inhibit their overt verbal / motor responses. A summary of the hypotheses from Experiment 2 is provided in Table 2.

Table 2 Summary of hypotheses for Experiment 2. Shaded areas represent the expected distribution of ERP Old/New positivity effects, with darker shading to show ERP regions where the effects were expected to be at maximum.

Task	**Behavioural**	**ERP Time Window**	**Old/New Results**		**Putative Cognitive Component**
Short-term	Total Correct < 90% (90/100)	Early Frontal Old/New Window (~250 to 500 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (~400 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Recent Long-term	Total Correct < 90% (90/100)	Early Frontal Old/New Window (~250 to 500 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (~400 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Remote Long-term	Total Correct < 90% (65/72)	Early Frontal Old/New Window (~250 to 500 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (~400 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	

A final comparison of Experiments 1 and 2 is presented in Chapter 4. This comparison sought to further address the validity of ERP Old/New responses as correlates of memory function by comparing the ERP responses from the Honest

Response experiment (Experiment 1) to the ERP responses from the Malingering experiment (Experiment 2). The goal was to explore to what extent, if any, feigning a memory impairment might influence ERP Old/New positivity effects compared to ERP responses elicited under standard responding conditions. That is, it was expected that in comparison of the two experiments, the behavioural responses would demonstrate large and significant differences, while the ERP data would not. This would imply that a participant can fake behavioural data but not ERP data.

Though each of the experiments is described and discussed in more detail in the subsequent chapters, as a general summary, Experiments 1 and 2 consisted of three visual recognition memory tests for faces: (1) Short-term memory, (2) Recent Long-term memory, and (3) Remote Long-term memory. The Short-term and Recent Long-term tasks were based on an adaptation of the Warrington Recognition Memory Test – Faces (WRMF) (Warrington, 1984). The Recent Long-term memory task consisted of a learning and a study phase. During the learning phase, the participant was presented with 50 faces in succession and was instructed to rate each face as pleasant or unpleasant. During the test phase, participants are presented with another sequence of faces. Some of these had been studied previously and some had not. Participants had to identify whether each face was one that had been presented previously (Old) or whether it was a new face (New). The Short-term memory task used a match-to-sample paradigm. In this paradigm participants were presented with a study face that was followed by a test face. Participants had to identify whether the test face was a match to the face that had just been studied (Old) or whether the face did not match (New). Note that the primary difference between the Short-term and the Recent long-term tasks is the timing of presentation. The Remote Long-term memory differed from the other two memory tasks in that no learning or study phase was required as the participants provided their own personally relevant stimuli. In the Remote Long-term task participants were presented with 72 faces in succession and instructed to identify whether the face was well-known (Old) or unknown (New).

The behavioral data consisted of a binary yes/no response, coded as correct or incorrect. In Experiment 1 participants were expected to demonstrate high behavioural accuracy based on the design of the tests. However, in Experiment 2 participants were expected to demonstrate low accuracy as a result of neurocognitive malingering.

The ERP data was collected from eight regions: left and right frontal regions (LF & RF), left and right temporal region (LT & RT), left and right central region (LC & RC), and left and right parietal region (LP & RP). Analyses focused on differences in ERP components with respect to Old versus New faces. Within each site, two time windows were examined for ERP Old/New positivity effects. The first corresponded to recognition memory effects for familiarity at approximately a 250 to 500 ms time window (the early frontal Old/New positivity effect) and recollection at approximately 400 to 1000 ms (the late parietal Old/New positivity effect). It was hypothesized that the late parietal ERP Old/New response associated with recollection would be observed for each recognition memory task in both the Honest Response experiment and the Malingering experiment regardless of the behavioural responses. In other words, the response would be observable in ERP responses averaged on the basis of stimulus category only. Given the non-specificity of the early frontal ERP Old/New response associated with familiarity (it can be elicited by highly similar, but unstudied New faces), the examination of this ERP response was exploratory in nature. If memory processing associated with familiarity were contributing to task performance, the early Old/New positivity effect would be expected most prominently over frontal regions. Similarly, the comparison of ERP Old/New responses between memory tasks and between two different study experiments was also exploratory in nature. If the early and late ERP Old/New recognition memory responses are elicited independently of cognitive activity associated with neurocognitive malingering, then no differences in ERP responses between the Honest Response and the Simulated Memory Malingering participants would be expected (Table 3).

Table 3 Summary of hypotheses for the comparison of Honest Response (HR) with Simulated Memory Malingering (SMM).

Task	**Behavioural Results**	**ERP Time Window**	**ERP Old/New Results**	**Putative Cognitive Component**
Short-term	Total Correct HR > SMM	Early Frontal Old/New Window (~250 to 500 ms)	HR = SMM?	Familiarity
		Late Parietal Old/New Window (~400 to 1000 ms)	HR = SMM	Recollection
Recent Long-term	Total Correct HR > SMM	Early Frontal Old/New Window (~250 to 500 ms)	HR = SMM?	Familiarity
		Late Parietal Old/New Window (~400 to 1000 ms)	HR = SMM	Recollection
Remote Long-term	Total Correct HR > SMM	Early Frontal Old/New Window (~250 to 500 ms)	HR = SMM?	Familiarity
		Late Parietal Old/New Window (~400 to 1000 ms)	HR = SMM	Recollection

CHAPTER 2 EXPERIMENT 1

Cognitive event-related potential (ERP) recordings have been found to be a useful tool for studying cognitive functioning including recognition memory. However, ERP are not commonly used in clinical settings. Experimental studies of recognition memory using ERP have consistently shown that the ERP responses to Old items (stimuli that were studied or learned as part of the memory test) are more positive in electrical amplitude than the ERP responses to New items (distractor stimuli that were not previously studied in the context of the specific recognition memory test). These differences between ERP responses to Old and New stimuli are typically referred to as Old/New positivity effects and have been observed for both auditory and visual information (Friedman & Johnson, 2000; Mecklinger, 2000; Rugg & Allan, 2000b).

ERP Old/New positivity effects have been used to provide a neurophysiological foundation for neurocognitive models of recognition memory by correlating ERP Old/New responses with the cognitive experiences of familiarity and recollection. Yonelinas (2002) uses the particularly relevant experience of face recognition to illustrate the concepts of familiarity and recollection. He describes familiarity as being able to recognize a person (i.e., they are *familiar*), but not being able to *recollect* whom the person is or where they were previously encountered. Recollection reflects the experience of recognizing a person as well as the contextual details associated with that person. Dual-process models of recognition memory contend that familiarity and recollection represent two separate neurocognitive mechanisms underlying recognition memory (for review see, Yonelinas, 2002). Unitary-process models contend that familiarity and recollection represent relative degrees of memory strength for the same neurocognitive process.

Two recognition memory ERP Old/New positivity effects (i.e., Old waveforms having higher or more positive amplitudes than New waveforms) that have been of particular interest to the study of recognition memory are an early frontal Old/New positivity effect and a later parietal Old/New positivity effect. The first Old/New positivity effect typically appears ~250-500 ms post-stimulus, has a fronto-central distribution (Rugg et al., 1998), and has been associated with a sense of familiarity with a stimulus or a feeling of having seen the stimulus before (e.g. Mecklinger, 2000; Schloerscheidt & Rugg, 2004). The second effect occurs later between 400-1000 ms, has a central-parietal distribution, and is associated with recollection or an explicit recognition of the stimulus or certainty of having encountered it before (e.g. Rugg, 1995). The late parietal effect has also been shown index recollection on the basis of recognition accuracy (Paller et al., 1999), and level of confidence in behavioural response (Curran, 2004).

Evidence from ERP studies of recognition memory have largely supported the dual-process model of recognition memory by identifying distinct ERP Old/New responses for both familiarity (i.e., early Old/New positivity effect, early midfrontal effect, FN400) and recollection (i.e., late Old/New positivity effect, parietal Old/New positivity effect, late positive component) (Rugg & Curran, 2007). However, some recent ERP studies of recognition memory have disputed this traditional distinction between frontal and posterior Old/New positivity effects (MacKenzie & Donaldson, 2007; Yovel & Paller, 2004). In support of dual-processing models, MacKenzie and Donaldson (2007) demonstrated an anterior and a posterior Old/New positivity. In contrast to the typical distribution of Old/New positivity effects for familiarity and recollection, they found that the *anterior* Old/New positivity effect was associated with recollection and that the *posterior* Old/New positivityeffect was associated with familiarity. In support of a single unitary-process model of recognition however, Yovel and Paller (2004) demonstrated late parietal Old/New positivity effects for both familiarity and recollection.

As discussed in Chapter 1, both the early and the late Old/New positivity effect have been reported in experimental studies of recognition memory for faces (Barrett & Rugg, 1989; Eimer, 2000; Guillem et al., 2001; Joyce & Kutas, 2005; Paller et al., 1999; Paller et al., 2003). Typically, these studies have used paradigms of short-term memory or recent long-term memory. However, fewer ERP memory studies have examined the brain waves associated with remote long-term recognition memory. Those studies that have attempted to study remote long-term memory have generally relied on paradigms that test recognition memory for famous faces. A weakness of this paradigm however is the inter-subject variability in prior exposure to or knowledge of the famous faces being used (Lezak et al., 2004).

The current experiment was developed to investigate the ERP correlates of Short-term, Recent Long-term and Remote Long-term visual recognition memory for faces. As discussed in Chapter 1, theories of memory processing suggest that different neural structures and possibly different neural mechanisms are mediating new learning and memory (i.e., short-term memory, recent long-term memory) versus remote long-term memory. Given the different brain regions and possibly different brain mechanisms mediating these different types of memory processes, the goal of this experiment was to investigate electrophysiological differences between the Old/New recognition effects for these different types of memory tasks. In particular, this thesis sought to explore the electrical brain activity associated with recognition memory for faces on a Remote Long-term memory task for personally relevant faces and to compare it with the brain activity from Short-term and Recent Long-term memory tasks for faces.

In addition a better understanding of the various ERP responses for different types of memory has clinical applicability. Although not commonly used in clinical settings, there is emerging evidence that ERP could be useful in clinical neuropsychological assessment as well. A primary advantage of this technique is that cognitive function can be investigated in the absence of verbal or motor responses (Luck, 2005) – thus making this methodology applicable to individuals having little or no communicative abilities (Connolly et al., 1999b). As discussed in the general introduction (Chapter 1), several clinical neuropsychology tests have been adapted for ERP recordings, including the Warrington Recognition Memory Test for Words (Tardif et al., 2000; Tardif et al., 2002). In the studies by Tardif et al. (2000, 2002), ERP responses to studied and new words were found to show both an early frontal ERP Old/New positivity effect and a late parietal ERP Old/New positivity effect.

In the present study, cognitive ERP were examined in three different types of visual recognition memory tests for faces: (1) Short-term memory (i.e., the recent past – seconds to minutes), (2) Recent long-term memory (i.e., hours to days), and (3) Remote memory (i.e., information from the distant past that was learned months to years before the time of testing). The Short-term and Recent Long-term tasks were based on an adaptation of the Warrington Recognition Memory Test – Faces (WMF) (Warrington,

1984) for simultaneous computer presentation and ERP recording (Wang & Connolly, 2000). The WMF is a commonly used neuropsychological test of non-verbal recognition memory (Lezak et al., 2004). Under standard administration conditions the participants are told that they will be given a memory test. The participant is presented with 50 photographs of faces in succession and asked to state whether each face is pleasant or unpleasant. Immediately following the presentation of the list, the participant is informed that he/she will be shown more faces two at a time and that he/she is to choose the one that he/she believes had been presented earlier. The WMF has shown adequate reliability (test-retest $r = .81$) as a measure of memory impairment (Soukup, Bimbela, & Schiess, 1999) and has also been studied as a measure of memory effort (Iverson & Franzen, 1998; Millis, 1994b; Millis & Putnam, 1994).

Two general modifications were made to the WMF test to adapt it for ERP recording. First, under standard WMF administration, the recognition phase is a forced-choice, two-alternative task in which participants choose between an Old face and a New face that are presented on a card simultaneously side-by-side. However, in order to clearly differentiate the ERP responses to Old faces from the ERP responses to New faces, the test stimuli in the test phase of the ERP-adapted versions were presented one at a time. The current thesis administered the stimuli via computer. Participants entered their responses by pressing a button to say YES if they had seen the face before or another button to say NO if they had not seen the face before.

The Short-term memory task was a match-to-sample test of visual recognition memory for faces taken from the WRMF. This administration format followed a similar pattern to clinical tests of simple short-term memory such as the Digit Memory Test

(Hiscock & Hiscock, 1989a) often used as a measure of effort. The Digit Memory Test contains very brief delays of 5, 10, and 15 seconds with no intervening stimuli between study and test; and it uses highly discriminable foils (i.e., each foil differs from the target by at least two digits, including the first and last digits). For the Short-term memory task in this experiment, each trial consisted of two sequentially presented photographs of faces on a computer screen. Participants were instructed to remember the first face so they could judge, whether or not the second face was the same (Old) or different (New) from the face that had just previously been presented via button presses on a response box. Each of the 50 study faces from the WRMF appeared twice (for a total of 100 trials) and was followed either by the same face or by the alternative face that is used in the standard administration of the test phase of the WRMF. The capacity of the visual short-term memory system is approximately four integrated items (Luck & Vogel, 1997) and is highly susceptible to interference. The matching-to-sample paradigm minimizes interference effects by limiting the number of faces to be remembered to just one per trial and keeping the study-test interval in the range of two to five seconds.

The Recent Long-term memory task used the same stimuli, instructions, and general format (e.g. study phase followed by a test phase) as the WRMF. However unlike the standard WRMF, the ERP-adapted version used a YES/NO recognition format during the test phase as opposed to forced-choice alternative recognition.

The Remote Long-term memory task in this study consisted of single YES/NO recognition memory judgments to a series of photographs containing personally relevant faces mixed with unknown faces. Each participant supplied their own personally relevant faces to be used in the study. No study phase of the personally relevant faces was used as participants supplied their own photographs of well-known faces (Old). Typically, Remote Long-term recognition memory has been studied with the use famous faces. However, the variable degree to which different individuals will have knowledge of and/ or interaction with the famous faces used represent a weakness of this approach to studying Remote Long-term memory. To date, there have been no studies that have examined Remote Long-term memory using photographs of faces well-known to each individual participant.

The goal of Experiment 1 was to explore the ERP Old/New recognition memory effects for familiarity and recollection independently of behavioural responses to mimic the condition of impaired communication. In addition, Experiment 1 served as a control group for Experiment 2. In particular this experiment sought to explore and compare the ERP responses to the Old and New faces on 3 different recognition memory tasks for faces – a Short-term memory task, a Recent Long-term memory task, and a Remote Long-term memory task. Behavioural responses to Old and New faces were also compared to provide behavioural measures of memory performance on the memory tasks. It was expected that participants would demonstrate high rates of behavioural accuracy on all three memory tasks. It was hypothesized that Old/New differences should also be observed for each task, with responses to Old faces being more positive than responses to New faces. According to the dual process theory of recognition memory, both familiarity and recollection processes could be expected to be contributing to recognition memory. As the late parietal Old/New positivity effect is associated with correctly judged Old stimuli in recognition memory paradigms, this effect was to be elicited by each of the memory tasks. However, the early frontal Old/New positivity effect has been shown to be elicited by both correctly identified Old stimuli as well as New stimuli incorrectly identified as Old (False Alarm) (Nessler et al., 2001). It was generally expected that the early frontal Old/New positivity effect should also be elicited by each of the tasks, although greater variation in this ERP response was to be expected compared to the late parietal Old/New response. Also to be explored in Experiment 1, was the extent to which the magnitude of the early frontal and the late parietal ERP Old/New positivity effects might differ across tasks of Short-term memory, Recent Long-term memory, and Remote Long-term memory. Understanding the similarities and differences of ERP Old/New positivity effects across the three different recognition memory tasks is important for making inferences about ERP Old/New positivity effects and recognition memory processes.

This thesis also sought to explore ERP Old/New positivity effects at the individual level. However, at present there is no generally accepted standard for analyzing ERP responses at the individual level. In this Experiment ERP responses at the individual level were explored and compared using two different approaches – a peak t-score difference analysis and a Wilcoxon signed-rank analysis.

2.1 Methods

2.1.1 Participants

Twenty-one healthy participants were recruited from the campus and general community, and included both students and non-students. Participants were screened for a history of conditions that could affect aspects of this research (i.e., epilepsy, neurotrauma, psychiatric disorders, language-related disorders, or audiological problems) and were required to have normal or corrected-to-normal vision. Participants were also required to have normal facial perception skills as measured by the Benton Test of Facial Recognition (Benton, Sivan, Hamsher, Varney, & Spreen, 1994). Three of the participants had an insufficient number of trials following electrooculogram (EOG) artefact rejection. One participant was excluded due to technical problems with the EEG recording equipment. All four of these participants were excluded from further analyses. The final sample of 17 participants (10 females, 7 males) had a mean age of 27.1 (s.e.m. = 1.1, range = 21-36) years. Fifteen participants were right handed, 1 was left handed, and 1 was ambidextrous as measured by the Edinburgh Handedness Questionnaire (Oldfield, 1971).

2.1.2 Stimuli and Experimental Conditions

2.1.2.1 Short-term memory task. The Short-term memory task used the black and white photographs of men's faces from the WMF that were used in the Recent Long-term memory task. However, the short-term test was designed to reduce delay and interference effects. This was accomplished by presenting the "test" face shortly after the studied target face. The delay between study and test ranged from two to five seconds and contained no intervening stimuli. On this task, participants were instructed to remember the first face they saw on a given trial so that they would be able to determine if the second face in the pair was the same or different than the first face. A behavioural response (button press by the preferred hand) was made to the second face to indicate whether it was a match to the preceding face or a mismatch.

The Short-term memory task consisted of 100 individual study-test trials. In other words, for each trial participants were shown a study face that was soon followed by the test face. In this task only, the start of each new trial was indicated by a crosshair at the centre of the computer screen (duration = 500 ms). For a given trial the target face was presented for 500 ms and followed by an interval of either 1600, 2400, or 5000 ms before the presentation of the test face (duration = 500 ms). An inter-trial-interval of 2500 seconds separated each trial. Participants responded via button press whether or not the test face matched the target face for each trial. Half of the trials consisted of "matched" pairs of faces (first and second face were the same) and half were "mismatched" faces (the pair of faces on for the trial were different).

2.1.2.2 Recent long-term memory task. In the ERP version of the WMF used for the Recent Long-term task, the test stimuli consisted of the same 100 black and white photos of men's faces from the WMF that were also used in the Short-term memory task. In the study phase, participants were shown consecutively a series of 50 different target faces (duration = 1500 ms; inter-trial interval = 3000 ms) and asked to judge by means of a button press whether the face was pleasant or unpleasant. As per the original instructions of the WMF task, the participants were not told that this was a memory test. During the recognition phase of the test, participants were shown 100 faces (50 Old - previously seen in the study phase; 50 new - not previously seen). The stimulus duration equaled 1500 ms and the inter-trial interval ranged from 3500 to 5000 ms to avoid eliciting ERP responses associated with anticipation of a response (Walter, Cooper, Aldridge, McCallum, & Winter, 1964). Participants were asked to identify with a button press which of the faces they had seen previously. The time between study and recognition for any given face was at least 5 minutes given the administration time of the study phase and the time needed by the examiner to provide the instructions for the recognition phase of the task. Of the three tasks in this thesis, the computerized Recent Long-term memory task bore the closest resemblance to the original WMF neuropsychological test.

2.1.2.3 Remote long-term memory task. Stimuli for the remote long-term recognition memory test included colour photographs of faces supplied by each participant (for the Old / Personally relevant condition) and by the author (for the New condition). Participants were asked to supply their own photographs for this test so to individualize the test and ensure that the Old faces in this task were indeed "well-known" to each participant. "Well-known" was defined as depicting an individual that had interacted with the participant at least two to three times per week for a period of at least one month at some point in his or her life. Each participant provided two different photos of eighteen different "well-known" individuals to be used as Old stimuli. Participants were asked to limit their faces to individuals eighteen years or older, and asked to avoid providing photographs with distracting backgrounds or extreme facial expressions. Participants indicated that they knew the individuals in the photographs of the personally relevant faces for 104.52 ± 9.84 months (mean, s.e.m.). For each participant the novel faces (New) consisted of photographs provided by the author and/or from the photographs of other participants (with the permission of the individuals whose faces were being used). All photographs were cropped to the head and shoulders. No attempts were made to alter the backgrounds of the photographs, which varied between photographs (for examples see Figure 1).

Figure 1 Examples of face stimuli used for the Remote Long-term memory task.

As Old faces in this test were already well known to the participants, no study phase was required. Participants were presented with a series of 72 faces (36 Old, 36 New; stimulus duration = 1500 ms; inter-trial-interval 3500 ms) and asked to respond with a button press to indicate whether the face was well known (i.e., provided by the participant) or New. At the end of the test, participants were always queried about whether they recognized any faces they did not personally provide for the experiment; no such indication was made by any participant.

2.1.3 Procedure

2.1.3.1 Study sessions. Participants attended two sessions. In the first session consent was obtained for participation; participants completed health checklist to screen for inclusionary and exclusionary criteria (see Participants section); and the Benton

Facial Recognition Test was administered to screen for facial perception. Participants were then asked to provide the examiner with a set of personally relevant faces. These images were allowed to come from previously taken photographs or newly taken photographs, so long as the individual in the photograph met the operational definition of well-known. Participants were also provided with consent forms to obtain permission from the individuals whose faces were depicted in the photographs for the use of their image. The interval between Sessions 1 and 2 ranged between one to three weeks to allow time for participants to collect and submit their personally relevant photographs to the researcher and to provide the researcher time to crop and prepare the photographs for the computer system to be used during the ERP testing. This session typically lasted between 20 to 30 minutes. All three memory tests and ERP recordings were made during the second session. Participants were seated in a comfortable chair and prepared for the electrophysiological recordings. Participants were then administered the memory tests following which the recording electrodes were removed. This session typically lasted between 2 to 2.5 hours. Approximately 30 to 45 minutes was required for applying and preparing the recording electrodes and equipment preparation, 75 minutes for administration of the memory tests (including two 5 minute breaks), and approximately 20 to 30 minutes to take down the recording montage.

2.1.3.2 Electrophysiological materials and recordings. The EEG was recorded from 30 tin electrodes embedded into an electrode cap (Electro-Cap International) that was placed on the participants' head. The electrode arrangement included sites used in the 10-10 system of the ACNS - FP1, FP2, F3, FZ, F4, F7, F8, FC3, FCZ, FC4, FT7, FT8, C3, CZ, C4, CP3, CPZ, CP4, P3, PZ, P4, T3, T4, T5, T6, TP7, TP8, O1, OZ, O2.

The letters refer to the location of the electrode placement on the head. For example, frontal (F), central (C), temporal (T), and parietal (P) refer to the topographical location on the recording electrode was positioned. Odd numbers refer to electrodes that are positioned over the left side of the head and even numbers refer to electrodes that are positioned over the right side of the head. Participants were grounded with an electrode placed over the forehead. Nose referenced recordings were made with a 0.01 – 100 Hz band pass and a sampling rate of 500 Hz. Impedances were kept at or below 5kΩ. The electrooculograph (EOG) was recorded with the same bandpass and sampling rate from tin electrodes placed above the right eye and over the outer canthus of the left eye to simultaneously monitor horizontal and vertical eye movements. Offline, the continuous EEG data were epoched (segmented into time periods) from 100ms pre-stimulus to 1000ms post-stimulus, digitally filtered with a bandpass of 0.1 to 20Hz (24 dB/octave), and baseline corrected to the 100ms pre-stimulus interval. The electrical fields generated by muscle activity associated with eye movements interfere with recording electrical activity from the brain. As such, Epochs with EOG artefacts greater than ±75 μV were rejected from subsequent analysis. EEG epochs timed to "old" and "new" faces were averaged separately. The procedure was repeated for each of the recognition memory tests.

For the ERP data, eight regions (frontal, temporal, central, and parietal regions over both hemispheres) were linearly derived from combinations of two electrode sites (Connolly, Phillips, & Forbes, 1995). The left frontal region (LF) combined electrodes F3 and FC3, the left temporal region (LT) combined FT7 and T3, the left central region (LC) combined C3 and CP3, and the left parietal region (LP) combined P3 and T5. The corresponding right hemisphere regions (RF, RT, RC, RP) were similarly derived using the corresponding right hemisphere electrodes.

The tests were administered in following order: Recent Long-term memory, Short-term memory, Remote Long-term memory. Breaks were provided in between tests as needed by the participants. This testing order was maintained for two reasons. First, the same stimuli were used in both the recent long-term memory and the short-term memory tasks. This was done to minimize any stimulus related differences between the results obtained from the two tasks of "anterograde" (i.e., new) memory. However, using the same stimuli also increased the potential influence of a stimulus repetition effect that would be more problematic for the Recent Long-term memory task than the Short-term task. This was because the Recent Long-term task was designed to assess learning after a single presentation of a face, similar to the original WRMF. The Short-term memory task was designed to assess memory for a recently seen face. Hence, the recent long-term memory task always preceded the short-term memory task. Thus, all faces would be expected to be familiar during the Short-term memory task.

The second reason for the test order was to address the issue of participant fatigue. From previous observations in the lab, it was noted that testing duration and level of attentional engagement both influence the level of participant arousal. Decreased arousal is associated with increased alpha EEG activity, an oscillatory patterns of EEG activity, over central-parietal areas (Luck, 2005) – these posterior areas are also the areas of interest for studying the late parietal Old/New positivity effect. Because of the rhythmical pattern of alpha activity, it does not get filtered out during the averaging process. As such, alpha activity interferes with recording the late parietal Old/New positivity effect. The remote long-term memory task was considered to be intrinsically more meaningful and engaging task for the participants, and thus one on which they were less likely to become bored or tired. Thus, the remote long-term task was always presented last to counter the potential effect of testing fatigue.

At the beginning of the Short-term memory task participants were informed that this task would be a memory test. Participants were instructed to pay attention and to remember the target face on each trial so that they could identify the subsequent test face as either the same or as a new face. Participants were told that some of the trials might be more difficult than others as the as they would have to remember the study face for longer periods of time. As such they were encouraged to try their best to pay attention and remember the target photo for each trial. This task was broken into 3 blocks and participants were provided with additional breaks between blocks if needed. The maximum score for behavioural responses on this task was out of 100 (Hits + Correct Rejections). Administration of this task required 17 to 20 minutes.

At the beginning of the Recent Long-term memory task participants were again informed that they would be completing a memory test. Participants were instructed to pay attention to the faces being presented and to make a judgment about whether each face was pleasant or unpleasant. They were informed that there were no right or wrong answers, but that they must make a choice by pressing a button on a hand-held response pad. Following the presentation of the study faces, the test faces were presented. Participants were instructed to identify, with a button press, each of the faces as either one that had been presented during the study phase (i.e., Old) or one that was New. Participants were reminded to pay attention to the faces. The maximum score for behavioural responses was out of 100 (Hits + Correct Rejections). Administration of the Recent Long-term memory task required 20 minutes.

For the Remote Long-term memory task, participants were instructed to pay attention to each of the faces that would be presented. Participants were to simply indicate with button press whether the face was well-known or new. The maximum score for behavioural responses on the Remote Long-term memory task was out of 72 (Hits + Correct Rejections). Administration time for this task was 12 minutes.

2.1.4. Statistical Analyses and Comparisons

Descriptive statistics for accuracy and reaction times were computed for Hits (Old faces correctly identified as Old), Correct Rejections (New faces correctly identified as New), False Alarms (New faces incorrectly identified as Old), and Misses (Old faces incorrectly identified as New), and Total Correct (percentage of correctly identified Old and New faces) were recorded. For each memory task a repeated measures analysis of variance (RM-ANOVA) using a within subjects factor of reaction time (Hits, Correct Rejections) was conducted to explore reaction time differences to correctly identified Old (Hit) and New (Correct Rejection) faces. Behavioural accuracy and reaction times were also compared across the three tasks. A RM-ANOVA using a within subjects factor of memory task (Short-term, Recent Long-term, Remote Long-term) was conducted to compare the total correct percentage scores. The difference between reaction times to correctly identified Old and New faces was calculated. A RM-ANOVA using a within subjects factor of Task (Short-term, Recent Long-term, and Remote Long-term) was used to compare the Old/New reaction time difference across all three tasks.

The statistical analyses of the ERP responses focused on the early frontal Old/New positivity effect associated with familiarity and the late parietal Old/New positivity effect associated with recollection. A visual inspection of the grand average waveforms from each task was done to determine the time windows used. Once the windows had been defined, a RM-ANOVA was performed separately for mean amplitudes of the early and late Old/New positivity effects on each memory task. The RM-ANOVAs for the mean amplitude of the ERP Old/New responses examined two factors: Condition (Old, New), and Region (LF, LT, LC, LP, RF, RT, RC, RF). Conservative degrees of freedom were employed when violations of sphericity were found. Following Howell's (Howell, 1997) recommendations, the Huynh-Feldt correction was used for smaller violations of sphericity (values between 0.75-1.00) while the Greenhouse-Geisser correction was employed for more severe violations of sphericity (epsilon < 0.75). Two effects were of importance to addressing the recognition memory ERP Old/New positivity effects. A main effect of Condition would indicate an overall difference between the ERP responses to Old and to New faces. However, given that the early frontal Old/New and the late parietal Old/New recognition memory ERP responses have different distributions for their maximal response, a significant Condition X Region interaction was also expected. Follow-up Wilcoxon analyses of significant Condition X Region interactions were conducted to compare the ERP responses to Old and to New faces at each region.

Between task comparisons of ERP Old/New positivity effects were performed using serial t-score values derived from a modified procedure developed by Marchand and colleagues (Marchand, D'Arcy, & Connolly, 2002; Marchand, Lefebvre, & Connolly, 2006). Serial t-scores provide a standardized score representing the difference between ERP waveforms elicited by Old and New faces. Thus the serial t-score values represented the difference between Old and New waveforms at each time point in the ERP, and were used to simplify the interpretation of the between task comparisons. The peak serial t-score values and their corresponding latencies were identified for the time window of both the early frontal and the late parietal ERP Old/New response from each memory test. The RM-ANOVAs for the peak serial t-score values and latencies were performed using a within subjects factor of Task (Short-term, Recent Long-term, Remote Long-term.

ERP data at the individual level of performance was also evaluated using the serial t-score values. This was done to explore the utility of these memory paradigms for identifying significant Old/New positivity effects at the individual level. For each individual the serial t-score from each cranial region was compared to the critical value t-value from the student's t-distribution table. Critical values were determined at the p = .05 level. The degrees of freedom were determined from the number of accepted trials used in computing the serial t-score. This process was repeated for both the early Old/New positivity effect and the late Old/New positivity effect on each of the memory tasks. For each individual, significant peak serial t-score values were coded as present or not present for each region. The frequency of individuals demonstrating a significant Old/New positivity effect in any region was observed.

The early ERP components (Key et al., 2005) have not been regularly compared in the memory ERP literature and were not of primary interest in the present thesis.

However, statistical comparisons of early ERP components were compared for the sake of exploratory interest and are included in Appendix A.

In addition, although the early Old/New positivity effect literature consistently reports ERP responses to Old items as more positive in amplitude than ERP responses to New items, this ‘positivity’ difference has been characterized by both positive going and negative going ERP components during the 250 to 500 ms time period post-stimulus. This thesis focused on the positive going deflection in the waveform. Although not a primary focus of this thesis, the negative going deflection that comes between the early and late positive deflections was also analyzed. The results of the analysis of the negative going deflection during the 400 ms time window can also be found in Appendix C.

2.2 Results

For all analyses, only the results of theoretical importance are discussed.

2.2.1. Behavioural Performances

2.2.1.1 Short-term memory task. Descriptive statistics for the behavioural performance on the short-term memory task are shown in Table 4.

Table 4 Experiment 1 (Honest Response). Behavioural results from the Short-term memory task.

	Accuracy (/100)		**Reaction Time (ms)**	
Effects	Mean	SEM	Mean	SEM
Hits	49.06	0.36	699.22	34.43
Misses	0.71	0.27	522.25	104.79
Correct Rejections	49.12	0.22	747.26	36.38
False Alarms	0.76	0.22	1116.14	142.55
Hit Percentage	98.12%	0.72		
FA Percentage	1.53%	0.44		
Total Correct Percentage	98.18	0.50		

Participants were highly accurate in discriminating between Old and New faces with a total correct accuracy of 98.18% (s.e.m. 0.50). The mean reaction time for Old faces was significantly faster than the reaction time for New faces ($F(1,16) = 14.36$, $p < .05$).

2.2.1.2 Recent Long-term memory task. Descriptive statistics for the behavioural performance on the recent long-term memory task are shown in Table 5.

Table 5 Experiment 1 (Honest Response). Behavioural results from the Recent Long-term memory task.

	Accuracy (/100)		Reaction Time (ms)	
Effects	Mean	SEM	Mean	SEM
Hits	34.47	1.57	1010.05	30.40
Misses	15.29	1.59	1191.88	65.96
Correct Rejections	35.12	1.58	1145.71	55.73
False Alarms	14.82	1.57	1152.53	44.32
Hit Percentage	68.94%	3.14		
FA Percentage	29.65%	3.14		
Total Correct Percentage	69.59%	1.81		

Behavioural performance was lower than expected, with a total accuracy of 69.59% (s.e.m. 1.81). The mean reaction time for identifying Old faces was significantly faster than that for New faces ($F(1,16) = 10.36$, $p < .05$).

2.2.1.3 Remote Long-term Memory Task

Descriptive statistics for the behavioural performance on the remote long-term memory task are shown in Table 6.

Table 6 Experiment 1 (Honest Response). Behavioural results from the Remote Long-term memory task.

	Accuracy (/72)		Reaction Time (ms)	
Effects	Mean	SEM	Mean	SEM
Hits	35.58	0.17	704.16	35.06
Misses	0.41	0.17	867.80	229.10
Correct Rejections	35.90	0.07	756.78	48.43
False Alarms	0.10	0.07	1088.00	320.00
Hit Percentage	98.86%	0.48		
FA Percentage	0.27%	0.19		
Total Correct Percentage	99.29%	0.27		

Participants were highly accurate in discriminating between personally-known and New faces with a total correct accuracy of 99.29% (s.e.m. .27). The mean reaction time for well-known Old faces was significantly faster than the reaction time for New faces ($F(1,16) = 6.67$, $p < .05$).

2.2.1.4 Between Task Comparisons

The Recent Long-term memory task was more difficult than both the Short-term and the Remote Long-term memory tasks. The RM-ANOVA comparison of total correct percentages showed a main effect of task ($F(2,32) = 86.93$, $p < .05$). Bonferroni-adjusted pair-wise comparisons showed that the Recent-long term memory task had a significantly lower hit rate percentage than the other two tasks, which did not differ from each other. Reaction times to correctly judged Old faces (hits) were also significantly different ($F(2,32) = 43.16$, $p < .05$). Bonferroni-adjusted pair-wise comparisons showed that these differences followed a similar pattern with both remote long-term and short-term reaction times to Old faces (hits) being similar and faster than the reaction time on the recent long-term memory task.

2.2.2 Grand Average Waveforms and RM-ANOVA

Time windows for examining ERP components were based upon a visual inspection of the waveforms. Early components observed during the 100 ms time window, 150 ms time window, and the 200 ms time window are reported in Appendix A. Statistical analyses of the ERP responses focused on the early frontal ERP Old/New positivity effect associated with familiarity and on the late parietal ERP Old/New positivity effect associated with recollection. To mimic a state of impaired limited capacity for overt responding, analyses were carried out on ERP waveform averages determined by category (i.e., all Old faces versus all New faces). Category-based averages include all trials in a stimulus category regardless of whether the behavioural response to the trial was correct or incorrect; these comparisons are referred to as category-based in all subsequent discussion. Subsequent analyses on accuracy corrected averages (i.e., averages of correctly identified Old and New faces) were carried out for comparison purposes and these comparisons are referred to as accuracy-based in subsequent discussions.

2.2.2.1 Short-term Memory Task

The grand average waveforms for Old and New faces across the eight cranial regions are shown in Figure 2. Figure 2 presents the waveforms for the stimulus category –based ERP data. The accuracy corrected waveforms are not shown because they are the same. Time windows for the ERP components were identified as follows. The early frontal Old/New positivity effect was identified by visually inspecting the grand average waveforms at the frontal regions for a positive peak in the ERP response between 250 to 450 ms collapsed across all subjects. In the short-term memory task an early frontal Old/New positivity effect was observed between 330 to 430 ms and the mean amplitude during this time period was used for subsequent statistical analyses. The late parietal Old/New response was identified by visually inspecting the grand average waveforms over the parietal regions between 400 to 1000 ms for the largest positive deflection in the ERP responses. In the Short-term memory task, such a peak was observed between 415 to 530 ms. The mean amplitude during this time period was used for subsequent statistical analyses of the late parietal Old/New positivity effect.

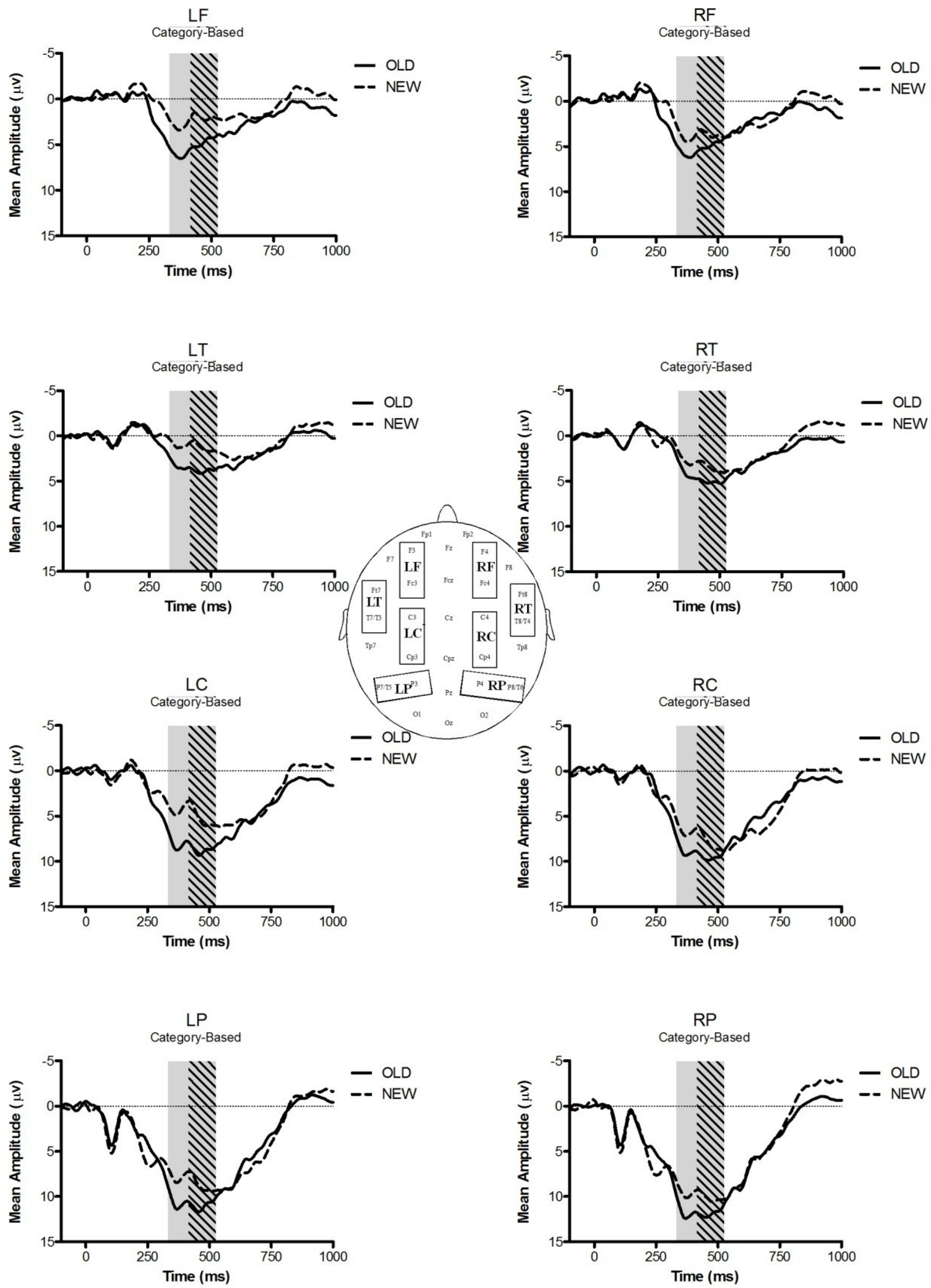

Figure 2 Category-based grand average waveforms across the eight regions for the Short-term Memory Task. Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

2.2.2.1.1 Early Frontal Old/New positivity effect - Mean Amplitude

An early Old/New positivity effect (330 to 430 ms) was visible over frontal, central, and parietal regions (Figure 2). Waveform amplitudes to Old faces were significantly more positive than amplitudes to New faces in the early Old/New time window. The RM-ANOVA for the early frontal Old/New positivity effect (Table 7) showed a main effect of Condition. The main effect of Region was an atheoretical result and indicated that the combined amplitude of the ERP responses, collapsed across condition, varied in its distribution between the different recording regions. A significant Condition X Region interaction was also present.

Table 7 Experiment 1 (Honest Response). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the early Old/New time window (330 to 430 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	19.78	**.000**	26.96	**.000**
REGION (R)	(7,112)	36.06	**.000†**	36.41	**.000†**
C x R	(7,112)	4.14	**.014†**	6.60	**.001†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over all regions, although larger z-scores were observed over left frontal and left central regions (Table 8).

Table 8. Experiment 1 (Honest Response). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the early Old/New window of the Short-term memory task (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-3.39	16/17	.001
LT	-2.82	14/17	.005
LC	-3.20	16/17	.001
LP	-2.68	14/17	.007
RF	-2.72	13/17	.006
RT	-2.15	12/17	.031
RC	-2.82	15/17	.005
RP	-2.58	14/17	.010

The accuracy-based RM-ANOVA showed the same pattern of results as the category-based RM-ANOVA but is not presented in the interest of brevity. In other words, the ERP responses sorted on the basis of category did not significantly differ from those sorted on the basis of category and correct behaviour. Overall, these results demonstrate that Old and New faces presented during the test trials of the Short-term task elicited a significant Old/New effect during the early frontal Old/New time window that has been associated with familiarity.

2.2.2.1.2 Late Parietal Old/New positivity effect – Mean Amplitudes

The peak for the late Old/New positivity effect (415 to 530 ms) was most prominent over central and parietal regions and appeared shortly after the peak for the early Old/New positivity effect (Figure 2). The category-based RM-ANOVA for the mean amplitudes during this time window showed main effects of Condition, Region, and a Condition X Region interaction (Table 9). The main effect of Region was an atheoretical result and indicated that the combined amplitude of the ERP responses, collapsed across condition, varied in its distribution between the different recording regions.

Table 9 Experiment 1 (Honest Response). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the late Old/New time window (415 to 530 ms).

		Category-based		Accuracy-based	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	15.96	**.001**	17.32	**.001**
REGION (R)	(7,112)	39.46	**.000†**	38.78	**.000†**
C x R	(7,112)	6.21	**.000†**	6.94	**.001†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over all regions except the right frontal region. Z-scores over left regions were larger than over right regions, with the largest scores over left temporal and left central regions (Table 10).

Table 10. Experiment 1 (Honest Response). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the late Old/New window of the Short-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-3.01	14/17	.003
LT	-3.39	15/17	.001
LC	-3.48	15/17	.001
LP	-3.01	14/17	.003
RF	-1.87	12/17	.062
RT	-2.53	12/17	.011
RC	-1.97	12/17	.049
RP	-2.44	13/17	.015

The accuracy-based RM-ANOVA results did not differ from the results of the category-based analysis as the ERP responses sorted on the basis of category did not significantly differ from those sorted on the basis of category and correct behaviour. As expected, faces presented during the Short-term task elicited the late parietal Old/New response associated with recollection. These results demonstrate that Old and New faces presented during the test trials of the Short-term task elicited a significant Old/New effect during the late parietal Old/New time window that has been associated with recollection.

2.2.2.2 Recent Long-term Memory Task

The grand average waveforms for Old and New faces across the eight cranial regions are shown in Figures 3 (category-based) and 4 (accuracy-based). Time windows for ERP components were identified as follows. The early frontal Old/New positivity effect was identified by visually inspecting the grand average waveforms at the frontal regions for a positive peak in the ERP response between 250 to 450 ms. In the Recent Long-term memory task a small positive deflection in the ERP waveforms was observed to peak between 250 to 360 ms and the mean amplitude during this time period was used for subsequent statistical analyses of the early frontal Old/New positivity effect. The late parietal Old/New response was identified by visually inspecting the grand average waveforms over the parietal regions between 400 to 1000 ms for the largest positive deflection in the ERP responses. In the Recent Long-term memory task, a slow deflection was observed between 640 to 1000 ms. The mean amplitude during this time period was used for subsequent statistical analyses of the late parietal Old/New positivity effect.

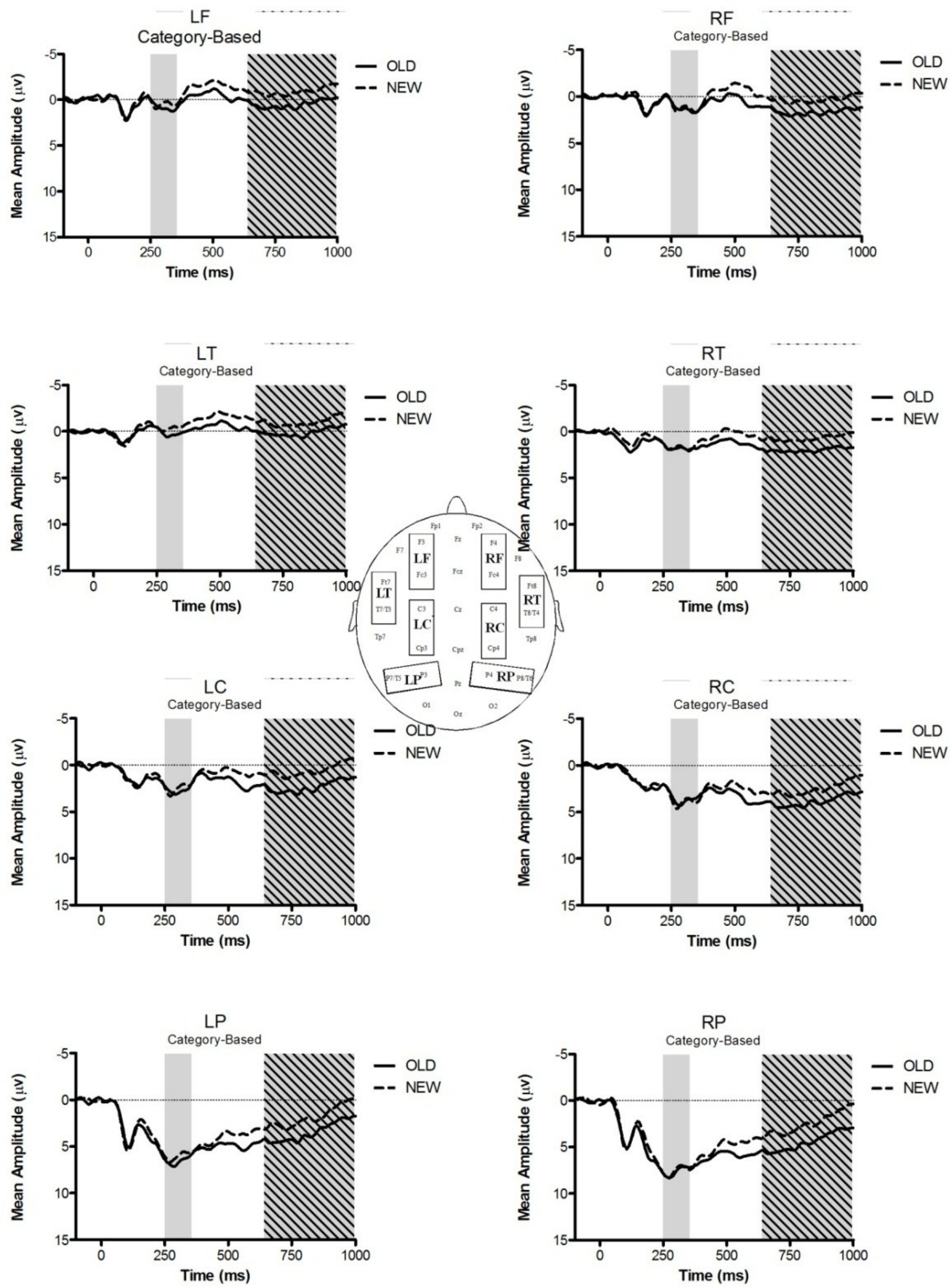

Figure 3 Category-based grand average waveforms across the eight regions for the "Recent" Long-term Memory Task. Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

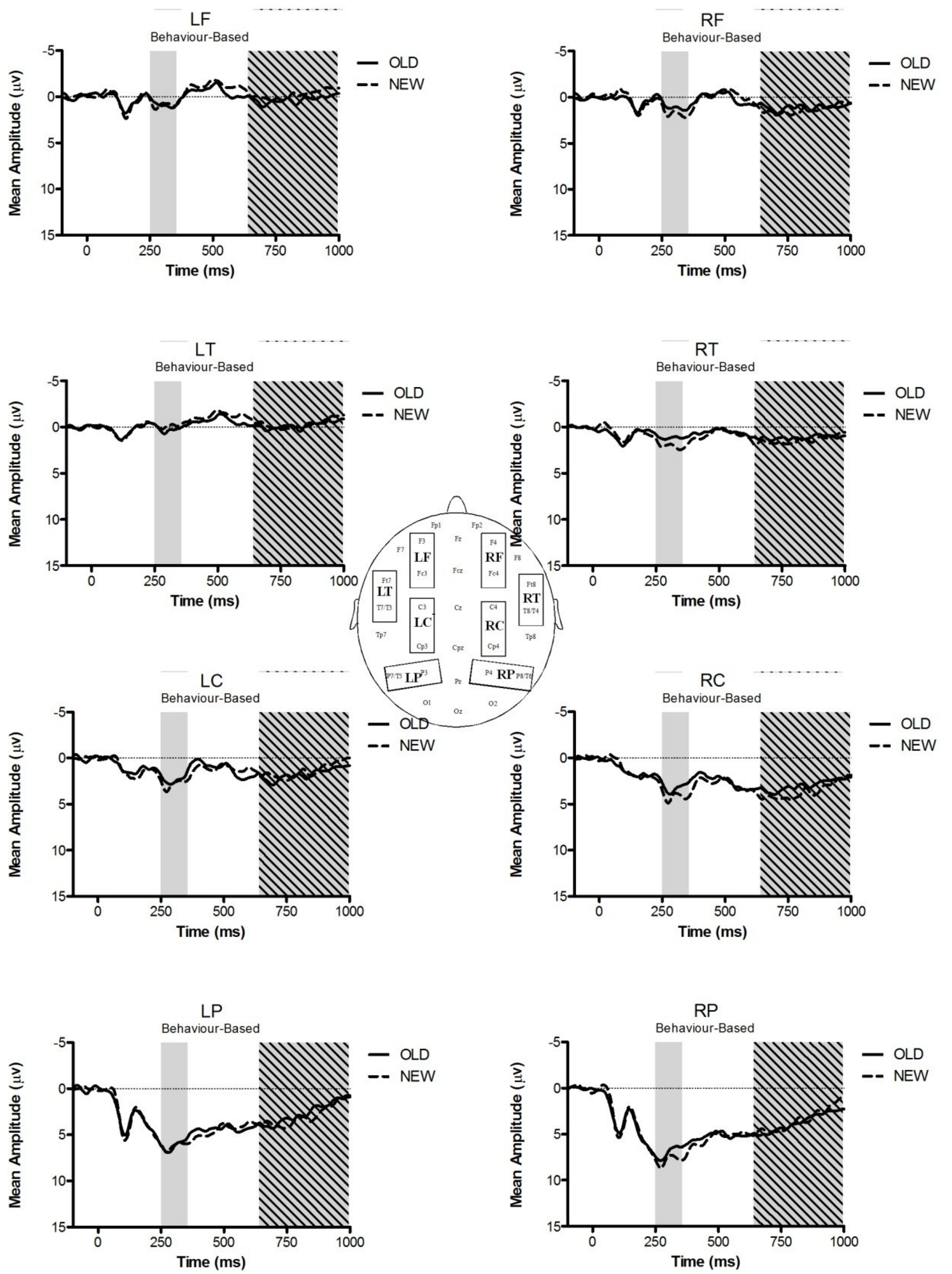

Figure 4 Accuracy-based grand average waveforms across the eight regions for the Recent Long-term Memory Task. Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

2.2.2.2.1 Early Frontal Old/New positivity effect – Mean Amplitudes

Positive deflections in the ERP waveform were observed for both Old and New faces during the early Old/New positivity effect time window (250 to 360 ms) (Figure 3). The RM-ANOVA for the early Old/New window showed no effect of Condition or Condition X Region interaction for the Category-based data (Table 11). Although the effect of Region was significant, this result is of little import. A Wilcoxon signed-rank post-hoc analysis found no participants showed a significant Old/New positivity effect at any region.

Table 11 Experiment 1 (Honest Response). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the early Old/New positivity effect time window (250 to 360 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.27	.61	0.83	.902
REGION (R)	(7,112)	32.58	**.000†**	31.04	**.000†**
C x R	(7,112)	1.19	.326†	3.04	**.034†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The accuracy-based RM-ANOVA differed from the category-based analyses in that a significant Condition X Region interaction resulted from the accuracy-based analyses. A Wilcoxon signed-rank post-hoc analysis showed that responses to New faces were more positive than responses to Old faces over the right temporal region for 13 of 17 participants ($z = -2.34$, $p < .05$); a result that was in the opposite direction than expected. These results suggest that faces presented during the recognition phase of the

Recent Long-term task did not elicit the early frontal Old/New response associated with familiarity.

2.2.2.2.2 Late Old/New positivity effect – Mean Amplitudes

An extended positive deflection was observed in the mean amplitudes during the late Old/New positivity effect time window (640 to 1000 ms) that was greater in amplitude for Old than New faces. The category-based RM-ANOVA showed the mean amplitude for Old faces was significantly more positive than the mean amplitude for New faces during this time window as expected. Although the effect of Region was significant, this result is of little import. However, there was no significant Condition X Region interaction in the category-based analyses (Table 12).

Table 12 Experiment 1 (Honest Response). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the late Old/New positivity effect time window (640 to 1000 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	6.31	**.023**	.002	.963
REGION (R)	(7,112)	9.03	**.000†**	9.16	**.000†**
C x R	(7,112)	1.30	.283†	1.73	.170†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Although the Condition X Region interaction was not significant, a Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region was conducted to provide a comparison for the other tasks. The results showed that responses to Old faces were more positive than responses to New faces over all regions except the left temporal region (Table 13).

Table 13 Experiment 1 (Honest Response). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the late Old/New window of the Short-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-1.97	10/17	.049
LT	-1.73	11/17	.084
LC	-2.20	12/17	.028
LP	-2.06	13/17	.039
RF	-2.06	13/17	.039
RT	-2.53	14/17	.011
RC	-2.11	13/17	.035
RP	-2.58	14/17	.010

The accuracy-based RM-ANOVA differed from the category-based analyses only in that the main effect of Condition was no longer significant. The change in results between the category-based and accuracy-based analyses was unexpected and is evaluated in more detail in the discussion.

2.2.2.3 Remote Long-term Memory Task

The grand average waveforms for Old and New faces across the eight cranial regions are shown in Figure 5. As the accuracy-based waveforms did not differ from the category-based waveforms, they are not shown. Time windows for the ERP components were identified as follows. The early frontal Old/New positivity effect was identified by visually inspecting the grand average waveforms at the frontal regions for a positive peak in the ERP response between 250 to 450 ms. In the Remote Long-term memory task an early frontal Old/New positivity effect was observed between 275 to 375 ms in the ERP responses to New faces but not to the Old (personally relevant). The mean amplitude during this time period was used for subsequent statistical analyses of the early frontal

ERP Old/New positivity effect. The late parietal Old/New response was identified by visually inspecting the grand average waveforms over the parietal regions between 400 to 1000 ms for the largest positive deflection in the ERP responses. In the Remote Long-term memory task, such a peak was observed between 400 to 650 ms. The mean amplitude during this time period was used for subsequent statistical analyses of the late parietal ERP Old/New positivity effect.

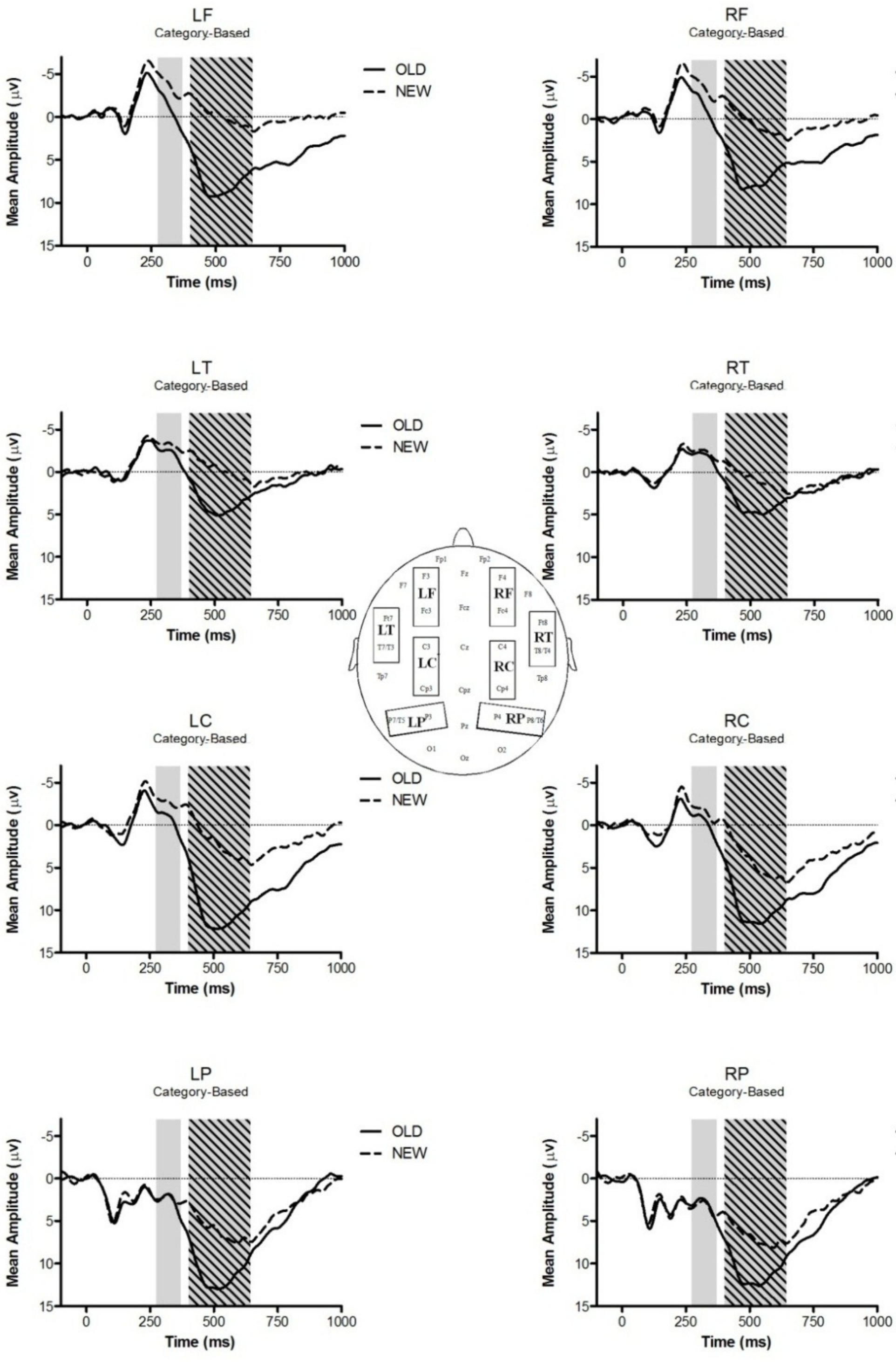

Figure 5 Category-based grand average waveforms across the eight regions for the Remote Long-term Memory Task. Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

2.2.2.3.1 Early Old/New positivity effect – Mean Amplitudes

A small positive deflection during the early Old/New time window (275 to 375 ms) was observed in the waveforms for New faces most prominently over frontal and central regions (Figure 5). The category-based RM-ANOVA for the early Old/New window showed a Condition X Region interaction but no main effect of Condition (Table 14). Although the effect of Region was significant, this result is of little import.

Table 14 Experiment 1 (Honest Response). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the early Old/New time window (275 to 375 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	2.65	.123	3.31	.087
REGION (R)	(7,112)	31.76	**.000†**	32.10	**.000†**
C x R	(7,112)	13.61	**.000†**	13.29	**.000†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive in amplitude than responses to New faces over right frontal, left frontal, and left central regions (Table 15). The results of the accuracy-based analyses were not statistically different from the results of the category-based comparisons. These results demonstrate that Old and New faces presented during the Remote Long-term task elicited a significant Old/New effect during the early frontal Old/New time window that has been associated with familiarity.

Table 15 Experiment 1 (Honest Response). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the early Old/New window of the Remote Long-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-2.96	14/17	.003
LT	-0.83	9/17	.407
LC	-2.30	12/17	.022
LP	-0.50	7/17	.619
RF	-2.77	13/17	.006
RT	-0.50	9/17	.619
RC	-1.25	11/17	.210
RP	-0.97	6/17	.332

2.2.2.3.2 Late Old/New positivity effect - Mean Amplitudes

A pronounced and widely distributed positive deflection was observed during the late Old/New window (400 to 650 ms) (Figure 5). This effect appeared for both Old and New faces, although the ERP response was larger in amplitude for Old faces than for New faces. The category-based RM-ANOVA for the late Old/New window confirmed the main effect of Condition and a significant Condition X Region interaction (Table 16). Although the effect of Region was significant, this result is of little import.

Table 16 Experiment 1 (Honest Response). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the late Old/New time window (400 to 650 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	42.42	**.000**	48.73	**.000**
REGION (R)	(7,112)	26.32	**.000†**	26.49	**.000†**
C x R	(7,112)	17.07	**.000†**	17.46	**.000†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over all regions, with the largest differences observed over the left frontal, left temporal, left central, and right frontal regions (Table 17). The accuracy-based analyses showed statistically similar results to the category-based comparisons and are thus not presented for the sake of brevity.

Table 17 Experiment 1 (Honest Response). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the late Old/New window of the Remote Long-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-3.72	17/17	.000
LT	-3.72	17/17	.000
LC	-3.72	17/17	.000
LP	-3.46	16/17	.001
RF	-3.72	17/17	.000
RT	-2.81	13/17	.009
RC	-3.51	16/17	.001
RP	-3.20	16/17	.002

The Remote Long-term memory task elicited a large ERP Old/New positivity effect. Contrary to expectation, this response was widely distributed across the head and did not show the characteristic maximal response over central-parietal regions. These results suggest that brain activity elicited by the faces from the Remote Long-term task involved neural processing from many areas in the brain.

2.2.2.4 Between Task Comparisons of ERP Old/New positivity effects

Standardized serial t-score curves represent the difference between Old and New ERP waveforms on a point-by-point basis over the duration of the ERP waveform. The peak t-score value and its latency were used to explore differences in magnitude of both the early frontal ERP Old/New and the late parietal ERP Old/New positivity effects between the three different memory tasks.

2.2.2.4.1. Early Frontal Old/New positivity effect

To compare the magnitude of brain activity associated with familiarity, peak t-scores during the early frontal Old/New window over the left frontal region (an expected region for the maximal early frontal ERP Old/New response) were compared from each of the recognition memory tasks. The RM-ANOVA using a within-subjects factors of Task (3 levels) for the mean peak t-score values during the early Old/New time window from each task showed a main effect of Task ($F(2,32) = 11.76$, $p < .05$). The largest early frontal Old/New difference (Short-term task 330 to 430 ms; Recent Long-term task, 250 to 360 ms; Remote Long-term Task, 275 to 375 ms) was observed for the Short-term memory task.

For the main effect of Task, bonferroni-adjusted pair-wise comparisons of the peak t-scores showed that the peak t-scores from the early Old/New positivity effect in the Short-term memory task were significantly larger than those in the Recent long-term memory task, but not the Remote memory task. The early Old/New positivity effect in the Remote Long-term memory task also did not significantly differ from the effect observed in the Recent Long-term memory task. These results suggest that discriminating between Old and New faces from the Short-term and Remote Long-term memory tasks elicited neural processing associated with familiarity to a greater extent than the on the Recent Long-term memory task.

2.2.2.4.2 Late Parietal Old/New positivity effect

To compare the magnitude of brain activity associated with recollection, peak t-scores during the late parietal Old/New window over the left parietal region (an expected region for the maximal late parietal ERP Old/New response) were compared from each of the recognition memory tasks. Differences in the magnitude of the late parietal ERP Old/New response, as measured by the peak serial t-scores, were observed between the three memory tasks for the late Old/New positivity effect. The RM-ANOVA showed a main effect for Task ($F(2,32) = 7.64$, $p < .05$).

Bonferroni-adjusted pair-wise comparisons showed that the late Old/New positivity effect serial t-score value for the Remote Long-term memory task was significantly larger than the serial t-scores for both the Recent Long-term and the Short-term memory tasks, which did not significantly differ from each other. These results suggest that personally-known faces from the Remote Long-term memory task elicited brain activity associated with recollection to a greater extent than the Old faces from the Short-term and Recent Long-term memory tasks.

2.3 Discussion

The purpose of the present experiment was to compare the ERP Old/New recognition memory effects for familiarity and recollection on three different visual recognition memory tasks for faces. The ERP responses of interest were uncorrected for behavioural responses so as to mimic the condition of impaired communication skills; results were also obtained when behavioural correction was employed (i.e., only trials to which the subject responded correctly were included to obtain ERP data for comparison purposes). The three tests included a task of (1) Short-term memory (i.e., the recent past – seconds to minutes), (2) Recent Long-term memory (i.e., several minutes), and (3) Remote Long-term memory (i.e., information from the distant past that was learned months to years before the time of testing). The goals were to (1) explore and compare the ERP differences between the Old and New faces on each task and (2) explore how these Old/New differences compared between short-term, recent long-term, and remote long-term recognition memory. Robust Old/New positivity effects were observed on both the Short-term and Remote Long-term recognition memory tasks. However, contrary to expectation weaker and mixed ERP results were observed on the Recent Long-term memory task. The main results of Experiment 1 are summarized in Table 18 (to be compared with summary of hypothesis for Experiment 1 in Table 1).

Table 18 A summary of the results from Experiment 1. Shaded areas represent the **observed** distribution of category-based ERP Old/New positivity effects, with darker shading to show ERP regions where the effects were maximal. To be compared with Table 1.

Task	Behavioural	ERP Time Window	ERP Old/New Results		Putative Cognitive Component
Short-term	Total Correct 98.18% (s.e.m. 0.50)	Early Frontal Old/New Window (330 to 430 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (415 to 530 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Recent Long-term	Total Correct 69.59% (s.e.m. 1.81)	Early Frontal Old/New Window (250 to 360 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (650 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Remote Long-term	Total Correct 99.29% (s.e.m. 0.27)	Early Frontal Old/New Window (275 to 375 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (400 to 650 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	

With respect to the individual tasks it was hypothesized that Old/New positivity effects would be observed for each task. In particular, it was expected that the late parietal ERP Old/New positivity effect associated with recollection would be observed on each task. As familiarity can also contribute to recognition memory judgments, the early frontal Old/New positivity effect was also examined to explore to what extent this recognition memory process was elicited by each of the tasks. Each of the tasks is discussed below.

2.3.1 Short-term Memory Task

The short-term memory task was designed to be free of intervening stimuli and to have short, but variable, delays of two to five seconds between the study and test phase of each individual trial. Although the test is relatively simple, the instructions for the task (i.e., "some trials may be more difficult than others") were similar in nature to neuropsychological tests of recognition memory that also provide an indication of effort (e.g., the Digit Symbol Test). Given that the late parietal ERP Old/New response has been associated with recollection, it was hypothesized that the ERP responses during the Short-term memory test would be more positive in amplitude to Old faces than to New faces. The presence of brain activity associated with familiarity processing was also explored by examining the early frontal ERP Old/New positivity effect. The ERP responses to Old faces were more positive in amplitude than ERP responses to New faces during both the early and the late Old/New positivity effect time windows.

The category-based ERP responses from the Short-term memory task were statistically similar to the accuracy-based ERP responses. Typically, ERP responses that have been averaged using only correct trials show an enhanced response compared to ERP responses derived from all trials for a particular category of stimulus. In the case of the Short-term memory task, the lack of behavioural-based enhancement to the ERP responses can be explained by the behavioural performance of participants on this task.

Participants were highly accurate on the Short-term memory task resulting in few trials being dropped for the accuracy-based comparison. As a result, ERP responses from the accuracy-based comparison were statistically similar to the category-based comparison.

Although the early frontal ERP Old/New response from the Short-term memory task was widespread across all regions, ERP responses to Old and New faces during the early Old/New time window showed evidence of larger differences over left fronto-central regions as hypothesized. The early ERP Old/New positivity effect from the short-term memory task shared many characteristics with the early Old/New positivity effect associated with familiarity described in the experimental literature (Mecklinger, 2000; Rugg & Curran, 2007; Rugg et al., 1998) including timing, mid-frontal distribution, and ERP responses to Old faces being more positive in amplitude than ERP responses to New faces. Importantly, this finding is consistent with the previous reports of an early frontal Old/New positivity effect in response to faces on a matching task of short-term memory (Barrett et al., 1988).

ERP response differences between Old and New faces during the late Old/New time window were significant across all regions, with evidence of the largest differences over left temporal and left central regions. The distribution and greater effect to Old faces during the late Old/New time window from the short-term memory task were generally in keeping with the late Old/New positivity effect associated with recollection that has been described in experimental ERP studies of recognition memory (Mecklinger, 2000; Rugg & Curran, 2007) including recognition memory for faces (Barrett et al., 1988). The timing of the late Old/New positivity effect in the Short-term task was between 330 and 430 ms and fell within the early range of the typical late Old/New time window (i.e., 250 to 500 ms). However, the "match / mismatch" nature of the discrimination between the study and test faces reduced the difficulty of the discrimination. In general, easier discrimination judgments have been associated with an earlier occurrence of late parietal Old/New positivity effects (Polich & Kok, 1995). The larger positivity of the ERP response over left temporo-central regions during the late Old/New window is consistent with the temporal-central-parietal distribution commonly described in the ERP recognition memory literature, although it was expected that increased involvement of parietal regions would also be observed.

In the present experiment, it is important to note that the largest positive deflections in the ERP responses during the late Old/New time window were observed over parietal regions – but a positive deflection in the ERP response was observed to both Old and New faces. Although the large positive deflection in the ERP response to New faces may appear counterintuitive, it is important to note that "new" faces in this task had been previously viewed during the Recent Long-term memory task. A positive ERP response to New faces is thus consistent with the participants' recollection of the "new" faces having been encountered in the Recent Long-term task. In other words, the advantage of maintaining stimulus consistency between the Recent Long-term and Short-term memory tasks comes with the cost of a confound for the late ERP Old/New response. As a result of the increased positivity to New faces during this window, the ERP response differences to Old and New faces during this time window may underestimate true Old/New positivity effects. A recognition response to the New faces in this task may also underlie the apparent shift to a larger positivity effect over the left temporal-central regions). Together, the early and late Old/New ERP responses from the

Short-term memory task are consistent with the typical ERP studies of recognition memory that support the dual-process models of recognition memory.

It is important that the ERP responses be measurable at the level of the individual participant if this test procedure is to have genuine application within an assessment context. Sixteen of the 17 participants showed a significant early Old/New positivity effect (at left frontal and left central regions) and 15 of the 17 participants showed a significant late Old/New effect (left temporal and left central regions). These results are encouraging and underscore the important potential of ERP responses for studying cognitive function in populations with limited communication ability. In addition, the lack of differences between the category-based and accuracy-based ERP responses becomes particularly relevant from a clinical perspective. This is because the lack of differences indicates that healthy participants will show the Old/New positivity effects regardless of the presence or absence of the ability to respond. Hence, if a subject does not show Old/New positivity effects it is possible that this reflects a pathological state.

2.3.2 Recent Long-Term Memory

The Recent long-term memory task was derived from similar neuropsychological tests of visual recognition memory for faces. This task had been adapted from the Warrington's Recognition Memory Test for Faces by changing a two-alternative-forced-choice response format during the recognition phase of the task to a serial Old/New (Yes/No) format (Connolly & Wang 2000). Serial presentation is also a standard test format used in other published neuropsychological tests of face memory (e.g., Wechsler Memory Scales – Faces, NEPSY - Faces). It had been hypothesized that the ERP responses during this test would show more positive amplitudes to Old faces than to New faces during the 250 to 1000 ms after viewing a face. In particular it had been hypothesized that the ERP responses would show the late parietal ERP Old/New positivity effect (i.e., more positive amplitudes to Old faces than to New faces) associated with recollection. The presence of brain activity associated with familiarity processing was also explored by examining the early frontal ERP Old/New positivity effect. However, no significant Old/New differences were found.

A small and protracted late Old/New positivity effect was observed for the category-based ERP responses that were recorded for both correct and incorrect Old/New choices (Figure 3). These observations of small and late responses are similar to the results from experimental studies of another cognitive ERP component, the oddball P300, wherein increased discrimination difficulty between frequent and rare stimuli results in ERP responses with reduced amplitudes and longer latencies (Picton, 1992).

However contrary to expectation, there was no late parietal Old/New positivity effect in the category-based responses to Old and New faces. The reduction of the late parietal Old/New positivity effect between the category-based and behavior-based ERP responses requires an explanation. Category-based ERP responses are composed of all trials for a class of stimuli (e.g., Old faces), regardless of the behavioural accuracy of identifying a previously seen face. In contrast, accuracy-based ERP responses use only trials to which the correct behavioural response was given to compute the ERP response. Hence, as a general rule in ERP recordings the variance in ERP responses is expected to decrease from category-based ERP responses to accuracy-based ERP responses. In other words, any ERP differences observed in a category-based comparison should be strengthened in when moving to an accuracy-based comparison. This was not the case for the late Old/New time window of the Recent Long-term task in this study. Indeed, a reduced Old/New positivity effect was also observed for the early frontal Old/New time window. In this instance, the category-based ERP responses to Old and New faces were not different from each other. However, the accuracy-based comparison showed an interaction characterized by ERP responses to *New faces* being more positive than the ERP responses to Old faces over the right temporal region, a finding that was opposite to expectation.

The reduction of the Old/New positivity effects in the ERP responses for the recent long-term memory task is indeed perplexing. The diminished accuracy-based ERP response from the recent long-term memory task is most likely related to the decreased behavioural performance on this task. The behavioural accuracy for both hits and correct rejections on this task was approximately 68% compared to chance performance of 50%. At such a low rate of accuracy, even correct choices could often have been lucky guesses thus calling into question the validity of the accuracy corrected ERP responses. As the original Warrington Test was not standardized using a serial presentation format, the behavioural results cannot be directly compared to the standardized norms. The change from forced-choice alternative to yes/no recognition memory has the potential to increase the difficulty of recognition memory for both verbal tasks (Huppert & Piercy, 1976) and faces (Bayley, Wixted, Hopkins, & Squire, 2008; Deffenbacher, Leu, & Brown, 1981). However, the yes/no recognition format remains consistent with other neuropsychological measures of memory for faces such was the Wechsler Memory Scales (WMS-III) Faces subtest (Wechsler, 1997). For example, compared to the Wechsler Memory Scale (3rd edition) – Faces subtest, a Yes/No format recognition memory test with 24 target faces that also has a similar stimulus duration rate during the study phase as the present study (2 seconds), a 68% level of performance would be at borderline to low average levels for the age range of our participants. Shorter stimulus presentation, higher numbers of intervening trials between study and test, and longer delays between study and test phases all increase the difficulty level of a recognition memory task (Levin, 1988; Shepard, 1967). The Recent Long-term memory task in this Experiment was unexpectedly more difficult than desired. That participants were experiencing more difficulty discriminating Old from New faces on this task was evidenced in the similar levels of behavioural responding between hits (68.94%) and correct rejections (70.35%) as well between misses (31.06%) and false alarms (29.65%).

Neurocognitive models of recognition memory, namely familiarity and recollection, may provide a possible, albeit atypical, explanation for the ERP responses for the recent long-term memory task. If the low behavioural accuracy on the recent long-term memory task represents weak recollection (Paller et al., 1999), then the small and protracted category-based ERP response during the late Old/New time window could represent cognitive processing related to familiarity. The category-based ERP response is a composite of both behaviour-correct and -incorrect trials (i.e., hits and misses). Assuming that missed trials were also recognized by the brain as familiar, then removing these trials for the accuracy-based ERP response could result in a loss of statistical power and the observed reduction of the late Old/New positivity effect in the recent long-term memory task (i.e., a type II statistical error). It must also be assumed that participants were relying on recollective judgments (i.e., remembering that a face was previously encountered during the study phase of the test) as the basis for their behavioural responses. Although this was not directly measured in this task, we contend that the task instructions to identify whether or not the face was one of those previously judged as pleasant or unpleasant would bias an individual towards a recollective threshold for decision making. Although considered atypical, the finding of a posterior Old/New positivity effect associated familiarity has been reported before by MacKenzie and Donaldson (2007) as well as by Yovel and Paller (2004).

From a theoretical perspective, the ERP responses from the Recent Long-term memory task support the notion of familiarity-based processing during the late Old/New time window. However, whether or not the Recent Long-term memory ERP responses support a unitary or a dual-process model of recognition memory is unclear. Although the results of the recent long-term memory task are informative from a theoretical perspective, changes in task administration to increase behavioural accuracy (i.e., breaking the task into blocks, reducing the number of items and amount of time between study and test, etc.) would be important for further investigation into the utility of this task in a clinical setting.

2.3.3 Remote Long-term Memory

The third task was designed to assess long-term memory for remote or well-known information. There are very few clinical neuropsychology tasks that assess remote long-term memory due to the methodological issues associated with standardizing the test stimuli. Such tests typically rely on memory of public events or people (i.e., famous people tests, news events tests) or autobiographical measures. Criticisms of these measures include cultural biases and the need for constant updating of stimuli and normative data for public information. Another issue concerns the reliability of information provided through autobiographical questionnaires (i.e., verifying a patient's memories) (Lezak et al., 2004). In the present study, participants supplied their own photographs of people that were well-known to them to be used as Old stimuli. This was done to ensure that the remote memory being tested was specific to each participant, thereby reducing effects related to culture, or exposure. To date, there does not appear to be any previous ERP studies of remote long-term memory using personally-known faces as stimuli.

ERP responses during the Remote Long-term memory test showed both the early frontal ERP Old/New positivity effect and the late parietal ERP Old/New positivity effect. The early Old/New positivity effect was significant over frontal (left and right) and left central regions. This pattern is consistent with the distribution of the early Old/New positivity effects generally described in the ERP recognition memory literature that are associated with familiarity (Mecklinger, 2000, 2006; Schloerscheidt & Rugg, 2004), including ERP studies of recognition memory for faces (Barrett et al., 1988; Paller et al., 1999; Schweinberger et al., 2002).

With respect to the late Old/New time window, a pronounced Old/New positivity effect was observed that was distributed widely across the head. This large Old/New positivity effect is consistent with the high behavioural accuracy demonstrated by participants on this task (Paller et al., 1999). Although the distribution of the late Old/New positivity effect across the head in this experiment was wider than typical, the timing and positivity characteristics are in keeping with the late Old/New positivity effect typically reported on tasks of new learning (i.e., anterograde memory). However, an important difference between the stimuli from the Remote Long-term memory task and stimuli from typical ERP studies of recognition memory is the use of personally relevant faces as stimuli. Memory for a personally relevant face involves processing beyond the simple detection of the structural features of someone's face. Linked with that image is an overabundance of information including name, physical characteristics, emotional characteristics, and details of interpersonal interactions with the individual. Paller and colleagues have demonstrated activation over distributed cortical networks associated even with the retrieval of limited face-specific background information of recently learned faces (Paller et al., 2003). On average, the Old faces in the Remote Long-term task in this experiment had been known for over eight years and eight months, a considerable amount of time to accumulate person-specific information about the Old faces used in our experiment. The widespread distribution of the late Old/New positivity effect in this experiment most likely reflects the automatic retrieval of a rich neural network of person-specific information associated with the well-known faces in the present study.

This task was also capable of demonstrating Old/New positivity effects at the individual level. During the early Old/New time window, 14 of 17 participants showed a significant Old/New positivity effect at the left frontal region. During the late Old/New time window all 17 participants showed a significant Old/New positivity effect at left and right frontal regions, left temporal, and left central regions. This finding is particularly important given the previously described limitations of current neuropsychological measures of remote memory.

2.3.4 Between Task Comparisons

An important goal of this experiment was to compare the ERP Old/New positivity effects between different types of recognition memory tasks. Peak standardized difference scores between Old and New ERP responses were used to compare the magnitude of the ERP Old/New positivity effects across the different tasks. The magnitude of the early Old/New positivity effect was shown to differentiate the memory tasks with high behavioural accuracy (i.e., Short-term and Remote Long-term tasks) from the task with low behavioural accuracy (i.e., Recent Long-term memory task) over the left/right frontal and left central regions. However, the magnitude of the early Old/New positivity effect did not differentiate the Short-term and Remote Long-term tasks from each other.

Similar to the early Old/New window, the magnitude of the late Old/New positivity effect did not differentiate each of the three types of recognition memory tests from each other. However, in this experiment, the differences in magnitude were not related to memory performance. Instead, the magnitude of the late Old/New positivity effect from the Remote Long-term task was significantly larger than the effects observed in both the Short-term and the Recent Long-term tasks (which did not significantly differ from each other). This result is in keeping with the notion of widespread activation of various memory networks for the additional person specific information that is associated with well-known faces. Further, this result suggests a possible dimension for differentiating between neural processing associated with new learning and recent memory versus remote long-term memory.

The observed early frontal ERP Old/New and late parietal ERP Old/New positivity effects in the present study were generally consistent with Old/New positivity effects previously reported for recognition memory tasks; the waveform associated with Old faces was significantly more positive than the waveform associated with New faces. The present results provide a novel examination of the ERP correlates of remote long-term recognition memory and suggest that similar electrophysiological mechanisms are mediating both new learning and memory and remote recognition memory, despite the evidence for differing neuroanatomical substrates.

As a note, Old/New differences between the early sensory components (i.e. 100 ms and 150 ms time windows) of the ERP responses to Old and to New faces were not expected or observed on the Recognition memory tasks in Experiment 1. See Appendix 2 for more detailed analyses of these time windows.

CHAPTER 3 EXPERIMENT 2

Within the last 15 years research into behavioural methods for detecting neurocognitive malingering has intensified as evidenced by several volumes of work dedicated to this topic (for examples, Boone, 2007; Hall & Poirier, 2000; Horton & Hartlage, 2003; Morgan & Sweet, 2009; Rogers, 1997). Although the number of studies is limited, cognitive ERP recordings have been studied and promoted as a means of detecting neurocognitive malingering (Ellwanger et al., 1999b; Tardif et al., 2000; Tardif et al., 2002; Vagnini et al., 2008). ERP studies of neurocognitive malingering have examined ERP responses on tasks of Short-term memory (Ellwanger, Rosenfeld, Hankin, & Sweet, 1999a; Rosenfeld, Sweet, Chuang, Ellwanger, & Song, 1996), Recent long-term memory (Tardif et al., 2000; Tardif et al., 2002; Vagnini et al., 2008), and autobiographical Remote Long-term memory (for example, birthdate, phone number) (Ellwanger, Rosenfeld, Sweet, & Bhatt, 1996; Ellwanger et al., 1999b; Rosenfeld, Ellwanger, & Sweet, 1995). In addition, these studies have included adaptations of standardized neuropsychological tests such as the match-to-sample Digit Recognition Memory Test (Ellwanger et al., 1999a; Rosenfeld et al., 1996), and Warrington Recognition Memory Test – Words (Tardif et al., 2000; Tardif et al., 2002).

However, ERP recognition memory Old/New positivity effects were only directly examined in some studies (Tardif et al., 2000; Tardif et al., 2002; Vagnini et al., 2008) In the series of studies by Ellwanger et al. (1996,1999) and Rosenfeld et al. (1995), recognition memory ERP Old/New positivity effects were confounded with the oddball P300 response. As discussed in the general introduction, this confound of ERP responses poses a problem for interpretation in the context of Old/New memory effects. While these studies have highlighted the potential use of ERP recordings in the context of neurocognitive malingering, a systematic comparison of recognition memory ERP responses on different types of recognition memory tasks under conditions of neurocognitive malingering has not been conducted. Such a comparison is important for understanding the contribution of ERP recognition memory Old/New positivity effects to the study of neurocognitive malingering.

The purpose of the present experiment was to compare the Old/New ERP effect for different types of recognition memory tasks using the same category of stimuli in three different experiments. The three visual recognition memory tasks for faces were the same as those used in Experiment 1: (1) the Short-term recognition memory task (short-term memory); (2) the Recent Long-term memory task, a more demanding recognition memory task that includes interference between study and test phases; and (3) the Remote Long-term recognition memory task.

This second experiment sought to build on the results of the first experiment by examining the influence of neurocognitive malingering on the ERP differences (or lack of differences) identified in Experiment 1. Specifically, this experiment sought to examine the ERP responses to Old and New faces on tasks of Short-term recognition memory, Recent Long-term recognition memory, and Remote Long-term recognition memory from individuals who were provided with a monetary incentive to feign a memory impairment.

The hypotheses for Experiment 2 were summarized previously in Table 2. With respect to behavioural accuracy, it was hypothesized that the malingering participants in this study would have total accuracy scores (Hits + Correct Rejections) well below those observed in Experiment 1, and well below 90% (a criteria commonly used in similar tests of symptom validity – e.g., TOMM (Tombaugh, 1997); DMT(Prigatano & Amin, 1993)) on all three recognition memory tests for faces. Similar to Experiment 1, it was hypothesized that ERP Old/New differences would be observed for each task, with responses to Old faces being more positive than responses to New faces, regardless of participants' behavioural accuracy. In particular, a late parietal ERP Old/New positivity effect associated with recollection was expected over central-parietal regions for each of the tasks as this Old/New positivity effect has been associated with Old stimuli that have been correctly recognized as Old. If familiarity processing also contributes to recognition memory performance on the memory tasks in this study, an early frontal ERP Old/New positivity effect would also be expected, with a maximal response over frontal regions. Differences in response magnitude were also compared across tasks to explore how the early frontal ERP Old/New and the late parietal ERP Old/New positivity effects differed or were similar to each other.

3.1 Methods

3.1.1 Participants

Twenty new participants were recruited and screened in the same manner as Experiment 1. Two of the participants had an insufficient number of artefact free trials following electrooculogram (EOG) artefact rejection and were excluded from further analyses. The final sample of 18 participants (9 females, 9 males) had a mean age of 25.9 (s.e.m. = 0.7, range = 20-32) years. Seventeen participants were right-handed, and 1 was ambidextrous as measured by the Edinburgh Handedness Questionnaire (Oldfield, 1971).

3.1.2 Stimuli, Tasks, Materials and Recording Procedures

The stimuli, tasks, materials and recording procedures used in Experiment 2 were the same as those used in Experiment 1. The personally-known faces for the Remote Long-term task were known for an average of 119.5 ± 19.7 (s.e.m.) months.

3.1.3 Task Instructions

The task instructions for each test used in Experiment 2 were identical to the instructions from Experiment 1, with one exception. The participants in Experiment 2 were instructed to feign a memory impairment during their performance of the recognition memory tests. At the beginning of the testing session each participant in Experiment 2 was given the following additional instructions that are similar to those used in previous studies of neurocognitive malingering (for example Suhr & Gunstad, 2000):

> We would like you to imagine that you have been involved in an accident during which you sustained mild to moderate head injury. Imagine that

> although you feel fine now, you are currently involved in legal action where your claim will be substantially increased should you be found to have memory impairments. As part of the legal proceedings you will be undergoing neuropsychological testing to investigate the existence and extent of any possible memory impairments. Part of that testing may contain memory tasks such as those you will perform today. During the testing today I want you to perform on these tasks as if you had a memory impairment resulting from a brain injury. Should you display a convincing performance on these memory tests you will be rewarded with an additional $30 dollars for your participation, representative of your increased insurance settlement.

Participants in Experiment 2 were not made aware that they would be asked to feign a memory impairment until the day of the ERP recording. Providing this information during the initial consent process would have provided opportunity for participants to research the nature of memory impairments following a brain injury and/or practice behavioural strategies for “impaired” memory. Although such practice and coaching effects are of empirical interest, they were not a primary focus of this study and represented potential confounds. Upon providing this additional information about the study, participants’ consent to participate was obtained again in order to be certain that they were comfortable with this experimental manipulation. Participants who might have objected to the idea of feigning a memory impairment were provided the opportunity to withdraw without forfeiture of compensation. No participants chose to withdraw from the study as a result of the additional information.

3.1.4 Statistical Analyses and Comparisons

The statistical analyses and comparisons used in Experiment 2 were the same as those used in Experiment 1.

3.2 Results

3.2.1 Behavioural Performances

3.2.1.1 Short-term memory task. Descriptive statistics for the behavioural performance on the Short-term memory task are shown in Table 19.

Table 19 Experiment 2 (Simulated Memory Malingering). Behavioural results from the Short-term memory task.

	Accuracy (/100)		**Reaction Time (ms)**	
Effects	Mean	SEM	Mean	SEM
Hits	31.67	2.76	1184.53	79.82
Misses	18.11	2.76	1280.57	101.48
Correct Rejections	34.67	2.97	1299.56	108.43
False Alarms	15.00	2.98	1116.14	103.11
Hit Percentage	63.33%	5.53		
FA Percentage	30.00%	5.97		
Total Correct Percentage	66.33%	5.41		

Participants discriminated between Old and New faces with a total correct accuracy of 66.33% (s.e.m. 5.41). The mean reaction times to Old and New faces were not significantly different from each other. As expected, total correct accuracy was below 90%.

3.2.1.2 Recent Long-term memory task. Descriptive statistics for the behavioural performance on the Recent Long-term memory task are shown in Table 20.

Table 20 Experiment 2 (Simulated Memory Malingering). Behavioural results from the Recent Long-term memory task.

	Accuracy (/100)		Reaction Time (ms)	
Effects	Mean	SEM	Mean	SEM
Hits	20.17	2.09	1168.98	60.04
Misses	29.78	2.08	1150.63	70.67
Correct Rejections	33.56	2.73	1168.29	66.00
False Alarms	16.17	2.69	1186.64	51.84
Hit Percentage	40.33%	4.18		
FA Percentage	32.33%	5.39		
Total Correct Percentage	53.72%	3.49		

As expected, participants performed below 90% accuracy at discriminating between Old and New faces. Total correct accuracy was effectively at chance level. The mean reaction time for identifying Old faces was not significantly different from the reaction time for New faces.

3.2.1.3 Remote Long-term memory task. Descriptive statistics for the behavioural performance on the Remote Long-term memory task are shown in Table 21.

Table 21 Experiment 2 (Simulated Memory Malingering). Behavioural results from the Remote Long-term memory task.

	Accuracy (/72)		Reaction Time (ms)	
Effects	Mean	SEM	Mean	SEM
Hits	16.61	2.87	1038.62	70.56
Misses	19.38	2.87	1036.47	73.76
Correct Rejections	30.60	2.15	1022.25	84.56
False Alarms	5.40	2.15	1134.71	92.04
Hit Percentage	46.16%	7.97		
FA Percentage	15.00%	5.97		
Total Correct Percentage	65.58%	5.97		

Participants correctly identified well-known faces at chance levels but were more accurate for New faces with a mean total correct accuracy of 65.58% (s.e.m. 5.97). The mean reaction time for well-known faces was not statistically different from the reaction time for New faces. Total accuracy was below 90% as hypothesized.

3.2.1.4 Between task comparisons. The malingering participants demonstrated <90% accuracy on all three memory tasks. An RM-ANOVA comparison of total correct percentages showed that the total correct percentage on the Short-term memory and the Remote Long-term memory tasks did not statistically differ from each other, but were both significantly higher than the total correct percentage score on the Recent Long-term memory task. Reaction times to Old faces (hits) were statistically similar across all three tasks.

Although the total correct accuracy scores were all below 90% on each task, the total accuracy scores on the Short-term and Remote Long-term tasks were still above chance. The chance level total accuracy score from the Recent Long-term task suggests that the malingering participants were possibly using a different response strategy on this task, were having more difficulty discriminating between Old and New faces on this task, or a combination of both. However, an inspection of the false alarm percentage scores from the three tasks shows similar rates of false alarms on the Recent Long-term and the Remote Long-term tasks. This observation suggests the notion that the ability of the malingering participants to feign a memory problem on the Recent Long-term task was influenced by their ability to discriminate between the Old and New faces. In other words, they could only malinger to items they actually recognized as being Old or New.

3.2.2 Grand Average Waveforms and RM-ANOVA

Statistical analyses of the ERP responses focused on the early frontal ERP Old/New positivity effect associated with familiarity and on the late parietal ERP Old/New positivity effect associated with recollection. The identification of time windows in the average ERP waveforms for subsequent analysis was done in the same manner as for Experiment 1.Analyses of early components observed during the 100 ms time window, 150 ms time window, and the 200 ms time window are reported in Appendix B. Given that participants were instructed to feign a memory impairment, the behaviour-corrected ERP responses are uninterpretable and are not used.

3.2.2.1. Short-term memory task. In the short-term memory task an early frontal Old/New positivity effect was visually observed over the frontal regions between 290 to 390 ms and the mean amplitude during this time period was used for subsequent statistical analyses. A late parietal ERP Old/New positivity effect was visually observed over the parietal regions between 415 to 515 ms. The mean amplitude during this time period was used for subsequent statistical analyses of the late parietal ERP Old/New positivity effect. The grand average waveforms for Old and New faces across the eight regions from the Short-term memory task are shown in Figure 6.

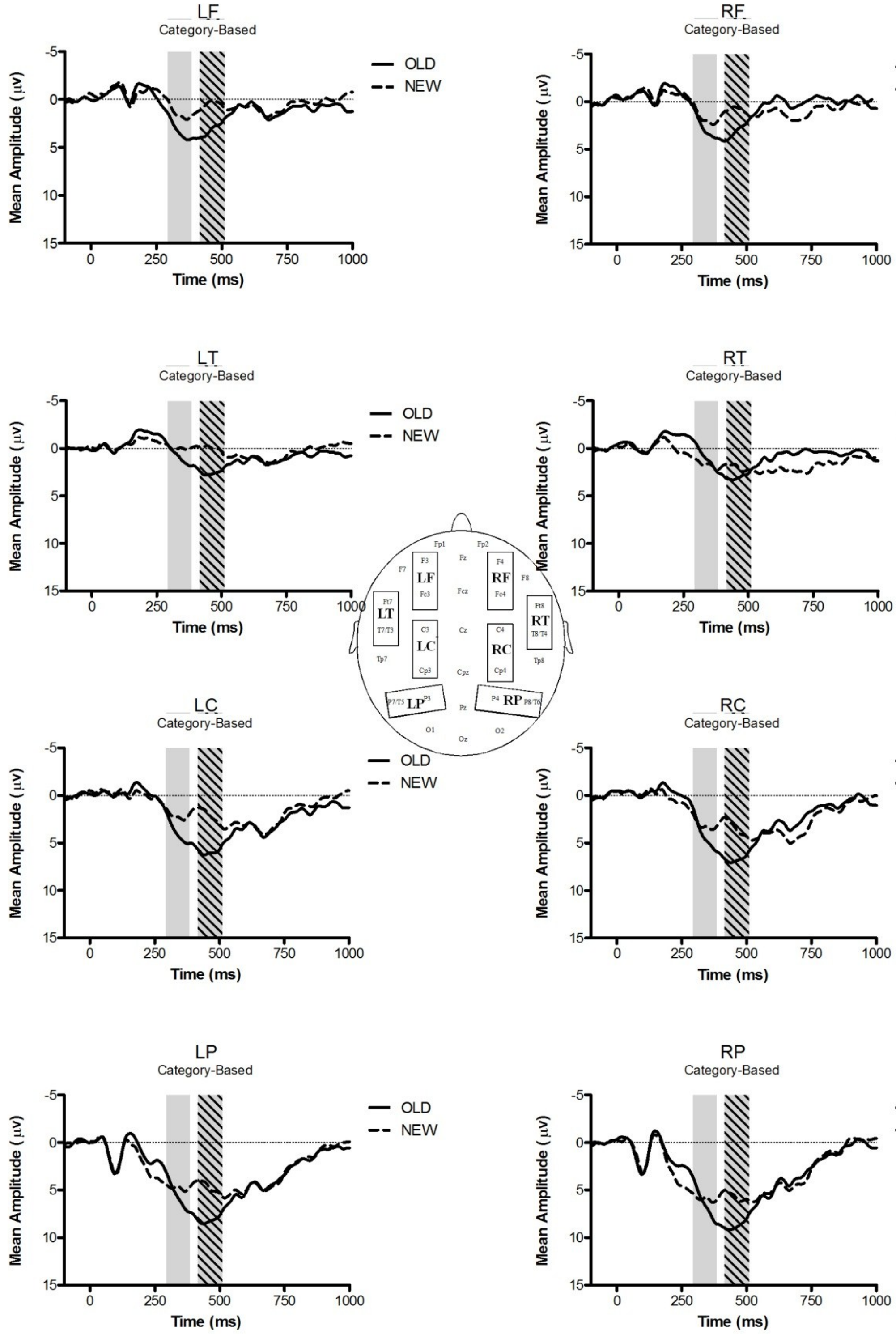

Figure 6 Category-based grand average waveforms across the eight regions for the Short-term Memory Task (Malingering). Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

3.2.2.1.1 Early frontal Old/New positivity effect - mean amplitude. To the extent that neural processing associated with familiarity was contributing to performance on the Short-term memory task, the ERP response to Old faces was expected to be more positive in amplitude than the ERP response to New faces during this time window. The category-based RM-ANOVA for the early Old/New positivity effect showed a main effect for Region and the hypothesized Condition X Region interaction, but no main effect of Condition (Table 22).

Table 22 Experiment 2 (Simulated Memory Malingering). Results from the Short-term Memory task for the category-based RM-ANOVA analysis RM-ANOVA analyses of mean amplitudes during the early Old/New time window (290 to 390 ms).

		Category-based	
Effects	Df	F	*P*
CONDITION (C)	(1,17)	1.85	.192
REGION (R)	(7,119)	24.32	**.000†**
C x R	(7,119)	4.03	**.013†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over the left frontal and left central regions (Table 23).

Table 23 Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the early Old/New window of the Short-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-2.29	14/18	.022
LT	-1.68	13/18	.094
LC	-2.16	13/18	.031
LP	-1.15	11/18	.248
RF	-1.46	11/18	.145
RT	-0.02	10/18	.983
RC	-1.37	12/18	.170
RP	-0.68	10/18	.500

These results suggest that the test faces from the Short-term memory tasks ellicted an ERP Old/New effect during the early frontal time window associated with familiarity.

3.2.2.1.2 Late parietal Old/New positivity effect – mean amplitudes. ERP responses to Old faces were expected to be more positive in amplitude than ERP responses to New faces during the late parietal ERP Old/New window. A positive deflection in ERP waveforms was observed for both Old and New faces during the late Old/New window, but was most prominent and widely distributed across recording regions in the waveforms for Old faces (Figure 6). The category-based RM-ANOVA for the late Old/New positivity effect showed the hypothesized main effect of Condition, Region, and the hypothesized Condition X Region interaction (Table 24).

Table 24 Experiment 2 (Simulated Memory Malingering). Results from the Short-term Memory task for the category-based RM-ANOVA analysis of mean amplitudes during the late Old/New time window (415 to 515 ms).

		Category-based	
Effects	Df	F	*P*
CONDITION (C)	(1,17)	15.95	**.001**
REGION (R)	(7,119)	33.28	**.000†**
C x R	(7,119)	4.69	**.006†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over all regions, although the largest z-scores were observed over left temporal, left central, and left parietal regions (Table 25).

Table 25 Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the late Old/New window of the Short-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-2.81	15/18	.005
LT	-3.38	15/18	.001
LC	-3.46	17/18	.001
LP	-3.33	16/18	.001
RF	-2.24	14/18	.025
RT	-1.94	15/18	.053
RC	-2.94	16/18	.003
RP	-3.07	16/18	.002

The ERP results suggest that neural processing associated with recollection was observed on the Short-term memory task, in spite of participants' attempts to feign a memory impairment.

3.2.2.2 Recent Long-term memory task. The grand average waveforms for Old and New faces across the eight regions are shown in Figure 7. Time windows for ERP components were identified as follows. The early frontal Old/New positivity effect was identified by visually inspecting the grand average waveforms at the frontal regions for a positive peak in the ERP response between 250 to 500 ms. In the Recent Long-term memory task a small positive deflection in the ERP waveforms was observed to peak between 320 to 370 ms and the mean amplitude during this time period was used for subsequent statistical analyses of the early frontal Old/New positivity effect. The late parietal Old/New response was identified by visually inspecting the grand average waveforms over the parietal regions between 400 to 1000 ms for the largest positive deflection in the ERP responses. In the Recent Long-term memory task, a slow deflection was observed between 600 to 1000 ms. The mean amplitude during this time period was used for subsequent statistical analyses of the late parietal Old/New positivity effect.

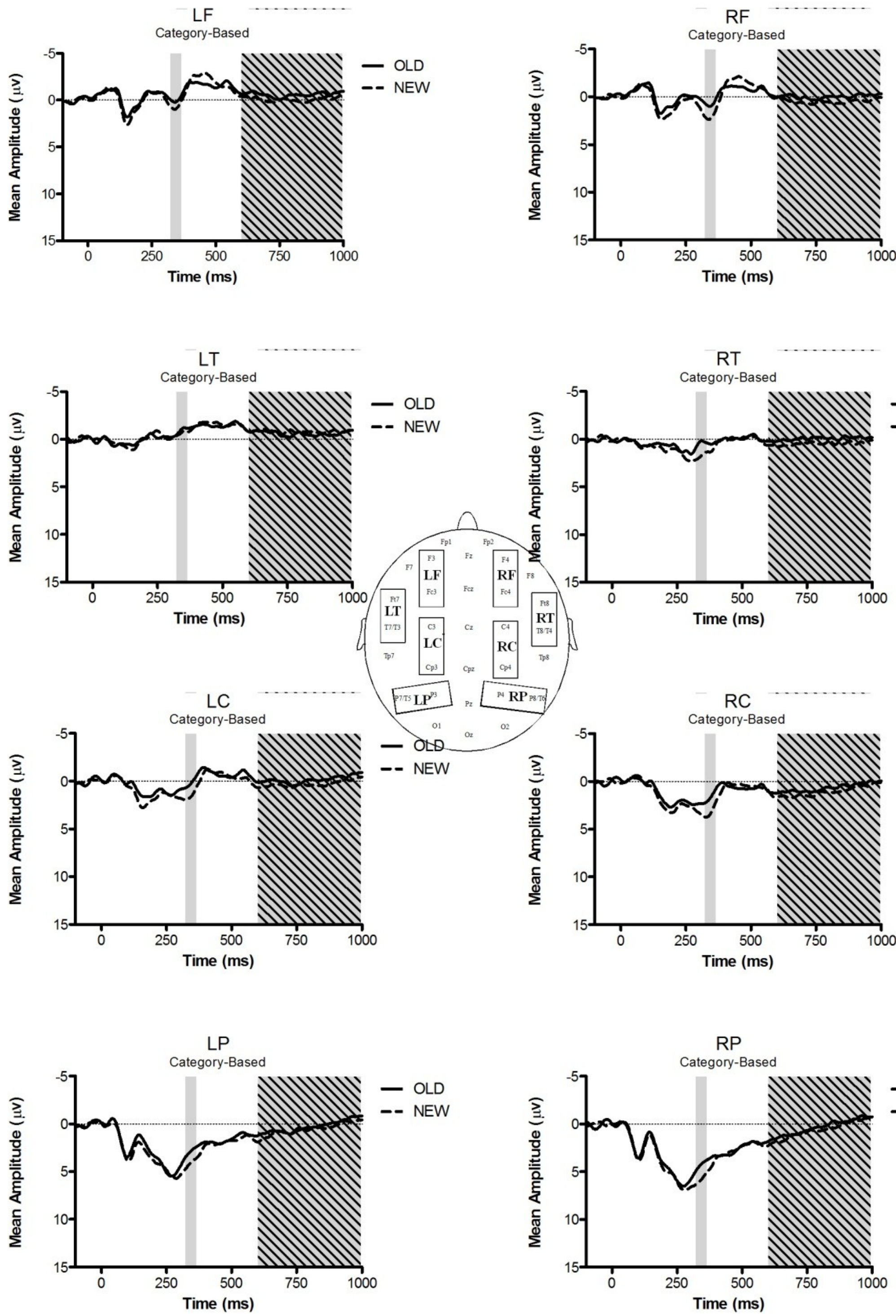

Figure 7 Category-based grand average waveforms across the eight regions for the Recent Long-term Memory Task (Simulated Memory Malingering). Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

3.2.2.2.1 Early frontal Old/New positivity effect – mean amplitudes. To the extent that neural processing associated with familiarity was contributing to performance on the Recent Long-term memory task, the ERP response to Old faces was expected to be more positive in amplitude than the ERP response to New faces. However, the category-based RM-ANOVA for the early Old/New positivity effect showed only an effect of Region; there was no evidence of the hypothesized main effect of Condition or the hypothesized Condition X Region interaction (Table 26).

Table 26 Experiment 2 (Simulated Memory Malingering). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the early Old/New positivity effect time window (320 to 370 ms).

		Category-based	
Effects	Df	F	*P*
CONDITION (C)	(1,17)	2.44	.137
REGION (R)	(7,119)	20.97	**.000†**
C x R	(7,119)	2.29	.089†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Although the Condition X Region interaction was not significant, for consistency with previous ERP analyses in this thesis, a Wilcoxon signed-rank post-hoc analysis was used to compare the mean amplitude of ERP responses to Old and to New faces at each region. There were no significant differences in ERP responses to Old and to New faces at any region (Table 27).

Table 27 Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the early Old/New window of the Recent Long-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	z-score	*n*	*P*
LF	-0.33	8/18	.744
LT	-0.20	10/18	.845
LC	-0.98	6/18	.327
LP	-0.76	9/18	.446
RF	-1.29	7/18	.119
RT	-1.59	6/18	.112
RC	-1.15	7/18	.248
RP	-1.55	7/18	.122

The ERP responses during the early frontal ERP Old/New time window did not differentiate between Old faces and New faces, contrary to what was expected. This result suggests that the malingering participants were able to suppress neural processing associated with familiarity or alternatively that familiarity was insufficient to discriminate between Old and New faces on the Recent Long-term memory task.

3.2.2.2.2 Late Parietal Old/New positivity effect - Mean Amplitudes. ERP responses to Old faces were expected to be more positive in amplitude than ERP responses to New faces during the late parietal Old/New time window. A long positive deflection of small magnitude can be observed in the mean amplitudes of the frontal and central regions during the late Old/New positivity effect time window for both Old and New faces (Figure 7). However, the category-based RM-ANOVA failed to find any significant effects or interactions (Table 28).

Table 28 Experiment 2 (Simulated Memory Malingering). Results from the Recent Long-term Memory task for the category-based RM-ANOVA analysis during the late Old/New positivity effect time window (600 to 1000 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.11	.746
REGION (R)	(7,119)	1.86	.149†
C x R	(7,119)	0.92	.438†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Again, although the Condition X Region interaction was not significant, for consistency with previous ERP analyses in this thesis, a Wilcoxon signed-rank post-hoc analysis was used to compare the mean amplitude of ERP responses to Old and to New faces at each region (Table 29).

Table 29 Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the late Old/New window of the Recent Long-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-0.33	9/18	.744
LT	-1.33	10/18	.184
LC	-0.11	9/18	.913
LP	-0.59	10/18	.557
RF	-0.02	9/18	.983
RT	-0.15	11/18	.879
RC	-0.07	10/18	.948
RP	-0.46	9/18	.647

Contrary to expectations, discriminating between Old and New faces by the malingering participants did not elicit the expected late parietal ERP Old/New response associated with recollection. This result suggests that the malingering participants were able to suppress the late parietal Old/New response or alternatively that processing associated with recollection was insufficient to discriminate between Old and New faces on the Recent Long-term memory task. This result is discussed further in Chapter 4.

3.2.2.3 Remote Long-term memory task. The grand average waveforms for Old and New faces across the eight regions are shown in Figure 8. The early frontal Old/New positivity effect was identified by visually inspecting the grand average waveforms at the frontal regions for a positive peak in the ERP response between 250 to 500 ms. In the Remote Long-term memory task a positive going deflection in the ERP waveforms was observed between 285 to 385 ms to New faces but not to the Old (personally-known). The mean amplitude during this time period was used for subsequent statistical analyses of the early frontal ERP Old/New positivity effect. The late parietal Old/New response was identified by visually inspecting the grand average waveforms over the parietal regions between 400 to 1000 ms for the largest positive deflection in the ERP responses. In the Remote Long-term memory task, such a peak was observed between 425 to 675 ms. The mean amplitude during this time period was used for subsequent statistical analyses of the late parietal ERP Old/New positivity effect.

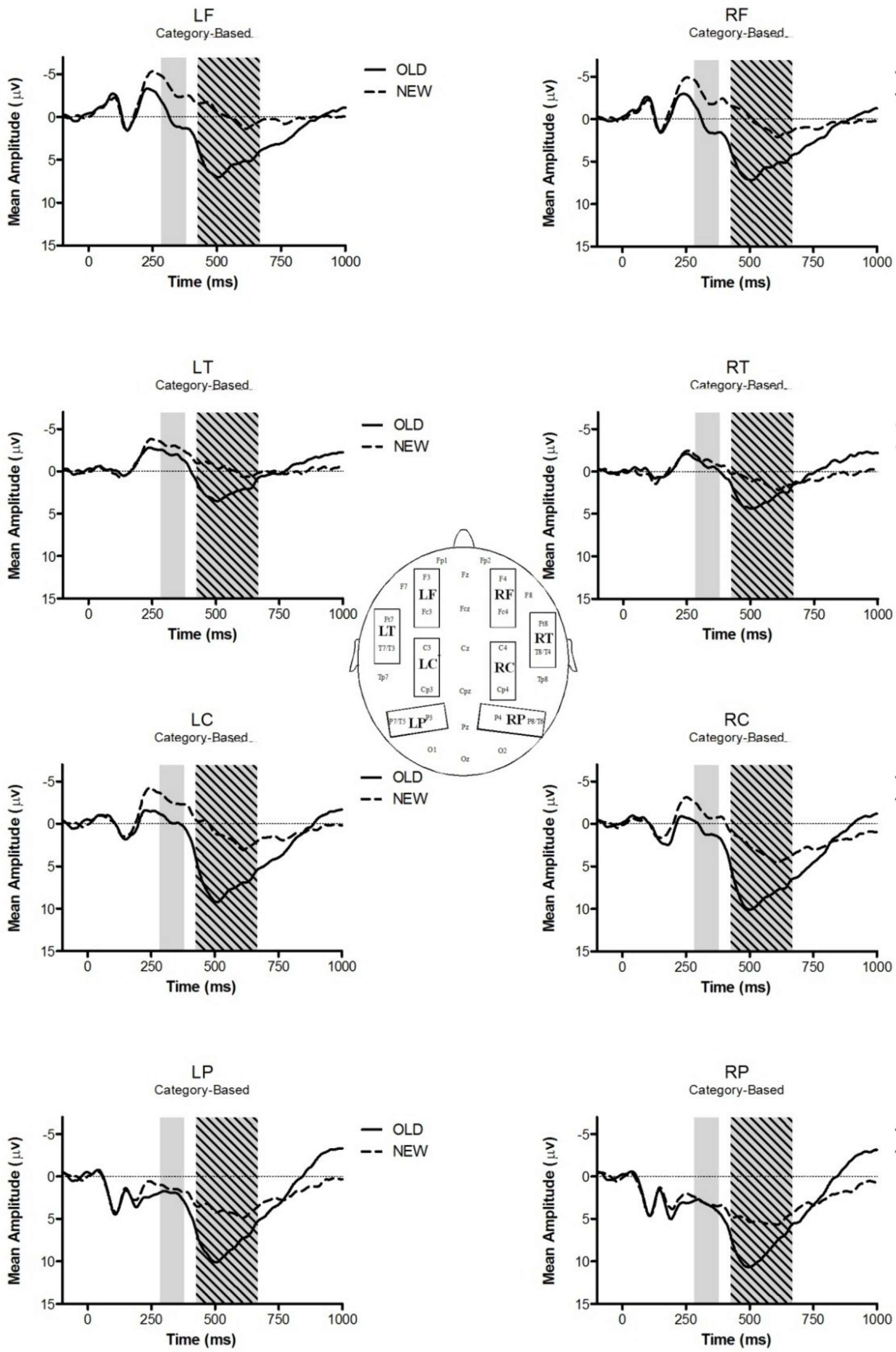

Figure 8 Category-based grand average waveforms across the eight regions for the Remote Long-term Memory Task (Simulated Memory Malingering). Shadings represent the early frontal Old/New time window (light solid) and the late parietal time window (dark hatched) selected for ERP analysis.

3.2.2.3.1 Early frontal Old/New positivity effect – mean amplitudes. Neural processing associated with familiarity was explored by examining the ERP responses to Old and to New faces during the early frontal ERP Old/New time window. To the extent that familiarity processing was contributing to performance on the Remote Long-term task, ERP responses to Old faces were expected to be more positive in amplitude than ERP responses to New faces. A small positive deflection during the early Old/New time window was most prominent over frontal regions with New faces showing a more defined deflection than Old faces (Figure 8). The category-based RM-ANOVA did not show the hypothesized main effect of Condition, however it did show an effect of Region and the hypothesized Condition X Region interaction (Table 30).

Table 30 Experiment 2 (Simulated Memory Malingering). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the early Old/New time window (285 to 385 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	4.08	.059
REGION (R)	(7,119)	17.32	**.000†**
C x R	(7,119)	15.51	**.000†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over right frontal, left frontal, right central, and left central regions (Table 31) – consistent with prior work.

Table 31 Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the early Old/New window of the Remote Long-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***n***	***P***
LF	-3.33	15/18	.001
LT	-1.11	10/18	.267
LC	-2.11	12/18	.035
LP	-0.15	9/18	.879
RF	-3.16	14/18	.002
RT	-0.46	10/18	.647
RC	-1.98	11/18	.048
RP	-0.15	9/18	.879

These results suggest that neural processing associated with recollection was observed on the Remote Long-term memory task, in spite of participants' attempts to feign a memory impairment.

3.2.2.3.2 Late parietal Old/New positivity effect - mean amplitudes. ERP responses to Old faces were expected to be more positive in amplitude than ERP responses to new faces with a maximal effect anticipated over parietal regions during the late parietal Old/New time window. A pronounced and widely distributed Old/New difference was visually observed during the late Old/New window (Figure 8). Although both waveforms showed a positive deflection, the amplitude of ERP responses to Old faces was greater than to New faces. The category-based RM-ANOVA for the late Old/New window confirmed the hypothesized main effect of Condition and also showed an effect of Region and the hypothesized significant Condition X Region interaction (Table 32).

Table 32 Experiment 2 (Simulated Memory Malingering). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the late Old/New time window (425 to 675 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	27.05	**.000**
REGION (R)	(7,119)	18.85	**.000†**
C x R	(7,119)	14.99	**.000†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A Wilcoxon signed-rank post-hoc analysis to compare the mean amplitude of ERP responses to Old and to New faces at each region showed that responses to Old faces were more positive than responses to New faces over all regions, although the largest z-scores were observed over right frontal, left frontal, right central and left central regions (17 of 18 participants showing a difference at each of the regions) (Table 33).

Table 33 Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the late Old/New window of the Remote Long-term memory task, (n is the number of participants showing an Old/New difference, P is the probability value).

Region	**z-score**	***N***	***P***
LF	-3.68	17/18	.000
LT	-2.50	14/18	.012
LC	-3.59	17/18	.000
LP	-3.03	15/18	.002
RF	-3.68	17/18	.000
RT	-2.29	1418	.022
RC	-3.68	17/18	.000
RP	-2.85	15/18	.004

As expected, ERP responses to Old faces were more positive in amplitude than ERP responses to New faces. However, this response was distributed across the recording regions and appeared to have a centro-frontal maximal distribution as opposed to a central-parietal maximum. These results suggest that brain activity associated with recollection from Remote Long-term memory involves processing from many areas in the brain. Nonetheless, these results are consistent with notion that neural processing associated with recollection was able to differentiate between Old faces and New faces in spite of the malingering participants' attempt to feign a memory impairment.

3.2.2.4 Between task comparisons of ERP Old/New positivity effects. Standardized serial t-score curves represent the difference between Old and New ERP waveforms on a point-by-point basis over the duration of the ERP waveform. The peak t-score value and its latency were used to explore differences in magnitude of both the early frontal ERP Old/New and the late parietal ERP Old/New positivity effects between the three different memory tasks.

3.2.2.4.1 Early frontal Old/New positivity effect. To compare the magnitude of brain activity associated with familiarity, peak t-scores during the early frontal Old/New window over the left frontal region (an expected region for the maximal early frontal ERP Old/New response) were compared from each of the recognition memory tasks. An RM-ANOVA using a within-subjects factors of Task (3 levels) showed that the largest early frontal Old/New differences were observed for the Short-term memory and Remote Long-term memory tasks. The RM-ANOVA for the mean peak t-score values during the early Old/New time window for each task showed a main effect of Task ($F(2,34) = 7.89$, $p < .01$). For the main effect of Task, Bonferroni-adjusted pair-wise comparisons of the peak t-scores showed that the peak t-scores from the early Old/New positivity effect in the Short-term memory and Remote Long-term memory tasks were significantly larger than the Recent Long-term memory task, but not from each other. These results suggest that discriminating between Old and New faces from the Short-term and Remote Long-term memory tasks elicited neural processing associated with familiarity to a greater extent than the on the Recent Long-term memory task for the Simulated Memory Malingering participants.

3.2.2.4.2 Late parietal Old/New positivity effect. To compare the magnitude of brain activity associated with recollection, peak t-scores during the late parietal Old/New window over the left parietal region (an expected region for the maximal late parietal ERP Old/New response) were compared from each of the recognition memory tasks. Differences in the magnitude of the late parietal ERP Old/New response, as measured by the peak serial t-scores, were observed between the three memory tasks for the late Old/New positivity effect. The RM-ANOVA showed a main effect for Task ($F(2,34) = 4.89$, $p < .05$).

For the main effect of Task, Bonferroni-adjusted pair-wise comparisons showed that the late Old/New positivity effect t-score value for the Remote Long-term memory task was significantly larger than the t-scores for the Recent Long-term but not the Short-term memory task. The t-scores from the Short-term memory task also did not significantly differ from the t-scores of the Recent Long-term memory task. These results suggest that discriminating between Old and New faces from the Remote Long-term memory task elicited brain activity associated with recollection to a greater extent than the Recent Long-term memory task.

3.3 Discussion

Experiment 2 focused on the issue of motivation and effort during recognition memory testing, specifically the issue of neurocognitive malingering. To address this issue, the ability of cognitive ERP to assess memory under conditions of simulated memory malingering was examined. Although this experiment used the same three tasks that were used in Experiment 1, the current discussion is focused solely on the results of Experiment 2. Comparisons of Experiments 1 and 2 are reserved for Chapter 4. The results from Experiment 2 are summarized in Table 34 (to be compared with the summary of Experiment 2 hypotheses in Table 2).

Table 34 A summary of the results from Experiment 2. Shaded areas represent the **observed** distribution of category-based ERP Old/New positivity effects, with darker shading to show ERP regions where the effects were maximal. To be compared with Table 2.

Task	**Behavioural**	**ERP Time Window**	**Old/New Results**		**Putative Cognitive Component**
Short-term	Total Correct 66.33% (s.e.m. 5.41)	Early Frontal Old/New Window (290 to 390 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (415 to 515 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Recent Long-term	Total Correct 53.72% (s.e.m. 3.49)	Early Frontal Old/New Window (320 to 370 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (600 to 1000 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	
Remote Long-term	Total Correct 65.58% (s.e.m. 5.97)	Early Frontal Old/New Window (285 to 385 ms)	LF	RF	Familiarity
			LC	RC	
			LT	RT	
			LP	RP	
		Late Parietal Old/New Window (425 to 675 ms)	LF	RF	Recollection
			LT	RT	
			LC	RC	
			LP	RP	

3.3.1 Short-term Memory Task

As expected, the Total Correct response accuracy scores of the participants in Experiment 2 on the Short-term memory task (see Table 34) were below the 90% level of accuracy. That is, given that the participants were known to be healthy, the behavioural response accuracy data suggest that the participants were indeed malingering on the Short-term memory task.

It was hypothesized that the ERP responses of the malingering participants during the Short-term task would show more positive amplitudes to Old faces than to New faces during the 250 to 1000 ms after viewing a face, even though participants were feigning a memory impairment. Two time windows were of particular interest, one for the early frontal ERP Old/New positivity effect (290 to 390 ms) associated with familiarity and the other for the late parietal Old/New positivity effect (415 to 515 ms) associated with recollection. The ERP responses to Old faces were more positive than ERP responses to New faces during both the early and the late Old/New positivity effect time windows.

The early frontal ERP Old/New positivity effect from the Short-term memory task was distributed over left fronto-central regions. This result was consistent with many characteristics of the early Old/New positivity effect associated with familiarity described in the experimental literature (Mecklinger, 2000; Rugg & Curran, 2007; Rugg et al., 1998) including timing, mid-frontal distribution, and ERP responses to Old faces showing a larger positivity than the ERP responses to New faces.

ERP response differences between Old and New faces during the late parietal ERP Old/New time window were significant across all regions, with evidence of the largest differences over left hemisphere temporal, central, and parietal regions. The characteristics of the ERP responses during the late Old/New time window from the

Short-term memory task were in keeping with the late Old/New positivity effect associated with recollection that has been described in experimental ERP studies of recognition memory (Mecklinger, 2000; Rugg & Curran, 2007).

It is important to establish whether tasks are capable of demonstrating ERP Old/New positivity effects at the individual level. This was the case with the Short-term memory task of Experiment 2. For example, during the early Old/New time window, 14 of the 18 participants showed a significant Old/New positivity effect at the left frontal region. During the late Old/New time window, 17 of the 18 participants showed the effect at the left central region. The finding that ERP responses from the large majority of individuals feigning a memory impairment on the Short-term memory task still show typical Old/New positivity effects is important.

These results suggest that even when participants attempted to feign a memory impairment, neural processing associated with recognition memory was still elicited by the faces in the Short-term memory task. These results are in keeping with previous reports of Old/New differences in cognitive symptom exaggerators (Tardif et al., 2000; Tardif et al., 2002). However, they are in contrast to the study by Vagnini et al. (2008) who failed to find Old/New positivity effects in a group of healthy individuals who were feigning a memory impairment.

3.3.2 Recent Long-term Memory Task

The Recent Long-term task was derived from neuropsychological tests of visual recognition memory. It was hypothesized that cognitive ERP responses to the Recent Long-term memory task would show more positive amplitudes to Old faces than to New faces between 250 to 1000 ms following face presentation, that is, participants' attempts to feign a memory impairment would not alter the ERP pattern of recognition memory Old/New positivity effects. Behaviourally, participants demonstrated a Total Correct response accuracy that was no better than chance and appeared to be even more "impaired" than on the Short-term and the Remote Long-term tasks (see Table 34). The behavioural data from the Recent Long-term task is in keeping with a rather convincing effort to feign a memory impairment.

Contrary to expectation however, no statistically reliable differences between the ERP responses to Old and New faces during either the early frontal or the late parietal Old/New positivity windows could be detected. The ERP results of the Recent Long-term memory task imply deficient recognition memory and suggest that it is indeed possible to successfully malinger on a task of recognition memory. That is, people can alter both their behavioral responses *and* their ERP responses to successfully feign a memory impairment. The lack of ERP Old/New positivity effects, particularly the late parietal effect that has been associated with recollection, would appear to be consistent with the results of Vagnini and colleagues (2008) who also found no statistically reliable recognition memory ERP Old/New positivity effects in a group of healthy participants asked to feign a memory impairment on a task of Recent Long-term memory.

3.3.3 Remote Long-term Memory Task

The Remote Long-term memory task was designed to assess long-term recognition memory for remote or well-known, personally relevant information. As expected, the Total Correct accuracy score of participants in Experiment 2 on this task was below 90% implying that the participants were indeed malingering. As with the other memory tasks used, it was hypothesized that the ERP responses during the Remote

Long-term memory task would show more positive amplitudes to Old faces than to New faces during the 250 to 1000 ms after viewing a face, even when participants attempted to feign a memory impairment. Two time windows in particular were examined, one for the early Old/New positivity effect (285 to 385 ms) and another for the late Old/New positivity effect (425 to 675 ms).

Visual evidence of a positive deflection during the early frontal Old/New window was evident in the ERP responses to *both* Old and New faces. However, the early Old/New positivity effect was significant over the frontal and central regions of both hemispheres only. This frontally maximal early frontal Old/New positivity effect was consistent with the distribution of the early Old/New positivity effects typically described in the ERP recognition memory literature that are associated with familiarity (Mecklinger, 2000, 2006; Schloerscheidt & Rugg, 2004), including ERP studies of recognition memory for faces (Barrett et al., 1988; Paller et al., 1999; Schweinberger et al., 2002).

With respect to the late Old/New time window, a pronounced Old/New positivity effect was observed that was distributed widely across the recording regions in spite of the low behavioural response accuracy by participants to the well-known faces. On average Old faces in the Remote Long-term task for this experiment had been known by the participants for over 11 years and 11 months. Thus, while the distribution of the Remote Long-term task late Old/New positivity effect in Experiment 2 was over more regions than typical, it remained consistent with the results from Experiment 1 and the notion that the automatic retrieval of the rich network of person-specific information can lead to widespread neural activation (Paller et al., 2003). Also of note was that the greatest differences between ERP responses to Old and New faces were observed over the frontal and central regions of both hemispheres. However, as demonstrated by the region effect, ERP responses for both Old and New faces were more positive in amplitude over parietal regions. This result may in part be due to cognitive processing associated with response strategy. For example, the ERP responses to New faces showed an increased negativity relative to Old faces starting in the 200 ms time window at fronto-central regions (see Appendix B for a detailed analyses and discussion of the ERP responses during the 200 ms time window), a difference possibly associated with brain activity related to monitoring response strategy (Donkers & van Boxtel, 2004). It is possible that this earlier differentiation between ERP responses to Old and New faces contributed to the greater differences between the waveforms during the subsequent time windows as well. Thus even though the ERP responses were more positive over parietal regions, the difference between them was greater over the fronto-central regions. Nonetheless, the timing and positivity characteristics of the ERP responses during the late Old/New window in the present study were again in keeping with the late Old/New positivity effect typically reported on tasks of new learning.

The significant differences between the ERP responses to Old and New faces during both the early Old/New time window and the late Old/New time window from the Remote Long-term memory task in Experiment 2 appear to contrast with the findings from the study by Vagnini and colleagues (Vagnini et al., 2008). The results from the Remote Long-term task in this Experiment were consistent with the results of the Short-term memory task in that Old/New recognition memory ERP effects were observed even when the participants feigned a memory impairment.

The Remote Long-term memory task was capable of demonstrating Old/New positivity effects at the individual level regardless of participants' simulation of a memory impairment. This is important for the potential use of this task in a clinical setting. During the early Old/New time window 15 of the 18 participants showed a significant Old/New positivity effect at the left frontal region. For the late Old/New time window 17 of the 18 participants showed the Old/New positivity effect over all regions. This finding is particularly important as it demonstrates that recognition memory can be assessed regardless of an individual's behavioural responses, even when an individual is attempting to feign a memory impairment.

3.3.4 Between Task Comparisons

An important goal of Experiment 2 was to compare the early frontal and later parietal ERP Old/New positivity effects on the different types of recognition memory tasks. Peak standardized difference scores between Old and New ERP responses were used to compare the magnitude of the ERP Old/New positivity effects across the different tasks. With respect to the early frontal ERP Old/New positivity effect, differences in response magnitude differentiated the Recent Long-term task from both the Short-term task and Remote Long-term task over fronto-central regions. However, the magnitude of the early Old/New positivity effect was not different between the Short-term and Remote Long-term tasks. These results provide further evidence that the magnitude of the differences between ERP responses to Old and New faces during the early Old/New time window is associated with the behavioural response accuracy.

As with the early Old/New window, the magnitude of late Old/New positivity effects failed to differentiate all three tasks from each other. However, the magnitude of the late Old/New positivity effect from the Remote Long-term task was significantly larger than the effects observed in both the Short-term and the Recent Long-term tasks (which did not significantly differ from each other) over the left and right frontal regions. These results from Experiment 2 provide further evidence that the magnitude of recognition memory Old/New positivity effects may differentiate neural processing associated with short-term and recent long-term memory versus remote long-term memory.

The participants in this experiment were asked to feign a memory impairment and received additional compensation for doing so. This type of research seeks to learn about human responses to real life situations that have been created experimentally. As such the additional compensation was key to providing the motivational context of the participants' performance on the memory tasks. The results of the present experiment showed recognition memory ERP Old/New positivity effects associated with familiarity and recollection that were generally in keeping with those typically reported in the experimental literature. As such, these findings strongly suggest the independent nature of recognition memory Old/New positivity effects from attempts to behaviourally exaggerate or simulate a memory impairment. To further assess the independence of ERP recognition memory Old/New positivity effects from behavioural attempts to feign a memory impairment, a direct comparison of recognition memory ERP Old/New responses from the standard responding participants of Experiment 1 with the ERP responses from the malingering participants in Experiment 2 is required. This comparison is described in Chapter 4.

As a note, Old/New differences between the early sensory components (i.e., 100 ms and 150 ms time windows) of the ERP responses to Old and to New faces were not expected or observed on the Recognition memory tasks in Experiment 2. See Appendix 2 for more detailed analyses of these time windows.

CHAPTER 4 HONEST RESPONSE VERSUS SIMULATED MEMORY MALINGERING: A COMPARISON OF EXPERIMENTS 1 AND 2

The experiments in the previous two chapters demonstrated that ERP responses are able to discriminate between Old and New items on tests of visual recognition memory under both Honest Response conditions (Experiment 1) and under Simulated Memory Malingering conditions (Experiment 2), (i.e., the Short-term and the Remote Long-term tasks). Further, the Old/New positivity effects observed in the ERP responses on those tasks were generally consistent with those typically described in the experimental literature. An important question yet to be addressed however is how the ERP responses of the Honest Response and the Malingering groups compared to each other. This question is particularly important given the apparent success of the simulated malingering participants in Experiment 2 at altering their ERP responses and their behavioural responses to feign a memory impairment on the Recent Long-term memory task, as well as given some of the contrasting ERP results from previous ERP studies of malingering (Ellwanger et al., 1999b; Tardif et al., 2000; Tardif et al., 2002; Vagnini et al., 2008).

Experiment 1 provided an important control condition for Experiment 2, even though that was not the sole purpose of Experiment 1. Behaviourally, it was predicted that the Simulated Memory Malingering group would obtain lower Total Correct response accuracy scores and longer reaction times than the Honest Response group when responding to faces, given that this group was instructed to feign a memory impairment during task performance.

As recognition memory ERP Old/New positivity effects for familiarity (early frontal Old/New) and recollection (late parietal Old/New) were expected to be associated with neural activity for memory processes, these effects would be expected to occur to the extent that the brain recognized faces, regardless of any biases in behavioural response accuracy. As such, it was hypothesized that the magnitude of the difference between the ERP responses to Old and to New faces during both the early frontal and the late parietal Old/New positivity effect time windows would not differ between the two groups for any of the tasks, regardless of group differences in behavioural accuracy.

For all three recognition memory tasks, the behavioural accuracy of the Simulated Memory Malingering participants was lower than the accuracy of the Honest Responders. Thus the behavioural accuracy results indicate success by the malingering participants at feigning a memory impairment (i.e., malingering). Further, the ERP Old/New positivity effects from the Short-term memory task did not change between the two experiments. That is, attempts to malinger were ineffective at altering ERP responses associated with recognition memory.

However, in the Recent Long-term task neither experiment demonstrated the expected pattern of Old/New positivity effects (i.e., ERP waveforms to Old faces being more positive in amplitude than ERP waveforms to New faces). This comparison is critical because it suggests that the lack of Old/New positivity effects in Experiment 2 was not due to successful malingering, but rather to an artifact of some characteristic of the Recent Long-term memory task itself.

Finally, in the Remote Long-term memory task, the ERP Old/New positivity results were similar between the Experiment 1 and Experiment 2. Again, this result implies that attempts to malinger on the Remote Long-term task were ineffective at altering ERP responses associated with recognition memory.

4.1 Statistical Analyses and Comparisons

4.1.1 Behavioural Response Accuracy

An overall comparison of the behavioural accuracy scores was done using a Mixed ANOVA using a between subjects factor of Group (Honest Response, Simulated Memory Malingering) and within subjects factor of Task (Short-term, Recent Long-term, Remote Long-term) and Response accuracy (%Old correct, %New correct). Of particular interest were the Group X Task and Group X Task X Response interactions. These interactions could provide some insight into how the Simulated Memory Malingering participants attempted to feign a memory impairment on the three different memory tasks (i.e., targeting their efforts to Old faces, New faces, or both). If the Simulated Memory Malingering participants on all three tasks employed a similar strategy, no interactions would be expected. However, significant interaction effects could imply that different behavioural approaches were used, possibly necessitated by differences in Task demands (e.g., the Recent Long-term memory task).

All results of this analysis were significant, however only the Group effect, and the Group X Task and Group X Task X Response interactions were of interest (Table 35).

Table 35 Results from the RM-ANOVA analyses of group differences in response accuracy (correct Old and correct New responses) across all tasks.

Effects	Df	Response Accuracy F	*P*
Group	(1,33)	33.01	**.000**
Task	(2,66)	61.47	**.000†**
Group x Task	(2,66)	10.58	**.000†**
Response	(1,33)	24.02	**.000**
Group x Response	(1,33)	20.78	**.000**
Task x Response	(2,66)	7.89	**.002†**
Group x Task x Response	(2,66)	7.27	**.003†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The Simulated Memory Malingering participants were expected to obtain lower accuracy scores than the Honest Response participants across all tasks. As expected, the results of the Mixed ANOVA showed a main effect of Group as the Honest Response group was more accurate than the Simulated Memory Malingering group across all three tasks and across both types of responses (89.02% ± 3.38 s.e.m. versus 61.88% ± 3.28 s.e.m.). That is, the behavioural accuracy of the Simulated Memory Impairment group implies a successful attempt overall to feign a memory impairment.

The Mixed ANOVA also showed significant Group X Task and Group X Task X Response interactions. The Group X Task interaction was characterized by a difference in accuracy scores (collapsed across Old and New) between the Honest Response and the Simulated Memory Malingering participants that was smaller for the Recent Long-term task than for the Short-term and the Remote Long-term tasks. That is, the Malingering participants were not as effective at feigning a memory impairment on the Recent Long-term task as they were on the other two tasks.

To further examine the Group X Task X Response interaction, Bonferroni-adjusted pairwise-comparisons were used to compare the Group mean Hit percent (i.e., identifying Old faces) and Correct Rejection percent (i.e., identifying new faces) scores for each task. The results showed that the Honest Response group obtained higher scores for both Hit percent and Correct Rejection percent than the Simulated Memory Malingering group on all three tasks with one exception. The mean Correct Rejection percent was not significantly different between the two groups on the Recent Long-term memory task. This would suggest that the decreased effectiveness in feigning a memory impairment on the Recent Long-term task was linked to the behavioural responses to New faces on this task. That is, the Simulated Memory Malingering participants focused their efforts on Old faces more than New faces when attempting to feign a memory impairment on the Recent Long-term task compared to the other two tasks.

4.1.2 Behavioural Reaction Times

As memory malingering is dependent upon recognition of the faces (i.e., a face must first be recognized as Old or New), the reaction times from the Simulated Memory Malingering participants could be expected to be longer than the reaction times from the Honest Response participants. Reaction times were compared on each task with a Mixed ANOVA using a between subjects factor of Group and within subjects factors of Task and Response.

All results of this analysis were significant with the exception of the Group X Response interaction. However, only the effect of Group, and the Group X Task and Group X Task X Response interactions were of interest (Table 36). As might be expected, the Simulated Memory Malingering group was significantly slower in their overall reaction times (1129.04 ms ± 54.42 s.e.m.), collapsed across Old and New faces, than the Honest Response group (843.87 ms ± 54.42 s.e.m.).

Table 36 Results from the Mixed ANOVA analyses of group differences in reaction times across all tasks.

Effects	df	Reaction Times	
		F	*P*
Group	(1,33)	13.73	**.001**
Task	(2,66)	25.38	**.000**
Group x Task	(2,66)	17.70	**.000**
Response	(1,33)	7.82	**.009**
Group x Response	(1,33)	3.75	.062
Task x Response	(2,66)	4.58	**.014**
Group x Task x Response	(2,66)	6.61	**.002**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Bonferroni-adjusted pairwise-comparisons of the Group mean reaction times for each task were used to investigate the Group X Task interaction. The results showed that the reaction times for the Honest Response group were significantly faster than the reaction times for the Simulated Memory Malingering group on the Short-term task and the Remote Long-term task. However, the reaction times of the Honest Response participants were not statistically different from the Simulated Memory Malingering participants on the Recent Long-term task. This behavioural result provides further evidence the lack of ERP Old/New positivity effects on the Recent Long-term task in Experiment 2 was the result of task characteristics (i.e., the Old/New discriminations were more difficult), and not due to successful malingering with respect to the ERP responses.

Bonferroni-adjusted pairwise-comparisons of the Group mean reaction times for Hit and Correct Rejection response trials for each task were used to follow-up the Group X Task X Response interaction. The results showed that the Honest Response group was faster for Hit and Correct Rejection response trials than the Simulated Memory Malingering group on all three tasks with one exception. The reaction times for Correct Rejection response trials between the two groups were not statistically different on the Recent Long-term memory task.

In summary, the Simulated Memory Malingering participants were less accurate and slower to respond to the Old and New faces on the Short-term and the Remote Long-term tasks than were the Honest Response participants. However, differences were attenuated for the Recent Long-term task particularly for the responses to New faces on this task.

4.1.3 ERP Comparisons

The ERP comparisons were made in two ways – first comparing the mean amplitudes of the ERP responses; and second comparing the standardized serial t-score values derived from the difference between ERP responses to Old and to New faces. No differences in ERP responses between the Honest Response and the Simulated Memory Malingering participants were expected for the late parietal ERP Old/New positivity effect associated with recollection. The analyses of the early frontal ERP Old/New positivity effect was more exploratory, given that it can be elicited by both Old faces and by New faces incorrectly judged as Old.

ERP comparisons were first made between the Honest Response and the Simulated Memory Malingering participants using the mean amplitudes of the ERP responses during both the early and the late Old/New positivity effect time windows. Group differences across tasks were analysed using a Mixed ANOVA with a between-subjects factor of Group (Honest Response, Simulated Memory Malingering) and within-subject factors of memory Task (Short-term, Recent Long-term, Remote Long-term), Condition (Old, New), and Region (LF, LT, LC, LP, RF, RT, RC, RF). Separate Mixed ANOVAs were carried out for both the early and late Old/New time windows. As the goal of these analyses was to explore group differences in ERP responses to Old and New faces, the Group X Condition, Group X Condition X Region, Group X Condition X Task, Group X Condition X Region X Task interactions were particularly meaningful. Post-hoc analyses were pursued only when one of these interactions was significant.

4.1.3.1 Early frontal Old/New positivity effect – mean amplitudes. The analysis of the time window in which the early frontal Old/New positivity effects were expected showed that the mean amplitudes of the ERP responses to Old and New faces did not significantly differ between the Honest Response and the Simulated Memory Malingering participants when compared across all three tasks. With respect to the interactions of interest there were no Group X Condition X Region, Group X Condition X Task, Group X Condition X Region X Task interactions, only the Group X Condition interaction was significant (Table 37). Bonferroni-adjusted pair-wise comparisons of the mean amplitude of early frontal ERP Old/New responses showed that when collapsed across tasks the means of the Old and the New conditions were significantly different for the Honest group, but not the SMM group. This appears to suggest that the Old/New effects were reduced for the SMM group compared to the Honest group. However, the mean amplitudes of the ERP responses for each condition (Old, New), collapsed across tasks, were not significantly different from each other.

Table 37 Results from the category-based RM-ANOVA analyses of mean amplitudes during the early frontal Old/New window.

Effects	df	Mean Amplitudes F	*P*
Group	(1,33)	2.57	.118
Task	(2,66)	22.96	**.000**
Group X Task	(2,66)	1.88	.161
Condition	(1,33)	0.75	.392
Group X Condition	(1,33)	4.35	**.045**
Region	(7,231)	67.00	**.000†**
Group X Region	(7,231)	2.99	**.030†**
Task X Condition	(2,66)	10.20	**.000**
Group X Task X Condition	(2,66)	0.53	.593
Task X Region	(14,462)	4.53	**.000†**
Group X Task X Region	(14,462)	1.39	.218†
Condition X Region	(7,231)	19.00	**.000†**
Group X Condition X Region	(7,231)	1.65	.183†
Task X Condition X Region	(14,462)	7.44	**.000†**
Group X Task X Condition X Region	(14,462)	1.04	. 393†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

This analysis suggests that the ERP responses elicited by memory for faces during the early frontal Old/New time windows were similar between the Honest Response and the Simulated Memory Malingering participants were similar across tasks. This would suggest that to the extent familiarity processes contributed to task performance, it did so in a similar fashion for the Honest Response and the Simulated Memory Malingering participants.

4.1.3.2 Late parietal Old/New positivity effect – mean amplitudes. The mean amplitude of the ERP responses elicited by Old and New faces during the late parietal ERP Old/New windows were not expected to differ between the Honest Response and the Simulated Memory Malingering participants. With respect to the interactions of interest, the Mixed ANOVA of the mean ERP amplitudes during the time window in which the late parietal Old/New positivity effects were expected showed that the mean amplitudes of the ERP responses to Old and New faces did not significantly differ between the Honest Response group and the Simulated Memory Malingering group when compared across all three tasks. The RM-ANOVA for the late Old/New window showed no Group X Condition, Group X Condition X Task, Group X Condition X Region, or Group X Condition X Region X Task interactions (Table 38).

Table 38 Results from the category-based RM-ANOVA analyses of mean amplitudes during the late parietal Old/New window.

		Mean Amplitudes	
Effects	df	F	*P*
Group	(1,33)	5.51	**.025**
Task	(2,66)	7.31	**.001**
Group X Task	(2,66)	0.16	.856
Condition	(1,33)	62.35	**.000**
Group X Condition	(1,33)	0.84	.367
Region	(7,231)	82.91	**.000†**
Group X Region	(7,231)	5.17	**.002†**
Task X Condition	(2,66)	17.87	**.000**
Group X Task X Condition	(2,66)	1.28	.285
Task X Region	(14,462)	12.27	**.000†**
Group X Task X Region	(14,462)	0.43	.827†
Condition X Region	(7,231)	23.47	**.000†**
Group X Condition X Region	(7,231)	1.68	.166†
Task X Condition X Region	(14,462)	13.57	**.000†**
Group X Task X Condition X Region	(14,462)	1.36	. 239†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

An overall main effect for Group was observed as the ERP responses collapsed across Old and New faces were more positive for the Honest Response group than the

Simulated Memory Malingering group. However, this difference was to both Old and to New faces and was consistent across tasks and regions as evidenced by the lack of significant interactions with the effects of Condition, Task X Condition, Condition X Region, or Task X Condition X Region. These results indicate that, in spite of the uniformly lower accuracy of the Simulated Memory Malingering participants, the pattern of ERP responses elicited by Old and New faces during the late parietal Old/New window were statistically similar between the Honest Response and the Simulated Memory Malingering participants on the three recognition memory tasks.

Similar ERP analyses were then carried out on the Honest Response and Simulated Memory Malingering groups using the peak serial t-score and latency values as dependent variables. As described in chapter 2, the serial t-score values provide a standardized difference measure between the ERP responses to Old and New items. This value allows for a direct comparison of the magnitude and latency of the recognition memory Old/New positivity effects. Group differences across tasks were analysed using a Mixed ANOVA again with the between subjects factor of Group and within-subject factors of memory Task and Region. Separate Mixed ANOVAs were carried out for time windows associated with the early frontal ERP Old/New positivity effect and the late parietal ERP Old/New positivity effect. As the goal of these analyses was to explore group differences in standardized difference scores between ERP responses to Old and New faces, the main effect of Group, as well as the Group X Region, and Group X Task X Region interactions were particularly meaningful. Post-hoc analyses were pursued only when one of these interactions was significant.

4.1.3.3 Early frontal Old/New positivity effect – difference scores.

Standardized t-scores for the difference between Old and New category-based waveforms were also used to compare the early frontal ERP Old/New positivity effects between the three different memory tasks. Overall, the magnitude of the early Old/New positivity effect was similar between Honest Response and the Simulated Memory Malingering groups when compared across all three tasks. The Mixed ANOVA for the peak serial t-score values during the early Old/New time window of each task did not show a significant effect of Group or interactions for Group X Task, Group X Region, and Group X Region X Task (Table 39).

Table 39 Results from the RM-ANOVA analyses to compare the magnitude of ERP differences between the Honest Response and the Simulated Memory Malingering groups using the peak serial t-score during the early frontal Old/New window across all tasks.

Effects	df	Serial t-score difference F	Serial t-score difference *P*
GROUP (G)	(1,33)	2.57	.118
TASK (T)	(2,66)	14.98	**.000**
G x T	(2,66)	0.98	.382
REGION (R)	(7,231)	14.45	**.000†**
G x R	(7,231)	1.14	.340†
T x R	(14,462)	8.33	**.000†**
G x T x R	(7,119)	0.36	. 872†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Similar to the analysis of the mean amplitudes during the early frontal Old/New time windows, the standardized t-scores for the difference between ERP responses to Old and New faces during this time window were statistically similar for the Honest Response and the Simulated Memory Malingering participants. These findings suggest that Old and New faces from the different memory tasks elicited neural activity associated with familiarity to similar degrees for both the Honest Response and the Simulated Memory Malingering participants, in spite of the latter group's attempt to feign a memory impairment through their behavioural responses.

4.1.3.4 Late parietal Old/New positivity effect – difference scores. Standardized t-scores for the difference between Old and New category-based waveforms were also used to compare the late parietal ERP Old/New positivity effects between the three different memory tasks. As recollection of an item would be required before one could generate a malingered ERP response, no statistical differences were expected between the Honest Response and the Simulated Memory Malingering participants. The Mixed ANOVA for the peak serial t-score values during the late Old/New time window across memory tasks did not show a significant effect of Group or interactions for Group X Task, Group X Region, and Group X Region X Task (Table 40).

Table 40 Results from the RM-ANOVA analyses to compare the magnitude of ERP differences between the Honest Response and the Simulated Memory Malingering groups using the peak serial t-score during the late parietal Old/New window across all tasks.

Effects	df	**Serial t-score difference** F	*P*
GROUP (G)	(1,33)	2.10	.157
TASK (T)	(2,66)	19.47	**.000**
G x T	(2,66)	0.71	.494
REGION (R)	(7,231)	11.77	**.000†**
G x R	(7,231)	1.65	.176†
T x R	(14,462)	12.01	**.000†**
G x T x R	(7,119)	1.25	.284†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Overall, the magnitude of the late parietal Old/New positivity effect was similar between Honest Response and the Simulated Memory Malingering groups when compared across all three tasks. The analysis of the difference t-scores between Old and New waveforms provides additional evidence that ERP responses to Old and New faces associated with recollection are elicited to similar levels in both Standard Responding and Simulated Memory Malingering participants.

4.1.4 ERP Old/New Positivity Effects at the Individual Level

Performance at the individual level between the Honest Response and the Simulated Memory Malingering participants was also compared in two ways. First, comparisons were made based upon the mean amplitudes as measured by the results of the Wilcoxon post-hoc tests from Experiment 1 and Experiment 2. Second, the peak serial t-score values were used to compare ERP Old/New positivity effects for individual ERP responses to Old and New faces. The serial t-score values were derived from a point-by-point comparison of the ERP responses to Old faces with the ERP responses to New faces during the time windows for the early and late Old/New positivity effects to determine if Old faces were more positive in amplitude than New faces. Critical t-values required for one-tailed statistical significance were determined for each individual using the Student's T distribution (alpha level of $p < .05$). Individual comparisons that resulted in the predicted significant difference between ERP responses to Old and New faces at any electrode region were used to determine the number of individuals showing an Old/New positivity effect. Fisher's exact tests were conducted to compare the frequency of individuals from both Experiment 1 (Honest Response) and 2 (Simulated Memory

Malingering) that showed Old/New positivity effects for their ERP responses during the early and the late Old/New time windows.

The percentage of participants from the Honest Response and the Simulated Memory Malingering groups showing the expected ERP Old/New positivity effects was statistically similar for both the early frontal and the late parietal Old/New time windows on each of the tasks (Table 41).

Table 41 The percentage of individuals showing ERP Old/New positivity effects as determined from the Wilcoxon analyses (based on mean amplitudes) and the ERP difference serial t-scores during the early and late Old/New window of each task.

	Short-term		**Recent Long-term**		**Remote Long-term**	
Effects	HR	SMM	HR	SMM	HR	SMM
WILCOXON						
EARLY OLD/NEW	94.2%	77.8%	58.8%±	55.6%±	82.4%	83.3%
LATE OLD/NEW	88.2%	94.4%	82.4%	61.1%	100.0%	94.4%
T-SCORES						
EARLY OLD/NEW	88.2%	55.6%	23.5%±	16.7%±	70.6%	55.6%
LATE OLD/NEW	64.7%	72.2%	58.8%	38.9%	100.0%	88.9%

(HR = Honest Response; SMM = Simulated Memory Malingering; ± Old/New differences were not significant at the group level.)

The results of the Fisher Exact test comparisons based on the mean amplitudes and the difference t-scores from each task are reported below.

4.1.4.1 Early frontal Old/New time window from the Short-term task: mean amplitude-based comparisons. Sixteen out of 17 individuals (94.2%) from the Honest Response group and 14 out of 18 individuals (77.8%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 0.338$, Fisher's exact test).

4.1.4.2 Early frontal Old/New time window from the Short-term task: t-score difference comparisons. Fifteen out of 17 individuals (88.2%) from the Honest Response group and 10 out of 18 individuals (55.6%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 0.060$, Fisher's exact test), but the trend was toward significance. This result appears to suggest that neural processing associated with familiarity was elicited in fewer Simulated Memory Malingering participants than Honest Response participants. This result could be interpreted as the influence of top down processing or "cognitive set" on the neural activity of the Simulated Memory Malingering participants, however such an explanation is unlikely. The fact that this effect did not replicate across tasks implies that this result is best characterized as a Type I statistical error.

4.1.4.3 Late parietal Old/New time window from the Short-term task: mean amplitude-based comparisons. Fifteen out of 17 individuals (88.2%) from the Honest Response group and 17 out of 18 individuals (94.4%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 0.603$, Fisher's exact test).

4.1.4.4 Late parietal Old/New time window from the Short-term task: t-score difference comparisons. Eleven out of 17 individuals (64.7%) from the Honest Response group and 13 out of 18 individuals (72.2%) from the Simulated Memory

Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different (p = 0.725, Fisher's exact test).

4.1.4.5 Early frontal Old/New time window from the Recent Long-term task: mean amplitude-based comparisons. Ten out of 17 individuals (58.8%) from the Honest Response group and 10 out of 18 individuals (55.6%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in that their ERP responses to Old faces were more positive in amplitude than their ERP responses to New faces, a difference that was not statistically different (p = 1.000, Fisher's exact test).

4.1.4.6 Early frontal Old/New time window from the Recent Long-term task: t-score difference comparisons. Four out of 17 individuals (23.5%) from the Honest Response group and 3 out of 18 individuals (16.7%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different (p = 0.691, Fisher's exact test).

4.1.4.7 Late parietal Old/New time window from the Recent Long-term task: mean amplitude-based comparisons. Fourteen out of 17 individuals (82.4%) from the Honest Response group and 11 out of 18 individuals (61.1%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different (p = 0.264, Fisher's exact test).

4.1.4.8 Late parietal Old/New time window from the Recent Long-term task: t-score difference comparisons. Ten out of 17 individuals (58.8%) from the Honest

Response group and 7 out of 18 individuals (38.9%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 0.318$, Fisher's exact test).

4.1.4.9 Early frontal Old/New time window from the Remote Long-term task: mean amplitude-based comparisons. Fourteen out of 17 individuals (82.4%) from the Honest Response group and 15 out of 18 individuals (83.3%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 1.000$, Fisher's exact test).

4.1.4.10 Early frontal Old/New time window from the Remote Long-term task: t-score difference comparisons. Twelve out of 17 individuals (70.6%) from the Honest Response group and 10 out of 18 individuals (55.6%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 0.489$, Fisher's exact test).

4.1.4.11 Late parietal Old/New time window from the Remote Long-term task: mean amplitude-based comparisons. Seventeen out of 17 individuals (100.0%) from the Honest Response group and 17 out of 18 individuals (94.4%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 1.000$, Fisher's exact test).

4.1.4.12 Late parietal Old/New time window from the Remote Long-term task: t-score difference comparisons. Seventeen out of 17 individuals (100.0%) from the Honest Response group and 16 out of 18 individuals (88.9%) from the Simulated Memory Malingering group showed the expected Old/New positivity effect in their ERP responses to Old and New faces, a difference that was not statistically different ($p = 0.486$, Fisher's exact test).

4.2 Discussion of Comparisons Between the Honest Response and the Simulated Memory Malingering Groups

The purpose of the present chapter was to compare the behavioural and ERP responses of the Honest Response participants with the Simulated Memory Malingering participants from Experiments 1 and 2 respectively. The goals were to explore and compare group differences (i.e., Honest Response versus Simulated Memory Malingering) in the ERP responses to the Old and New faces during the early frontal and late parietal Old/New time windows to explore the group differences in Old/New ERP responses when compared across the Short-term, Recent Long-term, and Remote Long-term recognition memory tasks.

With respect to the behavioural response data, the statistical comparisons in this chapter demonstrated that the Simulated Memory Malingering participants were able to alter their behavioural responses in order to successfully feign a memory impairment on all three memory tasks. However, the Simulated Memory Malingering participants were not able to alter their ERP responses from those associated with recognition memory when compared with the Honest Response participants from Experiment 1. That is, no significant differences in ERP Old/New positivity effects between the Honest Response and the Simulated Memory Malingering participants were found, in spite of the significant group differences in behavioural response accuracy and reaction times to Old and New faces. A summary of the results for the comparisons made in this study are reported in Table 42. The results of each of the tasks are discussed in more detail below.

Table 42 Summary of results for the comparison of Honest Response (HR) with Simulated Memory Malingering (SMM). To be compared with Table 3.

Task	Behavioural	ERP Time Window	ERP Old/New Results	Putative Cognitive Component
Short-term	Total Correct HR > SMM	Early Frontal Old/New Window	HR = SMM	Familiarity
		Late Parietal Old/New Window	HR = SMM	Recollection
Recent Long-term	Total Correct HR > SMM	Early Frontal Old/New Window	HR = SMM	Familiarity
		Late Parietal Old/New Window	HR = SMM	Recollection
Remote Long-term	Total Correct HR > SMM	Early Frontal Old/New Window	HR = SMM	Familiarity
		Late Parietal Old/New Window	HR = SMM	Recollection

4.2.1 Short-term Memory

As expected, behavioural accuracy on the Short-term memory task was lower for the Simulated Memory Malingering group compared to the Honest Response group. The decreased recognition accuracy was observed for both Old and New faces. The reaction times showed a similar pattern, with the Simulated Memory Malingering group taking longer to respond than the Honest Response group. The decreased accuracy and longer reaction times for the Simulated Memory Malingering group on the Short-term task were consistent with the longer reaction times for the Simulated Memory Malingering participants in the study reported by Tardif et al. (2002). The Short-term memory task used a paradigm and instructions that are similar to neuropsychological recognition memory tasks that provide an indication of effort. Although a comparison group of individuals with documented memory impairment was not included in this study, the behavioural performance of the Simulated Memory Malingering group was lower than what might be expected for a genuine memory impairment (Prigatano et al., 1997).

The pattern of memory impairment following a brain injury depends on the brain regions involved (Parkin & Leng, 1993). For example, damage to the medial temporal and hippocampal regions of the brain tend to produce a pattern of impairment whereby short-term memory is intact, but deteriorates quickly over time and is highly susceptible to interference, resulting in difficulty for learning new information. The primary impairment is for acquiring or learning new cognitive memories, while remote long-term memories formed prior to the brain injury remain relatively intact. With respect to the short-term memory task in the present study, even given the brief study/test delay and the absence of any interference stimuli between study and test, even individuals with severe amnesia resulting from damage to the medial temporal lobe system would be expected to obtain high accuracy scores (Leng & Parkin, 1995).

With respect to the ERP responses, there were no meaningful group differences between the ERP responses of the Honest Response and the Simulated Memory Malingering groups during the early frontal or late parietal ERP Old/New windows. This implies that the Honest Response and the Simulated Memory Malingering participants, despite the intentionally low behavioural response accuracy of the latter group, elicited neural processing during the early frontal and late parietal Old/New positivity windows to similar degrees.

From the perspective of performance at the individual level, the present experiment showed that a similar number of individuals from Honest Response and the Simulated Memory Malingering groups displayed early and late Old/New positivity effects on the Short-term task. This result was the same for comparisons based on the mean amplitude of the ERP responses or for comparisons based on the difference serial t-score values. A relatively high percentage of individuals showed ERP Old/New positivity effects on this task, particularly for the late Old/New positivity effect. That is, using the Wilcoxon method, 94.2% of the Honest Response group and 77.8% of the Simulated Memory Malingering group showed an early ERP Old/New difference. During the late Old/New time window of the Short-term task 88.2% of the Honest Response group and 94.4% of the Simulated Memory Malingering group showed the Old/New positivity effect. The combined sensitivity values (i.e., the probability of observing an Old/New positivity collapsed across groups) of the ERP responses on the Short-term task were 85.7% for the early Old/New ERP effect and 91.4% for the late Old/New ERP effect. This result is promising for the potential use of ERP responses, particularly the late parietal ERP Old/New positivity, to study memory functioning at the level of an individual examinee.

4.2.2 Recent Long-term Memory

The recent long-term memory task was an adaptation of the Warrington's Recognition Memory Test for Faces that required a change from a two-choice alternative to a serial presentation format during the recognition phase of the task (Connolly & Wang, 2000, technical report). However, serial presentation is also a standard test format used in other published neuropsychological tests (e.g., Wechsler Memory Scales – Faces, NEPSY - Faces). In the analyses described in this chapter, the goal was to compare the behavioural and the ERP responses of the two groups.

With respect to the behavioural response accuracy, the Simulated Memory Malingering group obtained lower accuracy scores and took longer respond than the Honest Response group, but only for correctly identifying Old faces. Recognition accuracy and response reaction times to New faces did not differ between the two groups (both groups demonstrated low accuracy and longer reaction times to New faces). Thus, while still successful at malingering the behavioural accuracy scores on this task, malingered responses appeared to be selective to Old faces on this task, compared to both Old and New faces on the other two tasks. No group differences were observed for any other class of response (i.e., correct rejection, miss, and false alarms). This pattern of behavioural response is consistent with previous reports of behavioural performance in ERP studies of malingering (Tardif et al., 2002). The results of the Tardif study also showed decreased response accuracy and increased behavioural response times for participants feigning a memory impairment compared to control participants.

If the response strategy adopted by the Simulated Memory Malingering group targeted both Old and New faces, as it did for the Short-term task, then one would expect accuracy and reaction times to be worse for both classes of stimuli. The finding of similar Correct Rejection percent rates for both groups may provide additional evidence of an unintended influence of increased task difficulty for the Recent Long-term task. Given the level of difficulty of the Recent Long-term task, the Simulated Memory Malingering group focused their response efforts on Old faces as opposed to both Old and New faces. In other words, it is more difficult to feign a memory impairment when one is truly having difficulty discriminating the Old and New faces on the task. Participants in the Simulated Memory Malingering study were not instructed or coached in the response strategy they should adopt for feigning a memory impairment. However, the behavioural accuracy of this group on the Short-term and Remote Long-term memory tasks wherein the Simulated Memory Malingering group showed lower response accuracy for both Old and New faces (discussed in more detail below) appears to support the above argument.

The comparison of the ERP responses on the Recent Long-term tasks of Experiment 1 and Experiment 2 was crucial. During the early frontal Old/New time window there were no meaningful group differences in the mean amplitudes (i.e., Group X Condition or Group X Region X Condition interactions) or the standardized difference t-scores between the Honest Response and the Simulated Memory Malingering groups. Similarly, no meaningful group differences in mean amplitude, or standardized difference t-scores of the ERP responses were present during the late parietal Old/New time window of the Recent Long-term task. Thus, whatever the task characteristics were that contributed to the lower behavioural accuracy and attenuated ERP Old/New positivity effects on the Recent Long-term task, those characteristics appeared to have a similar impact on both the Honest Response and the Simulated Memory Malingering groups.

There are a number of test characteristics and parameters that may have contributed to the increased difficulty of the Recent Long-term memory task that were discussed previously in Experiment 1, including the serial presentation “YES/NO” response format, study time, etc. It is also possible that incidental learning contributed to the lower behavioural accuracy and the attenuated ERP Old/New positivity effects in the Recent Long-term task. Incidental learning refers to the unplanned learning of information that was acquired while engaging in another activity. In the study phase of the Recent Long-term task used in this thesis, the instructions (as per the original Warrington instructions) were to make a subjective judgment (i.e., pleasant or unpleasant) about each of the faces. The participants were told they were being given a memory test; however, they were not explicitly instructed to "remember" the faces. Incidental learning conditions have previously been shown to decrease behavioural accuracy and attenuate ERP Old/New effects on tasks of recognition memory (Noldy, Stelmack, & Campbell, 1990). In an ERP study comparing intentional and incidental memory for words and pictures task, Noldy et al. (1990) showed that incidental learning resulted in decreased behavioural accuracy relative to intentional learning. Further, they found that incidental learning also resulted in attenuated recognition memory ERP Old/New positivity effects between 220 ms to 450 ms (frontal and centro-parietal regions) but not between 480 ms to 700 ms (parietal regions).

The extent to which incidental learning contributed to the behavioural and ERP results of the Recent Long-term task in this thesis, however, is unclear. Typically, incidental learning tasks have participants engage in tasks that reduce attention or effortful processing of the incidental information. However, the "alternative" task used in the Recent Long-term task in this thesis (and in the Warrington's faces task) directly involved making decisions about the faces that increased the depth of processing of the"incidental" stimuli. Increased depth of processing has been associated with increased magnitude of the late parietal Old/New positivity effect (Yonelinas, 2002). Further, in the Noldy et al. (1990) study, the late parietal Old/New effect was not different between incidental and intentional learning conditions. Thus, any impact of incidental learning on this task would likely have been limited to the early frontal ERP Old/New positivity.

Although fewer individuals showed Old/New positivity effects on the Recent Long-term task than on the other tasks, the results from this experiment showed that a similar number of individuals from the Honest Response and Simulated Memory Malingering groups showed an early frontal and a late parietal Old/New positivity effect using either the serial t-score method or the Wilcoxon method. For example, using the Wilcoxon method 58.8% of the Honest Response group and 55.6% of the Simulated Memory Malingering group showed an early ERP Old/New difference wherein ERP responses to Old faces were more positive in amplitude than ERP responses to New faces. For the late Old/New time window, 82.4% of the Honest Response group and 61.1% of the Simulated Memory Malingering group showed the Old/New positivity effect. The combined sensitivity values of the ERP responses on the Recent Long-term task were 57.1% for the early Old/New ERP effect and 71.4% for the late Old/New ERP effect. Although the percentage of individuals showing Old/New positivity effects on this task was relatively low compared to the other tasks, it is consistent with the unintended increased difficulty level of this task. This evidence further bolsters the notion that whatever variable was contributing to the relatively poor ERP performance on the Recent Long-term task (e.g., task difficulty) it did so for both the Honest Response and the Simulated Memory Malingering group equally.

4.2.3 Remote Long-term Memory

The Remote Long-term memory task was previously described Experiment 1. In brief, participants were asked to discriminate between personally well-known faces and New faces. Behaviourally, it was expected that the Simulated Memory Malingering group would be less accurate and take longer to respond than the Honest Response group. It was also hypothesized that ERP responses to well-known and to New faces during the early and late Old/New time windows would not differ between the Honest Response and the Simulated Memory Malingering groups.

As expected, the overt behaviour of the Simulated Memory Malingering group was less accurate than the Honest Response group at correctly identifying both well-known and New faces. The group differences in accuracy were greater for the well-known faces than for the New faces. A similar pattern was also shown for reaction times. The Simulated Memory Malingering group demonstrated longer reaction times to both well-known and New faces than the Honest Response group, with the reaction time discrepancy being greater for well-known faces than for New faces. Given the lack of coaching or instruction as to the typical impact of a brain injury on memory, these group differences are in keeping with what would be expected from individuals attempting to feign a memory impairment who were naïve to the relative sparing of remote long-term memory following a brain injury.

With respect to the ERP responses, there were no differences between the ERP responses of the Honest Response and the Simulated Memory Malingering groups for magnitude or distribution of the early or the late Old/New positivity effects on the Remote Long-term memory task. This result is important for demonstrating the robustness of Old/New positivity effects for remote long-term memory, even under conditions of malingered memory impairment. Similar to the results of the Short-term task described above, the ERP results of the Remote Long-term task are again in direct contrast to the reduced ERP Old/New positivity effects between Honest and Malingering groups reported by Vagnini et al. (2008) and provide additional evidence of the independence of ERP Old/New positivity effects from behavioural attempts to feign a memory impairment. The reduced late parietal Old/New positivity effect for the Malingering participants in the Vagnini study is perplexing. Task difficulty does not appear to be an important factor, as appeared to be the case in the present experiments, as the Honest participants' overall accuracy was reported to be greater than ninety percent. One possible explanation for their findings may be in the extent to which the malingering participants were actively attentive or engaged in the task. By not attending to test items during the study phase, it could be plausible to see a reduced / absent late parietal Old/New positivity effect in the test phase of a recognition memory task.

From the perspective of performance at the individual level, the present experiment showed that a similar number of individuals from the Honest Response and Simulated Memory Malingering groups showed both early and late Old/New positivity effects on the Remote Long-term task. This result was the same for comparisons based on the mean amplitude of the ERP responses or for comparisons based on the difference serial t-score values. Similar to the results of the Short-term task, a relatively high percentage of individuals showed ERP Old/New positivity effects on the Remote Long-term task, particularly for the late Old/New positivity effect. For example, using the Wilcoxon method 82.4% of the Honest Response group and 83.3% of the Simulated Memory Malingering group showed an early ERP Old/New difference. During the late

Old/New time window of the Remote Long-term task 100.0% of the Honest Response group and 94.4% of the Simulated Memory Malingering group showed the Old/New positivity effect. The combined sensitivity values of the ERP responses on the Remote Long-term task were 82.9% for the early Old/New ERP effect and 97.1% for the late Old/New ERP effect. This result shows promise for the use of ERP responses to study memory functioning at the level of an individual examinee.

4.2.4 General Summary

An important goal of this thesis was to compare the performances of the Honest Response and Simulated Memory Malingering groups across the three different recognition memory tasks, with the Honest Response experiment serving as a control condition. With respect to the behavioural performances, the Simulated Memory Malingering group was expected to be less accurate and to have longer reaction times than the Honest Response group across all three tasks. By and large, the data were in line with the expectations. The Simulated Memory Malingering group was less accurate than the Honest Response Group in their responses across all three tasks. However, the group differences were larger for the responses to Old faces than to New faces. In addition, the Recent Long-term memory task differed from the other two tasks in that group differences in behavioural accuracy were only present in responses to Old faces and not in responses to New faces. The pattern of group differences in reaction times mimicked the pattern for the accuracy responses, with the Simulated Memory Malingering group taking longer to respond to both Old and New faces on all tasks except the Recent Long-term memory task. The groups were statistically similar in their reaction times to New faces on the Recent Long-term task.

The behavioural results suggest that when attempting to feign a memory impairment, the Simulated Memory Malingering group may have used a strategy that was dependent upon their ability to discriminate between Old and New faces. For example, when the Simulated Memory Malingering participants encountered more difficult discrimination decisions about whether a face was New or Old (i.e., Recent Long-term task) they targeted Old faces for decreased accuracy. However, when they felt more discriminating between the task stimuli was not as difficult (i.e., Short-term and Remote Long-term tasks) they targeted both Old and New faces, although a greater emphasis on Old faces still remained.

The advantage to Old faces and the targeting of Old faces by the Simulated Memory Malingering group on more difficult Old/New discriminations could be explained by processing associated with familiarity. The early frontal Old/New positivity effect is typically associated with familiarity in studies of recognition memory (Mecklinger, 2000; Schloerscheidt & Rugg, 2004). As such, Old faces begin to be recognized by the brain as “Old” during the early Old/New time window, whereas the classification of a new face as “New” presumably occurs during the late Old/New time window that is typically associated with recollection. With respect to reaction times, this earlier recognition would allow an earlier generation of processing related to the behavioural response of an item, thus resulting in faster reaction times to Old faces compared to New faces. With respect to feigning a memory impairment, the earlier recognition of an Old face as being Old would allow for more time to inhibit the initial correct behavioural response and to decide whether to proceed with the correct response or to deliberately respond in error. Based on these arguments, one would expect to see longer reaction times by the Simulated Memory Malingering group for both correctly identified Old faces and New faces. This is what was found. One might also expect a greater emphasis on strategically determined responses to Old faces, especially when the discrimination difficulty level of the task was harder. This would be expected because a face must be classified as being Old or New prior to deciding whether or not to proceed with the correct response or the malingered response and as suggested above, the recognition of Old faces would begin earlier than the recognition of New faces. In the present experiment Old faces were targeted for malingering by the Simulated Memory Malingering group on the relatively more difficult Recent Long-term memory task was indeed the case.

For the ERP responses during the early frontal Old/New time window, the magnitude of the early Old/New positivity effect was statistically similar between the Honest Response and the Simulated Memory Malingering groups when compared across all three tasks. Similarly, no significant group differences were observed during the late parietal Old/New window for the magnitude of the late Old/New positivity effect. This finding is in keeping with the results from previous ERP studies that found no differences between Control and Malingering groups in the magnitude and distribution of ERP recognition memory Old/New positivity effects during the 250 to 1000 ms time window (Tardif et al., 2000; Tardif et al., 2002) and directly contrasts with the previous report by Vagnini and colleagues in which Old/New positivity effects were reported as absent and thus significantly smaller for a Malingering group relative to a control group (Vagnini et al., 2008). The lack of differences in ERP responses between the Honest Response and the Malingering groups in the present experiment further strengthens the association of these ERP reponses with recognition memory processing. That is, successful recognition memory, regardless of the behavioural response, is associated with Old/New positivity effects (specifically the late parietal Old/New positivity). It also provides additional validation for the use of the late Old/New ERP response to evaluate memory functioning in the context of a clinical assessment. The observation of a late parietal Old/New positivity effect in an individual unable to provide verbal or motor responses could be used to infer intact recognition memory.

In summary, the results of the Short-term and the Remote Long-term tasks demonstrated that memory functioning could be assessed based on the ERP responses of the brain alone, regardless of the behavioural responses to the task. Unfortunately, the Remote Long-term memory task did not elicit the expected ERP results. That is, the procedure simply did not work as intended for either Experiment 1 or Experiment 2. Further study of task parameters to increase the discriminability of the stimuli on the Recent Long-term task is warranted to improve its clinical utility. Such parameters might include increased stimulus duration times in the study phase or providing more direct memory instructions.

There is an important distinction that must be made between using ERP responses from recognition memory tasks to assess memory functioning and using ERP responses to classify someone as a cognitive symptom exaggerator. The results of the present set of experiments did provide evidence of ERP Old/New positivity effects as markers of recognition memory. However, a reliable ERP response specific to Simulated Memory Malingering was not observed in the present set of experiments. This raises an important caveat when the context of a clinical assessment is primarily for the purpose of detecting neurocognitive malingering. In such situations, the Old/New ERP responses that appear during tasks such as those used in the present set of experiments will simply provide evidence that recognition memory processes are functioning. Although not a specific marker of neurocognitive malingering, the ERP responses are complimentary to the behavioural responses and add credibility to suspicions of neurocognitive malingering based on the behavioural responses. That is, the observation of a late parietal ERP Old/New positivity effect in conjunction with low behavioural accuracy would be suggestive of malingering.

Although a marker of neurocognitive malingering was not identified in this thesis, it does not necessarily mean that none exists. It is possible that a single specific ERP marker of neurocognitive malingering does not exist. Rather it is more likely that a combination of ERP components (e.g., ERP responses associated with attention and memory) and behavioural components will be more effective in identifying neurocognitive malingering. In addition, as the results of the Recent Long-term memory task suggest, any markers are also likely to depend upon task parameters that influence the discriminability between Old and New stimuli. For example, the Simulated Memory Malingering participants' efforts at malingering shifted from targeting both Old and New faces to targeting Old faces as the discrimination between Old and New faces became more difficult. In other words, an electrophysiological marker of malingering may be difficult to detect because the behavioural strategies for malingering may manifest differently on different types of recognition memory tasks. This may explain why other studies, such as those by Tardif and colleagues that used only one type of recognition memory task paradigm across different studies found consistent differences between their

Honest Response and Simulated Memory Malingering groups (Tardif et al., 2000; Tardif et al., 2002). Further examination of the relationships between task parameters and neurocognitive malingering will be important for furthering our understanding of cognitive markers of neurocognitive malingering. A critical comparison group in such studies, however, will be the inclusion of patient populations with documented memory impairments. Such research will be important to increase the confidence in the use of ERP responses in the clinical setting.

CHAPTER 5 DISCUSSION

The major focus of this thesis was to compare the early frontal ERP Old/New positivity effect (associated with familiarity) and the late parietal ERP Old/New positivity effect (associated with recollection) on recognition memory tests of Short-term memory, Recent Long-term memory, and Remote Long-term memory. In addition this thesis sought to compare the ERP responses and the behavioural responses from a group of participants who performed the tasks in the standard, honest way with a healthy group that was simulating a memory impairment.

In the Honest Response experiment (Chapter 2) ERP Old/New positivity effects were elicited during the time windows associated with both familiarity (the early frontal Old/New window) and recollection (late parietal Old/New window) for the Short-term memory and the Remote Long-term memory tasks. Contrary to expectation, weaker and mixed ERP results were observed on the Recent Long-term memory task. Interestingly, the weak ERP effects were associated with weak sensitivity to discriminating Old from New faces in the behavioural accuracy of the Honest Response participants. Total percent correct scores for the Honest Response participants was 98% on the Short-term and 99% on the Remote Long-term task, but a score of only 69% was obtained on the Recent Long-term task.

In the Simulated Memory Malingering experiment (Chapter 3) a similar pattern of ERP Old/New positivity effects for the time windows associated with familiarity and recollection was observed for the Short-term and the Remote Long-term memory tasks, and no significant ERP Old/New positivity effectswere elicited in the Recent Long-term task. As expected, the behavioural accuracy of the Simulated Memory Impairment participants was significantly lower than the accuracy of the Honest Response participants. The pattern of ERP across tasks was again paralleled by differences in the behavioral responses. The Simulated Memory Malingering group obtained total percent accuracy scores in the Short-term and the Remote Long-term tasks of 66% and these means were statistically higher than the 54% total accuracy score obtained on the Recent Long-term task. Importantly, a comparison of the ERP results from the two groups of participants showed that the recognition memory ERP Old/New positivity effects generally did not statistically differ between the Honest Response participants and the Simulated Memory Malingering participants, despite significant differences in the behavioural accuracy scores and reaction times.

5.1 ERP Old/New Positivity Effects and Honest Response Behaviour

This thesis provides one of the first systematic comparisons of ERP recognition memory Old/New positivity effects to faces on tasks of Short-term, Recent Long-term and Remote Long-term memory. The observed Old/New positivity effects during the time windows associated with familiarity and recollection were consistent with the ERP recognition memory literature using both auditory and visual stimuli (Friedman & Johnson, 2000; Mecklinger, 2000; Rugg, 1995; Rugg & Curran, 2007) and with the results of ERP recognition memory studies to faces (Barrett et al., 1988; Eimer, 2000; Joyce & Kutas, 2005; Nessler et al., 2005; Paller et al., 1999; Paller et al., 2000; Paller et al., 2003; Schweinberger et al., 1995; Schweinberger et al., 2002).

The Remote Long-term task was of particular interest to this thesis given the lack of ERP studies of Remote Long-term memory for personally relevant information. The late parietal ERP Old/New positivity effect was large in magnitude but deviated somewhat from the typical late parietal Old/New positivity effect in that it was widely distributed across the scalp. Although ERP responses over a given area of the head do not necessarily represent brain activity in areas directly beneath the recording electrode, this widespread distribution is in keeping with combined MRI and neuropsychological data indicating that recollection of remote (and autobiographical) long-term memory is widely distributed throughout the cortex and is particularly dependent upon frontal, lateral temporal, and occipital regions (Bayley et al., 2005).

With respect to theoretical models of memory organization this thesis provided a novel comparison of recognition memory ERP Old/New correlates of Remote Long-term recognition memory with Short-term and Recent Long-term memory. The ERP results of this thesis suggest that similar electrophysiological mechanisms (i.e., Old/New positivity effects) are mediating recognition memory retrieval-related processing for familiarity and recollection across the different types of memory tasks. This observation may provide a bridge between unitary models of memory organization which postulate that both short-term and long-term memory are dependent upon the same neural structures (Jonides et al., 2008; Nairne, 2002; Ranganath & Blumenfeld, 2005) and multi-modal models that compartmentalize these different types of memory into distinctly separate systems (Repovs & Baddeley, 2006). That is, what is "unitary" between the different types of memory is the neurophysiological mechanism involved (i.e., Old/New positivity effects), albeit one that can be generated from multiple sources in the brain. For example, as ERP responses reflect a summation of postsynaptic potentials from synchronously firing neurons, it is possible that such synchrony arises during the recognition process to the degree that the memory trace for features of recently experienced event (such as an Old face) matches with previously stored electrophysiological "cues" of that event. In other words, ERP responses may provide the mechanism by which the "matching" process postulated by unitary models of memory organization occur. However, consistent with multi-component models of memory organization, this electrophysiological mechanism could be produced from several different neuroanatomical substrates that have been associated with different types of memory (Bayley et al., 2005).

One important difference between most ERP studies of recognition memory and this thesis was that ERP effects were evaluated without reference to the overt behavioural response provided by the participants. This method simulates impaired overt communication and has been previously used in studies that have adapted neuropsychological tests for recording electrophysiological responses (Connolly & D'Arcy, 2000). The ERP results from the Short-term and the Remote Long-term memory tasks used in this thesis show promise for additional studies of ERP recognition memory responses in clinical populations with impaired communication skills and/or memory skills who may be difficult to test using standard neuropsychological measures. Studying the ERP Old/New effects in clinical control groups with demonstrated memory impairments for Short-term versus Recent Long-term versus Remote Long-term memory will be particularly important. In addition, further study of the procedural changes incurred adapting the Recent Long-term task in this thesis for ERP recording appears to be warranted. Ideally, the accuracy scores on the Recent Long-term task should be closer to those of the Short-term and the Remote Long-term tasks. However, the Recent Long-term memory task in this study still provides important insight into the relationship between behavioural performances on memory tests and ERP Old/New responses.

5.2 Recognition Memory and Simulated Memory Malingering

The recognition memory ERP Old/New positivity effects from the Simulated Memory Malingering group were statistically equivalent to the ERP responses of Honest Response group. In other words, recognition memory ERP Old/New positivities were elicited to the same extent in the Simulated Memory Malingering group as the Honest Response group in spite of the former group's instruction to feign a memory impairment. Comparisons with respect to previous ERP studies of memory malingering were discussed in more detail in Chapter 4.

The application of neuroimaging methodologies to detect “deception,” “lying,” “malingering,” or “neurocognitive malingering” is not without controversy (Sip, Roepstorff, McGregor, & Frith, 2008; Wolpe, Foster, & Langleben, 2005). For example, Sip et al. (2008) have described a number of issues that arise when attempting to interpret studies that use neuroimaging to detect deception, including reverse inferences, identification of effects at the individual level, and contextual factors influencing behaviour.

The problem of reverse inferences refers to the functional attribution of brain activity as a marker of neurocognitive malingering. Most neuroimaging studies of neurocognitive malingering have the goal of identifying a “marker” of deception or neurocognitive malingering. However, the search for such a cognitive marker will likely be as enigmatic as Lashley’s attempts to localize memory in the brain (Lashley, 1950). This is because being deceptive is not a discrete well-defined cognitive process, but rather one that relies on several other cognitive processes. For example, in this thesis ERP responses were recorded from participants who were instructed to feign a memory impairment while performing different tasks of recognition memory. Deceptive responding has been theorized to be more cognitively challenging than honest responding (Stelmack, Houlihan, & Doucet, 1994) given the additional effort and executive control that would be required for generating deceptive responses (Johnson, Barnhardt, & Zhu, 2004). Feigning a memory impairment could thus be expected to depend upon processing associated with attention, executive functioning (i.e., controlling how and when to respond) including response planning, response monitoring, and response inhibition, as well as processing associated with memory and emotions. As predicted, ERP Old/New positivity effects that are typically associated with recognition memory processing were observed in the ERP responses of the participants. As was previously discussed in Chapters 3 and 4, the presence of early frontal and late parietal ERP Old/New positivity effects *does* provide direct evidence of normal ERP responses associated with recognition memory. However, to interpret these ERP effects as markers of neurocognitive malingering would require a reverse inference from the ERP responses that could not be supported on the basis of the ERP responses alone. The ERP response can demonstrate that memory recognition processes are active, but an individual may fail to behaviourally respond accurately for other reasons, malingering being just one possible reason. Even for individuals where it is known that behavioural deception is occurring, observation of brain activity associated with attention, response monitoring, or memory is simply an association. Hence, detecting malingering should rely on information from multiple sources, with ERP Old/New positivities representing one important variable in the equation used to detect malingering. Other important variables will include both psychometric (e.g., reaction times, response accuracies) and psychosocial factors (e.g., emotional state, attitudes and beliefs, potential gains and risks for the behaviour).

The second issue identified by Sip et al. (2008) is the problem of applying neuroimaging findings observed at the group level to individual cases. This thesis showed that Old/New differences in ERP responses observed at the level of the group average were also reflected at the level of the individual, and replicates similar findings from previous ERP adaptations of neuropsychological tests (Connolly et al., 1999a; Connolly et al., 2006; Connolly et al., 1999b). From an individual perspective, this finding is critical to using neuroimaging methods for assessment of behaviour. Effects that can only be observed at group levels have limited utility for individual assessment of cognitive behaviour. In addition, as the magnitude of the ERP responses differed across recognition memory tasks, there is the potential issue of how to classify an individual who does not show the expected ERP response despite behavioural accuracy scores indicating good recognition memory. Although when behavioural responses are available, ERP responses are less likely to be examined. Iin the event that both ERP and behavioural responses are available, and in the absence of factors to suggest suboptimal effort, giving more weight to the behavioural response would appear prudent. However, as ERP recordings are more likely to be used in situations where overt behavioural responses are unavailable (Connolly et al., 1999b), it also highlights the potential for communication-impaired individuals with intact recognition memory functioning to be misclassified as having impaired memory. The demonstrated sensitivity rates of at least the Short-term and the Remote Long-term tasks suggest that a relatively small percentage of cases would be misclassified this way.

The third issue identified by Sip et al. (2008) is that of ecological validity. Ecological validity refers to the extent to which results obtained in the laboratory setting are representative of real life experience. With respect to the study of "lying," such as may occur in studies of deception or studies of neurocognitive malingering, Sip et al. argue that providing participants with explicit instructions to "lie" removes two crucial components of deception by removing the moral sanctions against lying and by removing the need for decision making under conflict. Their argument has merit; however it must be placed within the context of the scientific study of psychological (and neuropsychological) constructs. Research in psychology seeks to learn about human responses to situations that have been created experimentally. In psychological research there will always be a balancing act between ecological validity and the scientific control of experimental variables. In the present thesis, a number of measures were taken to try and achieve this balance. For example, in the Simulated Memory Malingering experiment (Chapter 3) participants were asked to feign a memory impairment that would have resulted from a brain injury, even though they were feeling well. However, they were not explicitly instructed to "lie" nor were they coached on how to "appear" impaired. To further enhance the ecological validity of the paradigm, the participants were provided with an additional monetary incentive that they were told would be contingent upon the successful demonstration of impaired memory. Hence participants were not restricted in their choice of whether to display a memory impairment. Specifically, participants were not told they *must* feign a memory impairment nor were they restricted in their choice of strategy for malingering the memory impairment. Instead they were simply told that the additional monetary compensation was dependent on their skill at malingering a memory impairment. As a result, the overall group performance most likely represents a heterogeneous set of response strategies.

Contextual factors refer to social and environmental variables that contribute to the attitudes and beliefs that one may have about being deceptive in a given situation. Although these factors were not explicitly measured in the present thesis, many of them have already been identified with respect to the exaggeration of cognitive symptoms in clinical neuropsychological assessments. Important factors include attitudes towards coaching clients for neuropsychological assessments by those in legal profession (Victor & Abeles, 2004), attitudes of caregivers towards individuals with cognitive complaints (Chodosh et al., 2004), and the availability of primary and secondary gains (Strauss, Sherman, & Spreen, 2006). In the present thesis, monetary gain was used as a factor to enhance the ecological validity of the malingering manipulations. Interestingly, none of the participants declined to participate as a result of being instructed to feign a memory impairment.

One final caveat in the use of cognitive ERP for the clinical assessment of memory functioning relates to the type of memory being assessed. The tasks used in the present thesis are all measures of recognition memory. Recognition memory testing represents a form of "cueing" for the information to be recalled. When learning new information is severely impaired, cueing typically will provide no benefit to the retrieval of previously studied information. However, brain injury does not always affect free recall and recognition memory equally. For example, memory impairments associated with multiple sclerosis (Winkelmann, Engel, Apel, & Zettl, 2007) and anterior communicating artery strokes (Parkin & Leng, 1993) are commonly characterized by impaired free-recall but intact recognition memory. In other words, the presence of recognition memory ERP Old/New positivity effects again will provide evidence of intact recognition memory, but does not necessarily preclude the presence of memory difficulties for the free recall of information. Nonetheless, ERP Old/New positivity effects would still provide valuable inferences about recognition memory that otherwise may not be detectable by clinical judgment based on subjective behavioural observations.

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Appendix A

Although the recognition memory Old/New effects were the primary focus of this experiment, the early sensory ERP responses were also analyzed. Although no significant ERP Old/New effects were observed, a reversal in polarity for the 100 ms time window and 150 ms time window components was observed. Early visual components during the 100 ms and 150 ms time windows have been associated with processes related to visual attention / arousal and visual perception respectively (for a review see Key et al., 2005). Although the exact mechanism driving this reversal is unclear, this pattern of reversal has been reported previously in ERP studies of face perception during both the 100 ms time window (Rossion et al., 1999) and the 150 ms time window (Joyce & Rossion, 2005). In addition, this reversal can be seen in the waveform morphology of other studies of recognition memory for faces that did not specifically address early ERP responses, (e.g. Paller et al., 2003).

Supplementary ERP component analyses from Experiment 1: Honest Response (HR).

Short-term memory task (Experiment 1)
Time windows for the early ERP components were identified as follows: 100 ms time window (65 to 115 ms), 150 ms time window (115 to 175 ms), N200 (175 to 275 ms). Supplementary analyses of these time windows are presented below.

Table A1. 100 ms time window of the Short-term memory task, for Experiment 1 (Honest Response). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 100 ms time window (65 to 115 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.43	.520	0.48	.498
REGION (R)	(7,112)	36.60	**.000†**	35.69	**.000†**
C x R	(7,112)	1.03	.388†	0.95	.426†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Upon inspecting the waveforms on the short-term memory task it is clear that very small ERP negative deflecting ERP response in the 100 ms time window at frontal regions reverses polarity over parietal cranial regions in the same time window. The category-based RM-ANOVA for the 100 ms time window showed no Old/New effects, but a main effect of Region was observed for the 100 ms time window. Bonferroni adjusted pair-wise comparisons for Region showed that the mean amplitudes at the frontal regions were more negative in amplitude than those in the temporal, central, and parietal regions during the 100 ms time window. The accuracy-based RM-ANOVAs for the 100 ms time window showed similar results to the category-based comparisons.

Table A2. 150 ms time window of the Short-term memory task, for Experiment 1 (Honest Response). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 150 ms time window (115 to 175 ms).

		Category-based		Accuracy-based	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.002	.610	0.005	.946
REGION (R)	(7,112)	4.16	**.016†**	4.13	**.017†**
C x R	(7,112)	0.872	.451†	0.81	.487†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The ERP response during the 150 ms time window at frontal regions reversed polarity over parietal cranial regions in the same time window. The category-based RM-ANOVAs for the 150 ms time window showed no Old/New effects, but a main effect of Region was observed for the 150 ms time window. Bonferroni adjusted pair-wise comparisons for Region showed that the difference in mean amplitudes was greatest between the frontal and the parietal regions for the 150 ms time window. The accuracy-based RM-ANOVAs for the 150 ms time window time windows showed similar results to the category-based comparisons.

Table A3. N200 window of the Short-term memory task, for Experiment 1 (Standard Response). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the N200 time window (175 to 275 ms).

		Category-based		Accuracy-based	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	.017	.899	0.00	.984
REGION (R)	(7,112)	24.96	**.000†**	25.35	**.000†**
C x R	(7,112)	6.78	**.001†**	7.09	**.000†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The N200 was most prominent at the frontal regions and was observed in the waveforms for both Old and New faces. The category-based RM-ANOVA for the N200 mean amplitudes showed a main effect of Region and a significant Condition X Region interaction, but no overall Old/New differences. Bonferroni adjusted pair-wise comparisons of the mean amplitudes for each region showed the frontal regions to be significantly more negative than the amplitudes over the parietal regions. A Wilcoxon signed-rank post-hoc analysis of the paired Old/New differences at each region showed no significant Old/New differences at any of the regions (i.e., the Condition x Region interaction resulted from a non-meaningful difference of Old faces at one region from New faces at a different region). Both of these N200 effects were also shown in the accuracy-based RM-ANOVA.

Recent Long-term Memory Task (Experiment 1)

Time windows for the early ERP components from the Recent Long-term task in Experiment 1 were identified as follows: 100 ms time window (65 to 115 ms), 150 ms time window (115 to 160 ms), N200 (175 to 250 ms).

Table A4. 100 ms window of the Recent Long-term memory task, Experiment 1 (Honest Response). Results from the Recent Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 100 ms time window (65 to 115 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.10	.92	0.29	.596
REGION (R)	(7,112)	51.72	**.000†**	42.42	**.000†**
C x R	(7,112)	3.23	**.03†**	1.03	.387†

(†Greenhouse-Geisser correction, sphericity < .75; ††Huynh-Feldt correction, sphericity > .75).

During the 100 ms time window a reversal in polarity (i.e., positive to negative) was observed in the ERP responses over parietal to frontal regions respectively. The category-based RM-ANOVA for the 100 ms time window showed a main effect of Region and a Condition X Region interaction. However, only the effect of Region remained in the accuracy-based RM-ANOVA.

Table A5. 150 ms window of the Recent Long-term memory task, Experiment 1 (Honest Response). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the 150 ms time window (115 to 160 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.91	.92	0.02	.902
REGION (R)	(7,112)	4.06	**.019†**	3.73	**.027†**
C x R	(7,112)	3.23	.237†	0.80	.489†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The category-based and the accuracy-based RM-ANOVAs for the 150 ms time window showed only main effects of Region. However, bonferroni adjusted pair-wise comparisons showed parietal regions being significantly more positive in amplitude than all other regions.

Table A6. N200 ms window of the Recent Long-term memory task, Experiment 1 (Honest Response). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the N200 time window (175 to 250 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.72	.41	0.08	.786
REGION (R)	(7,112)	21.40	**.000†**	20.08	**.000†**
C x R	(7,112)	0.45	.724†	0.63	.489†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The category-based and the accuracy-based RM-ANOVAs for the N200 window showed only a main effect of Region. Bonferroni adjusted pair-wise comparisons of the mean regional amplitudes for the N200 window showed that parietal cranial regions were significantly more positive in mean amplitude than all other cranial regions.

Remote Long-term memory task (Experiment 1)

Time windows for the early ERP components were identified as follows: 100 ms time window (65 to 115 ms), 150 ms time window (115 to 160 ms), N200 (175 to 250 ms).

Tables A7. 100 ms window of the Remote Long-term memory task, Experiment 1 (Honest Response). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 100 ms time window (65 to 115 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.01	.949	.13	.724
REGION (R)	(7,112)	54.99	**.000†**	56.12	**.000†**
C x R	(7,112)	0.80	.494†	1.01	.392†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A visual inspection of the grand average waveforms showed that the ERP response during 100 ms time window at parietal regions reversed polarity over frontal regions during the same time window. The category-based RM-ANOVAs for the 100 ms time window showed no Old/New differences between the waveforms, but a main effect of Region was observed for the 100 ms time window. Bonferroni adjusted pair-wise comparisons of the regional mean amplitudes showed the 100 ms time window responses at frontal and parietal regions were significantly different from each other and all other cranial regions. The accuracy-based RM-ANOVA produced statistically similar results to the category-based RM-ANOVA.

Table A8. 150 ms window of the Remote Long-term memory task, Experiment 1 (Honest Response). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 150 ms time window (115 to 175 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	1.16	.298	1.93	.184
REGION (R)	(7,112)	10.39	**.000†**	10.58	**.000†**
C x R	(7,112)	1.48	.236†	1.64	.198†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A visual inspection of the grand average waveforms showed that 150 ms time window components at parietal regions reversed polarity over frontal regions during the same time windows. The category-based RM-ANOVAs for the 150 ms time window showed no Old/New differences between the waveforms, but a main effect of Region was observed for the 150 ms time window. Bonferroni adjusted pair-wise comparisons of the regional mean amplitudes showed the 100 ms time window responses at frontal and parietal regions were significantly different from each other and all other cranial regions. For the 150 ms time window, the Region effect was shown to result only from significant differences between the parietal and temporal regions. The accuracy-based RM-ANOVA produced statistically similar results to the category-based RM-ANOVA.

Table A9. N200 window of the Remote Long-term memory task, Experiment 1 (Honest Response). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the N200 time window (175 to 275 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	0.49	.494	0.87	.366
REGION (R)	(7,112)	39.09	**.000†**	39.64	**.000†**
C x R	(7,112)	2.87	**.050†**	2.70	.060†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A negative peak during the N200 time window was observed over all regions, but appeared most prominently in frontal, central, and temporal regions (figure 5). The category-based RM-ANOVA found a main effect of Region and a Condition X Region interaction, but no main effect of Condition. A Wilcoxon signed-rank post-hoc analysis to accommodate the Condition x Region interaction did not show significant differences at any region. However this interaction was no longer significant when behaviour corrected waveforms were compared. Bonferroni adjusted pair-wise comparisons of the regional mean amplitudes showed that the N200 amplitudes were more negative in frontal than parietal regions.

Appendix B

Early ERP component analyses – Experiment 2: Simulated Memory Malingering (SMM).

Short-term Memory Task (Experiment 2)

Time windows for ERP components were identified as follows: 100 ms window (85 to 125 ms), 150 ms window (125 to 160 ms), N200 (165 to 270 ms).

Table B1. 100 ms window of the Short-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 100 ms time window (65 to 125 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.24	.631
REGION (R)	(7,119)	16.48	**.000†**
C x R	(7,119)	0.52	.681†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A reversal in polarity can be observed during the 100 ms time window, with frontal regions showing a negative deflection in the waveform, and posterior regions showing a positive deflection. The category-based RM-ANOVA for the mean amplitudes during the 100 ms time window only showed a significant effect of Region. A Bonferroni post-doc comparison showed that the regional differences between frontal and parietal regions were significant.

Table B2. 150 ms window of the Short-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 150 ms time window (125 to 160 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.17	.685
REGION (R)	(7,119)	0.50	.682†
C x R	(7,119)	0.52	.657†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

No significant differences in mean amplitudes were observed between the Old and New waveforms during the 150 ms time window on the category- RM-ANOVA.

Table B3. N200 window of the Short-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the N200 time window (165 to 270 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	1.48	.240
REGION (R)	(7,119)	11.16	**.000†**
C x R	(7,119)	2.63	.052†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The category-based RM-ANOVA of the N200 time window showed a main effect of Region but not Condition. Bonferroni adjusted pair-wise comparisons of the regional mean amplitudes showed that the N200 amplitudes were most negative over frontal, central, and temporal regions, and that while these regions were not significantly different from each other, all were significantly more negative than the parietal regions than parietal regions.

Recent Long-term Memory Task (Experiment 2)

Time windows for the early ERP components were identified as follows: 100 ms window (65 to 120 ms), 150 ms window (130 to 175 ms), N200 (210 to 310 ms).

Table B4. 100 ms window of the Recent Long-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Recent Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 100 ms time window (65 to 120 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.06	.811
REGION (R)	(7,119)	36.54	**.000†**
C x R	(7,119)	0.37	.739†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A reversal in polarity can be observed during the 100 ms time window, with frontal regions showing a negative deflection in the waveform, and posterior regions showing a positive deflection. The category-based RM-ANOVA for the mean amplitudes during the 100 ms time window only showed a significant effect of Region. A Bonferroni post-doc comparison showed that the regional differences between frontal and parietal regions were significant.

Table B5. 150 ms window of the Recent Long-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the 150 ms time window (130 to 175 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	1.24	.281
REGION (R)	(7,119)	1.58	.214†
C x R	(7,119)	1.31	.283†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

No significant differences in mean amplitudes were observed between the Old and New waveforms during the 150 ms time window in the category-based RM-ANOVA.

Table B6. N200 window of the Recent Long-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the N200 time window (210 to 310 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.55	.469
REGION (R)	(7,119)	32.18	**.000†**
C x R	(7,119)	0.95	.429†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

The category-based RM-ANOVA of the N200 time window showed only an effect of Region that reflected a reversal in polarity of the amplitudes in frontal regions (negative going deflection) to posterior regions (positive going deflection) during the N200 time window.

Remote Long-term Memory Task

Time windows for the early ERP components were identified as follows: 100 ms window (70 to 120 ms), 150 ms window (130 to 180 ms), N200 (185 to 285 ms).

Table B7. 100 ms window of the Remote Long-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 100 ms time window (70 to 120 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.45	.510
REGION (R)	(7,119)	39.70	**.000†**
C x R	(7,119)	.590	.638†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A visual inspection of the grand average waveforms showed that the ERP response during the 100 ms time window at frontal regions reversed polarity over parietal regions during the same time window. There were no visible differences between Old and New waveforms during this time windows. The category-based RM-ANOVA for the 100 ms showed only a main effect of Region. Bonferroni adjusted pair-wise comparisons of the regional mean amplitudes showed that frontal regions were significantly more negative in amplitude than all other regions, and that parietal regions were significantly more positive than all other regions.

Table B8. 150 ms window of the Remote Long-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 150 ms time window (130 to 180 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.02	.894
REGION (R)	(7,119)	2.19	.121†
C x R	(7,119)	0.48	.698†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A visual inspection of the grand average waveforms showed that the ERP response during the 150 ms time window frontal regions reversed polarity over parietal regions during the same time window. There were no visible differences between Old and New waveforms during this time window.

Table B9. N200 window of the Remote Long-term memory task, Experiment 2 (Simulated Memory Malingering). Results from the Remote Long-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the N200 time window (185 to 285 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	2.82	.112
REGION (R)	(7,119)	21.81	**.000†**
C x R	(7,119)	5.15	**.004†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

A negative deflection during the N200 time window was observed over all regions, but was most prominent over frontal, central, and temporal regions. The category-based RM-ANOVA found a main effect of Region ($F(7,119) = 21.81$, $p < .05$) and a Condition X Region interaction ($F(7,119) = 5.15$, $p < .05$), but no main effect of Condition. Bonferroni adjusted pair-wise comparisons of the regional mean amplitudes showed that the N200 amplitudes were most negative over frontal, central, and temporal regions, and that while these regions were not significantly different from each other, all were significantly more negative than the parietal regions than parietal regions. A Wilcoxon signed-rank post-hoc analysis to accommodate the Condition x Region interaction showed that responses to New faces were more negative than responses to Old faces over right frontal (10 of 18 participants showing a difference), left frontal (12 of 18 participants showing a difference), right central (14 of 18 participants showing a difference), left central regions (13 of 18 participants showing a difference).

ERP components during this time window fall within the class of "N2" components. For visual stimuli, anterior negativities during this time window have been associated with the cognitive processing for the (1) detection of novel stimuli or stimuli that deviate from a predominant mental template (i.e., the visual mismatch negativity (Winkler, Czigler, Sussman, Horvath, & Balazs, 2005) or N2b), and (2) the cognitive control of one's response strategy (i.e., no-go N2), while posterior negativities have been associated with visual attention and a separate index of stimulus classification from the anterior visual MMN (i.e., the posterior N2 or N2c); (for review see, Folstein & Van Petten, 2008). In the present experiment, ERP responses to New faces were more negative in amplitude than the ERP responses to Old faces with a fronto-central distribution. Given the equal probability of Old and New faces in the present experiment, the N2 Old/New difference may be best explained in relation to the N2 components associated with cognitive control such as the no-go N2. Cognitive control has been defined in terms of response inhibition and monitoring / managing response conflict and response errors (Folstein & Van Petten, 2008). For example, in go/no-go paradigms trials for which participants must inhibit a preplanned response (i.e., no-go trials) result in an ERP responses that are more negative than ERP responses on go trials.

The notion of cognitive control is particularly relevant to the current experiment given that participants must engage in monitoring and regulating their responses as they feign a memory impairment. Given that it is the inhibition of a response that is thought to generate the no-go N2, one might expect that ERP responses to Old faces would show the no-go N2 effect in individuals malingering a memory impairment. However, in the present study it was the ERP responses to New faces that showed a greater negativity during the no-go time window. An explanation for this observation can be found in the behavioural responses on this task. Participants' attempts to feign a memory impairment on this task appeared to focus on Old faces rather than New faces (i.e., more misses than false alarms). Given that (1) participants were intentionally malingering a memory impairment, and (2) that this strategy was used predominantly for Old faces one might argue that on trials with New faces, participants had to inhibit the planned response (i.e., respond in a contradictory fashion). As such, the fronto-central N2 Old/New difference in the present study may reflect a marker of neurocognitive malingering. Unfortunately, it does not appear to be a reliable marker as this difference was not consistently observed in the ERP responses from each of three tasks in this experiment, even though participants were presumably engaging in cognitive control processing for each of the tasks. For example, although a significant Condition X Region interaction was observed during the 200 ms time window of the Short-term memory task, this Old/New difference was characterized by ERP responses to *Old faces* being more negative in amplitude than ERP responses to New faces. Further, the Old/New difference from the Short-term task was significant over the right parietal region and not fronto-central regions. While it is possible that the negativity shift from new to Old faces on the Short-term task resulted from a change in the inhibition strategy used for the task, the discrepancy in the distribution of the difference between the Short-term and Remote Long-term tasks is more difficult to explain. Although promising, further examination of this time window in ERP studies of neurocognitive malingering is necessary to understand the relationship between ERP responses during this time window and neurocognitive malingering.

Also of interest was the finding of an effect during the 200 ms time window that has been previously associated with cognitive control processes. Thirteen of the 18 participants showed this difference at the right central region. As mentioned previously, the relationship of this 200 ms window effect with neurocognitive malingering is deserving of more study before labeled as a marker of neurocognitive malingering. However, its presence strongly suggests that an individual is engaging in strategies to monitor and regulate their response strategy to a task. It may be most likely however, that a combination of a 200 ms window effect and an Old/New effect are a more certain electrophysiological indication of neurocognitive malingering.

Appendix C

Supplementary ERP component analyses: the 400 ms time window. Experiment 1: Honest Response (HR).

400 ms time window

The early Old/New effect literature is characterized by both positive going and negative going ERP components during the 250 to 450 ms time period post-stimulus for characterizing differences between Old and new waveforms. In many studies, there appears to be a tendency to ignore the fact that the component they describe is typically a negative-going response for one category of stimuli. We have taken a different perspective from the majority of this work and have focused on the positive deflection in the waveform (occurring within the time window commonly reported for the early Old/New positivity effect). Although not a primary focus of this thesis, for the sake of thoroughness, the negative going deflection that comes between the early and late positive deflections was also analyzed. This negative going deflection is explicitly referred to by its exact timing to hopefully avoid any confusion with the well documented N400 component related to language functioning that occurs within the same time window.

400 ms time window - mean amplitudes on the Short-term memory task in Experiment 1 (Honest Response)

Table C1. Experiment 1 (Honest Response). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 400 ms time window (380 to 430 ms).

		Category-based		**Accuracy-based**	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	28.74	**.000**	30.60	**.000**
REGION (R)	(7,112)	35.35	**.000†**	34.12	**.000†**
C x R	(7,112)	5.85	**.002†**	7.30	**.000†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Table C2. Experiment 1 (Honest Response). Wilcoxon post-hoc analyses of the Condition X Region interaction during the 400 ms window of the Short-term memory task (p < .05).

Region	**z-score**	***n***
LF	-3.62	17
LT	-3.39	17
LC	-3.62	17
LP	-3.15	17
RF	-2.53	17
RT	-2.96	17
RC	-2.72	17
RP	-2.77	17

All of the participants showed a significant Old/New positivity effect during the 400 ms time window (at left frontal and left central regions). Fifteen of the 17 participants showed a significant late Old/New positivity effect (at left temporal and left central regions).

Relatively small negative going deflections for both Old faces and New faces were observed during the 400 ms time window (380 to 430 ms) separating the peaks for the early frontal and late parietal Old/New positivity effects. This negative deflection was present for New faces across all cranial regions, but for Old faces was most prominent over central and parietal regions. ERP responses to New faces were more negative in amplitude than to Old faces. The category-based RM-ANOVA showed main effects of Condition and Region, and a Condition X Region interaction. Bonferroni adjusted pair-wise comparisons of the mean amplitudes for each region showed a similar pattern to that observed for the early Old/New positivity effect in that responses were the least negative in the parietal regions relative to the other cranial regions. A Wilcoxon signed-rank post-hoc analysis of the Condition x Region interaction showed that responses to New faces were more negative than responses to Old faces over all regions, although z-scores over left frontal (17 of 17 participants) and left central regions (17 of 17 participants) were 1 standard deviation larger than the z-scores over the right frontal region. The accuracy-based RM-ANOVA showed statistically similar results to the category-based waveforms.

ERP responses to Old faces were also more positive than responses to New faces during the 400 ms time window. The differences during the 400 ms time window followed a pattern more similar to the early frontal Old/New time window than the late parietal Old/New time window.

400 ms window - mean amplitudes on the Recent Long-term memory task in Experiment 1 (Honest Response)

Table C3. Experiment 1 (Honest Response). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the 400 ms time window (375 to 640 ms).

		Category-based		Accuracy-based	
Effects	df	F	*P*	F	*P*
CONDITION (C)	(1,16)	**11.27**	**.004**	0.51	.868
REGION (R)	(7,112)	25.40	**.000†**	25.04	**.000†**
C x R	(7,112)	0.17	.922†	1.60	.199†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Negative going deflections were observed in the waveforms for both Old and New faces during the 400 ms time window (375 to 640 ms) more prominently over frontal, temporal, and central cranial regions. Old faces however, were more positive in mean amplitude than New faces during this time window. The RM-ANOVA showed main effects of Condition and Region, but no Condition X Region interaction. Bonferroni adjusted pair-wise comparisons showed frontal regions to be significantly more negative in mean amplitude than parietal regions. However, the accuracy-based waveforms (Figure 2.4) resulted in a reduced effect of condition compared to the category-based waveforms. The accuracy-based RM-ANOVA failed to show the main effect of Condition with only the Region effect remaining.

An Old/New positivity effect was also observed in the ERP responses to Old and New faces during the 400 ms time window of the Recent Long-term memory task. ERP responses to New faces were more negative than ERP responses to Old faces during this time window, with evidence of the largest differences over left frontal and left central regions. This was the same distribution pattern observed in the early Old/New time window of the Short-term memory task. The similar distribution and time proximity of these two ERP responses suggests that they may represent the same process, i.e., familiarity processing. However, the 400 ms time window ERP response in the Recent Long-term memory task was more closely related to the late Old/New response. One explanation for this could be that at that the negativity observed during the 400 ms window is simply a return in the direction of the baseline between the early mid-frontal effect and the later posterior effect. Thus depending on the time window sampled, the ERP response during the 400 ms window may share properties of either the early or the late Old/New positivity effect. Further investigation using higher density recording montages may be helpful in teasing apart the relationship between these responses.

400 ms window - mean amplitudes on the Short-term memory task in Experiment 2 (Simulated Memory Malingering)

Table C4. Experiment 2 (Simulated Memory Malingering). Results from the Short-term Memory task for category-based and accuracy-based RM-ANOVA analyses of mean amplitudes during the 400 ms time window (390 to 440 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	34.22	**.000**
REGION (R)	(7,119)	28.92	**.000†**
C x R	(7,119)	5.91	**.002†**

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Table C5. Experiment 2 (Simulated Memory Malingering). Wilcoxon post-hoc analyses to compare the mean amplitude of Old/New ERP responses at each region during the 400 ms window of the Short-term memory task (p < .05).

Region	**z-score**	***n***
LF	-3.07	15/18
LT	-3.33	15/18
LC	-3.72	18/18
LP	-3.72	17/18
RF	-2.64	15/18
RT	-2.33	16/18
RC	-3.72	18/18
RP	-3.68	18/18

Negative going deflections were observed for New faces but not Old faces during the 400 ms time window. New faces were significantly more negative in amplitude than Old faces. The category-based RM-ANOVA showed main effects of Condition, Region, and a Condition X Region interaction. Bonferroni adjusted pair-wise comparisons showed that mean regional amplitudes were most negative over temporal regions in comparison to all other regions. A Wilcoxon signed-rank post-hoc analysis to accommodate the Condition x Region interaction showed that responses to New faces were more negative than responses to Old faces over all regions, although the largest z-scores were observed over left central, left parietal, and right central regions (18 of 18 participants showing a difference).

A widely distributed Old/New positivity effect was also observed in the ERP responses to Old and New faces during the 400 ms time window of the Short-term memory task. Similar to the results in Experiment 1, ERP responses to New faces were more negative than ERP responses to Old faces during this time window. However, unlike the left fronto-central distribution observed in Experiment 1, the ERP responses of the 400 ms time window in this experiment showed evidence of the largest differences over left central-parietal and right central regions. This distribution was more similar to the distribution of the late Old/New positivity effect observed in this task than to the distribution of the early Old/New positivity effect. Although one might suggest that this difference is associated with neurocognitive malingering, it also supports our previous suggestion that the negativity observed during the 400 ms window is simply a return in the direction of the baseline between the early mid-frontal effect and the later posterior effect. As a result, the ERP response during the 400 ms window may share properties of either the early or the late Old/New positivity effect.

400 ms window - mean amplitudes on the Recent Long-term memory task in Experiment 2 (Simulated Memory Malingering)

Table C6. Experiment 2 (Simulated Memory Malingering). Results from the Recent Long-term Memory task for the category-based and accuracy-based RM-ANOVA analyses during the 400 ms time window (375 to 525 ms).

		Category-based	
Effects	df	F	*P*
CONDITION (C)	(1,17)	0.02	.896
REGION (R)	(7,119)	18.99	**.000†**
C x R	(7,119)	1.58	.205†

(†Greenhouse-Geisser correction (sphericity estimate < .75); ††Huynh-Feldt correction (sphericity > .75).

Negative going deflections were observed in the waveforms for both Old and New faces at all regions during the 400 ms time window (Figure 3.2). The category-based RM-ANOVA showed only a significant effect of Region for mean amplitudes during the 400 ms time window as frontal regions were more negative in amplitude than parietal regions.

No statistically reliable differences between the ERP responses to Old and New faces during the 400 ms time window could be detected. This finding was similar to that of both the early frontal and the late parietal Old/New windows.