Recognition memory impairments in temporal lobe epilepsy: The contribution of recollection and metacognition

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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ABSTRACT

Temporal lobe epilepsy (TLE) is a complex neurological condition associated with a variety of memory problems. This thesis attempted to elucidate the nature and extent of memory impairments further in this clinical group by drawing on dual-process theory of memory (Tulving, 1985; Jacoby, 1991; Yonelinas, 1994). This theory asserts that memory is subserved by two interrelated but independent memory processes. *Recollection* involves the vivid retrieval of contextual and associative information from memory. Conversely, *familiarity* involves recognition in the absence of this contextual information. The novel approach taken in this work was to compare paradigms that assess participants' objective and strategic use of these two processes with measures of people's subjective experience of their memory.

Chapter 2 set the scene by presenting the extent of objective memory impairment in the current patient sample by means of standardised neuropsychological testing. Chapter 3 – 5 assessed subjective and objective recollection in anterograde recognition memory tasks. Chapter 3 showed that patients' subjective experience of remembering may be driven by qualitatively different types of information to healthy adults. Chapter 4 demonstrated that patients were impaired in their strategic use of recollection and concurrently showed reduced levels of subjective remembering. This demonstrated that patients can be consciously aware of deficits in underlying cognitive processes contributing to memory performance. Chapter 5 specifically examined a metacognitive account of this recollection deficit. Patients were found to have impairments in a number of measures that index relational binding ability. However, their subjective confidence was assigned appropriately; they were lesser confident in their recognition judgments overall and adjusted this confidence in line with the difficulty of materials and task demands comparably to controls. Chapter 6 took a more naturalistic approach and assessed self-reported memory complaint as well as retrograde memory for salient public news events. As expected, people with TLE subjectively complained of dissatisfaction with their day-to-day to memory. The public events task revealed that although patients had reductions in subjective measures associated with recollecting the events, they were just as able as controls to accurately date the news items and monitor their memory for these. Chapter 7 found correlations between a variety of the subjective and objective recollection scores derived in the various tasks.

This thesis provides confirmatory evidence that memory impairment in TLE is characterised by disordered recollection and recollective experience. Several important theoretical and clinical applications of these findings are discussed.

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Abbreviations

AI – Associative Identification
AM – Autobiographical Memory
ANOVA – Analysis of Variance
BMIPB – BIRT Memory and Information Processing Battery
CPS – Complex Partial Seizures
EA – Epilepsy Action
EC – Entorhinal Cortex
EEG – Electroencephalography
F – Familiarity
FOK – Feeling-of-Knowing
FP – False Positive
G – Guess
HADs – Hospital Anxiety and Depression scale
JOL – Judgment of Learning
MRI – Magnetic Resonance Imaging
MTLE – Medial Temporal Lobe Epilepsy
MTT –Multiple Trace Theory
NART – National Adult Reading Test
PDP – Process Dissociation Procedure
PHc – Parahippocampal cortex
PRc – Perirhinal cortex
R - Remember/recollection
R/K – Remember/Know
ROC – Receiver Operating Characteristic
SD – Standard Deviation
SGTC – Secondary Generalised Tonic Clonic
SMC – Standard Model of Consolidation
SMF – Source Monitoring Framework
SPS – Simple Partial Seizure
TEA – Transient Epileptic Amnesia
TLE – Temporal Lobe Epilepsy
WASI – Wechsler Abbreviated Scale of Intelligence

1 Introduction

"I enter a friend's room and see on the wall a painting. At first, I have the strange, wondering consciousness, 'surely I have seen that before,' but when or how does not become clear. There clings to the picture a sort of penumbra of familiarity, — when suddenly I exclaim: 'I have it, it is a copy of part of one of the Fra Angelicos in the Florentine Academy' — I recollect it there! (emphasis added)"

(William James, 1890, p.658)

1.1 Overview

The above quote by William James illustrates how personal introspections on our mental happenings can be revealing about the underlying processes which govern our conscious experience. The terms he uses – recollection and familiarity – are now common parlance within the psychological literature. They are identified by some researchers as cognitive processes that contribute to memory performance (Jacoby, 1991; Yonelinas, 1994) and similar to James' description above, others view them as subjective states of consciousness that arise from a constellation of processes (Tulving, 1985, Gardiner, 2001). According to these *dual-process* theories, recollection involves the retrieval of qualitative information about a prior event, whereas familiarity is characterised by a feeling of oldness in the absence of such contextual information. Although recent research has provided compelling evidence for the existence of recollection and familiarity, the nature of the *relationship* between underlying cognitive memory processes and subjective experiences is still relatively unexplored.

The discipline of neuropsychology is well suited to this area. By definition, neuropsychology is concerned with examining the relationship between behaviour and cognition. Studying conditions in which there is a breakdown in some cognitive system contributes to our understanding not only of the architecture of the healthy brain, but also provides important understanding of the neuropsychological condition under investigation. This thesis takes such an approach, and uses temporal lobe epilepsy (TLE) as its basis.

The study of memory in TLE has a long history, but the application of empirically driven approaches, such as those briefly mentioned above, has not been so widespread. The main aim of this thesis was thus to provide added depth to our knowledge about memory impairment in this group using the dual-process theory of memory as an empirical framework. This was achieved by identifying behavioural aspects of memory in terms of separable processes, as well as exploring the conscious experiences associated with these. Therefore, the work makes a novel attempt at delineating the relationship between memory dysfunction and awareness in this patient group. This has important theoretical applications for the wider memory literature, and adds to ongoing clinical debate within the field of TLE.

This chapter first sets the scene by describing the clinical characteristics of TLE in more detail, including what has been learnt from traditional neuropsychological approaches over the years. Some of the major clinical questions in the TLE literature are then outlined, which further emphasises the rationale for the present research. Following this, a detailed review is presented of alternative dual-process theories, the measurement methods used throughout this thesis, and what has already been learnt from the application of these to TLE. The chapter ends with some clearly defined aims, based on this review of the literature.

1.2 Temporal lobe epilepsy

Epilepsy is a complex neurological condition characterised by recurring episodes of abnormally synchronized electrical discharges in clusters of neurons —commonly known as *seizures*. Temporal lobe epilepsy (TLE) is the name given to a heterogeneous group of disorders that share the same *focal* onset of these seizures, i.e. in the temporal lobes of the brain. Other types of focal, or partial-onset epilepsies exist, and are likewise determined by the lobe where the seizure activity begins; TLE is however, the most common of this class of epilepsy, and is estimated to comprise approximately 30-35% of all the epilepsies (Panayiotopoulos, 2005).

Based on recommendations by the International League Against Epilepsy, TLE can be further broadly divided by the anatomical regions of onset within this area of the brain; mesial TLE (MTLE) seizures originate in amygdalo-hippocampal areas, and lateral TLE seizures originate in more neocortical areas. The former is by far the most common, occurring in approximately two-thirds of cases, and of these, about 65% of patients have an aetiology of hippocampal sclerosis (Berg *et al*., 2010; Wolf *et al*., 1993). There are a variety of other causes however, including infectious diseases (e.g. encephalitis), cerebrovascular disorders (e.g. stroke), head trauma, tumours, and abnormal cortical development, among others.

Accurate diagnosis of TLE requires a synthetic approach, combining both subjective evaluation of seizure semiology and objective evidence from magnetic resonance imaging (MRI), electroencephalography (EEG) and neuropsychological evaluation. The primary overt clinical manifestations of TLE come in the form of simple partial seizures (SPS), complex partial seizures (CPS) and secondary generalised tonic clonic seizures (SGTCs). These terms are used to define the onset and relative spread of epileptic activity in the brain; SPS have a focal onset in the temporal lobe, and may or may not evolve into a CPS, where consciousness is impaired due to activity propagating throughout a network of brain regions. In SGTCs, consciousness is lost due to widespread neuronal discharge, including the motor cortex, which results in the convulsions that are most often associated with epileptic seizures.

Subjective ictal manifestations during SPS, sometimes referred to as 'auras', are experienced by more than 90% of TLE patients (Gloor, Olivier, Quesney, Andermann, & Horowitz, 1982). The most common of these are rising sensations in the stomach or gut (epigastric aura); experiential phenomenon (alterations of perception, thought, memory and affect); fear and panic; auditory hallucinations and olfactory or gustatory hallucinations. SPS can often quickly spread into CPS, and a number of objective ictal manifestations are visible to an observer. These include automatisms (semi-purposeful, coordinated involuntary motor activity), autonomic disturbances, speech disturbances and deviations of the head and eye. The careful assessment of these ictal features in early neurology by researchers such as Hughlings-Jackson (1888) suggested the dependence of human behaviour on activity in localised areas of the brain.

1.3 Temporal lobe seizures and memory

The crucial role of the medial temporal lobes (MTL) in human memory was provided in the classic work of Brenda Milner with the TLE patient HM throughout the latter twentieth-century (Milner, 1968; Scoville & Milner, 1957). However, certain mnestic characteristics of the ictal phase in TLE pointed towards the involvement of memory in the MTL much beforehand. As mentioned above, experiential symptoms are often encountered by patients during partial-onset seizures, and although disturbances in thought and cognition in general occur, other memory based phenomena are quite frequent. For example, the experiences of déjà vu (already seen), déjà vecu (already lived) or the 'dreamy state' were recorded early on by pioneers such as Hughlings-Jackson, and these investigations began linking the mnestic quality of these experiences directly to their origin in medial temporal areas. These alterations in normal cognitive processing are now thought to be a result of transient dysfunction of specific neuroanatomical areas responsible for separable memory processes (*see* Illman, Butler, Souchay, & Moulin, 2012, for a review). Although this is a topic of burgeoning interest in itself, the key point is that early observations of patients' memory 'illusions' or 'flashbacks' implied involvement of the temporal lobes in memory.

When consciousness is impaired or lost during CPS or SGTCs, patients are also unable to recall what happened during the ictal phase. Post-ictal confusion and amnesia for the events that occurred during the seizure can last for up to several hours afterwards. If this also involves drowsiness, headache and concentration problems, the post-ictal phase may even be more debilitating than the seizure itself. This lack of memory for the events suggests that the activity in the temporal lobes has interfered with, or temporarily disabled encoding and consolidation mechanisms. Although such post-ictal memory phenomenon are interesting in their own right, it is the disturbance to memory in between seizures, or the *inter-ictal* phase, that is the topic under investigation throughout this thesis.

1.4 The consequences of TLE

For most people with epilepsy, treatment with anti-epileptic drugs (AEDs) provides an excellent clinical prognosis, as approximately 60-70% of people will experience seizure-freedom (Sander & Sillampaa, 1998). However, for those remaining who are medically refractory and unsuitable for resective surgery of the epileptic temporal lobe, quality of life (QOL) can be significantly reduced (McLachlan *et al*., 1997). The reduction in QOL in TLE has been linked to the existence of co morbid psychiatric problems such as anxiety and depression, which have a higher prevalence rate in this group than in the normal population (Bragatti *et al*., 2010; Hermann *et al*., 2000; Jones *et al*., 2007). Patients also face the social stigma of having the condition, with potentially catastrophic affects on their social identity, and hence QOL (Jacoby, Snape, & Baker, 2005).

People with chronic TLE are often left with significant problems with their general cognitive function (Jokeit & Ebner, 1999) . Of these, memory complaints are the most common, with up to 80% of patients reporting some degree of impairment in memory functioning and approximately 50% stating that these are moderate to severe (Thompson & Corcoran, 1992). Appreciating patients' subjective perception of memory is of both theoretical and clinical importance; therefore, this issue is approached later in Chapter 6 where a novel self-report questionnaire was administered to people with TLE and healthy adults.

A variety of factors contribute to memory problems in TLE. In terms of brain pathology, this neurological condition is associated with bilateral structural abnormalities in sulcal and gyral shape, and significant reductions in neocortical thickness and complexity (Lin *et al*., 2007; Oyegbile *et al*., 2004). Memory impairment is particularly exacerbated by atrophy of the hippocampus and amygdala (Cendes *et al*., 1993; Lencz *et al*., 1992; Trennery & Ivnik, 1993) and entorhinal (EC) and perirhinal cortices (PRc) (Bernasconi, 2003). As will be discussed below, it is episodic, or declarative (conscious) memory that is most affected, due to the involvement of the above structures in the encoding, consolidating and retrieval of experiences bound to these representations (Eichenbaum, 2000).

Whereas discrete structural alterations to medial temporal areas have long been associated with memory impairment in this group, more recently, decreases in white matter have been found in chronic TLE in both temporal and extra-temporal areas (Seidenberg *et al*., 2005), with other research showing that synchronisation between these dispersed networks is paramount to memory and cognitive function (Gaffan, 2002).

There are also other factors that affect memory in TLE. For example, both human and animal research suggests the seizures themselves can accelerate forgetting in patients (Hermann *et al*., 2006; Jokeit, Daamen, Zang, Janszky, & Ebner, 2001; Lin, Holmes, Kubie, & Muller, 2009). Moreover, there can also be adverse neurocognitive effects associated with high serum levels of AEDs (Arif *et al*., 2009; Jokeit, Krämer, & Ebner, 2005; Motamedi & Meador, 2004), which in itself presents a major challenge to the treatment of the disorder. Finally, as mentioned above, co morbid anxiety and depression is common, and these are well known factors that impact memory (Hall, Isaac, & Harris, 2009; Salas-Puig *et al*., 2009). Because of this constellation of interacting variables in TLE related memory disorder, diagnosis and treatment is a complex process. However, important developments in neuropsychological approaches to the measurement of memory and cognition over the twentieth-century have aided this process.

1.5 Neuropsychological assessment of TLE

The importance of neuropsychological assessment in TLE exploded following the devastating impairments found in anterograde memory after the removal of epileptic medial temporal lobe tissue in classic patients such as HM, PB and FC (Penfield & Milner, 1958; Scoville & Milner, 1957). These early surgical interventions and subsequent investigations with the patients revealed the importance of the MTL in memory. Since this time, neuropsychological assessment has been a core part of epilepsy surgical interventions; memory assessment can be used to aid information regarding localisation, functional adequacy of the epileptic lobe, reserve capacity of the contralateral hemisphere, and ultimately be used to predict how function may change following the resective procedure (McAndrews & Cohn, 2012). This is achieved by the administration of an array of standardised psychometric tests that focus on episodic learning of new visual and verbal materials, whilst also incorporating an extensive assessment of other cognitive functions such as language, attention, executive function and intellectual ability. A patient's score is compared to some age scaled normative value derived from population estimates, and significant impairment or sparing in function is used in the surgical decision process. This history of assessment in surgical patients with refractory TLE has provided immeasurable amounts of knowledge to the study of human memory. However, as McDonald et al. (2011) recently advocated, neuropsychological assessment of people with newly diagnosed epilepsy and systematic long-term follow up is likely to reveal more about the cognitive sequalae of the condition. Studying groups of patients with diverse clinical profiles is therefore likely to further enhance our understanding of the architecture of memory. This was the approach taken in this thesis.

1.5.1 Lateralisation and the material specificity principle

At the heart of neuropsychological assessment and surgical decision making in TLE is the 'material specificity principle' (Milner, 1970), which posits that in language dominant individuals, the left temporal lobe is preferentially involved in verbal memory and the right in visual or non-verbal forms of memory. Material specific *verbal* memory impairments in left temporal lobe epilepsy (LTLE) are generally well accepted, and a higher level of functioning in verbal tasks pre-operatively has consistently been found to be a risk factor for significant post-operative decline (Alpherts, Vermeulen, van Rijen, da Silva, & van Veelen, 2006). In this respect, neuropsychological assessment of memory function before surgery can be instrumental not only in providing complementary evidence regarding lateralisation of seizure focus, but also in providing useful evaluation of the risk of surgery. As McAndrews and Cohn (2012) discuss, this role is currently evolving due to the advent of advanced structural and functional neuroimaging techniques that are able to provide laterality analyses for both language and memory.

Although research does exist to support the non-verbal functions of the right medial temporal lobe (Baxendale *et al*., 1998; Golby, 2001; Pegna *et al*., 2002), its strict functional independence in this form of memory is typically much more contested in the literature (e.g. Vingerhoets, Miatton, Vonck, Seurinck, & Boon, 2006). Typical standardised 'non-verbal' tests are often confounded by the fact that their contextual elements can be covertly verbalised internally by the candidate (Helmstaedter, Pohl, & Elger, 1995), and much variation exists in performance between the different tests available due to the wider network of interhemispheric regions involved in their processing. Visuospatial memory tests can thus be inaccurate in providing lateralising information, mainly because they tap into a variety of other cognitive domains (Wisniewski, Wendling, Manning, & Steinhoff, 2012). Language dominance and gender differences also play a role in this.

In a recent article, Saling (2009) discussed the current problems with the adoption of the material specificity principle as it currently stands. He makes a critique of the assumption that the two forms of memory are unitary constructs, and are independent from one another. In what he urges to be a paradigmatic shift in methods of assessing memory, he draws on research showing that individual differences in performance within-domains reflects the fact that verbal and non-verbal memory can be further fractionated by their localisation within the temporal lobe. Thus, memory impairments may be task-specific.

The above issues are addressed in the experiments throughout this thesis; as will be outlined later. Although assessment of laterality differences was not a fundamental objective here, efforts were made to make some contribution to this aspect of the study of memory in TLE. One important theme in this thesis mirroring Saling's (2009) suggestions relates to the issue of task-specificity, and the sensitivity of tests in measuring differential impairments in the various components of memory. From Section 1.7 and thereafter, the utility in applying a *process* rather than *task*-driven approach is discussed.

1.6 The clinical context: Differences between patients' subjective memory reports and neuropsychological assessment

In the UK, the National Institute for Clinical Excellence guidelines stipulate that referral for neuropsychological assessment must be completed not only as part of comprehensive neurosurgical work-up, but also in cases where the patient *subjectively complains* of memory decline. However, evidence has consistently shown that patients' subjective reports of their memory difficulties are often weakly correlated with results of psychometric assessments. Studies have overwhelmingly displayed patients tend to overestimate their memory problems (Elixhauser, Leidy, Meador, Means, & Willian, 1999; Giovagnoli, Mascheroni, & Avanzini, 1997; Gleißner, Helmstaedter, Quiske, & Elger, 1998; Helmstaedter & Elger, 2000; Hendriks, Aldenkamp, van der Vlugt, Alpherts, & Vermeulen, 2002; McGlone, 1994; Piazzini, Canevini, Maggiori, & Canger, 2001; Sawrie *et al*., 1999; Vermeulen, Aldenkamp, & Alpherts, 1993). There are also reports of underestimation (Thompson & Corcoran, 1992) and instances where correspondence exists between self-report and objective measurements; for example, Rayner, Wrench, and Wilson (2010) found that objective performance was a significant predictor of subjective memory scores along with mood in patients with MTLE.

This discrepancy between a patient's beliefs about their memory and scores on standardised instruments presents a variety of challenges. Worries about a poor memory are likely to fuel further psychosocial problems – significant anxiety can result when someone feels that others will notice a memory problem. For example, unemployment is disproportionately high in people with epilepsy, and although a life with uncontrolled seizures may be the cause of this in some cases, people's worries that others will notice them making mistakes in a working environment due to memory failure may also contribute to a lack of willingness in pursuing a vocation. If a patient presents to a clinician with these worries, and objective performance does not match up, then simply telling the person that their memory is fine is of little use.

Some estimates suggest that between 30-70% of epilepsy patients experience depressive disorders (Prueter & Norra, 2005), and a number of studies have found a significant relationship between subjective memory, depression and anxiety in this group (Au *et al*., 2006; Baños *et al*., 2004; Butler *et al*., 2009; Giovagnoli *et al*., 1997; Piazzini *et al*., 2001; Salas-Puig *et al*., 2009). This clearly has clinical implications and suggests that patients presenting with epilepsy *and* memory complaints should be screened for other neuropsychiatric disorders as well as a possible amnesic syndrome. Successful psychological and pharmacological intervention targeting depressive or anxious symptoms may then ameliorate any subjective memory problems.

In their recent comprehensive review on this topic, Hall et al. (2009) discuss a number of other factors that may have an influence on the subjective-objective memory discrepancy, and why variations are seen between similar studies. They note that differences in sampling methods, patients' premorbid functioning, laterality, gender and statistical analyses all partially explain the discordance in the literature. However, pertinent to the current thesis is their discussion about the effect different measurement methods have.

One of the key aims of neuropsychological tests is to measure underlying memory constructs that are purported to give rise to subjectively experienced memory problems. Hall et al. (2009) suggest a potential reason for differences in subjective and objective memory measures may be due to a lack of ecological validity in these tests, a lack of sensitivity, and lack of correspondence between the domains assessed. In recent years, a number of unusual memory impairments have begun to surface in TLE through careful and detailed experimental testing (see Butler & Zeman, 2008, for a review). The study of these memory disorders, which are often undiagnosable through the use of standardised instruments, strongly suggests that disruption to memory *processes* not specifically addressed in neuropsychological instruments may play a causal role in the subjective-objective discrepancy. Therefore, below I provide a review of dual-process theories of memory and discuss their application to TLE.

1.7 Recollection and Familiarity

For approximately 30 years, dual-process theories of human memory have permeated through experimental research and have provided a useful way of conceptualising how recognition and retrieval of information is conducted by humans. Differences between the theories themselves will be discussed below, but essentially the commonality between them is that recognition memory is proposed to be subserved by two independently arising processes: recollection and familiarity. Recollection involves the effortful retrieval of contextual and associative information from a prior study event whereas familiarity involves recognition in the absence of such contextual information. For some theorists, these are viewed as underlying cognitive processes that are used in synchrony to govern behaviour during memorial operations (Jacoby, 1991; Mandler, 1980; Yonelinas, 1994). For others, however, they are viewed as personally experienced subjective states of awareness that accompany recognition experiences (Gardiner, Ramponi, & Richardson-Klavehn, 1998; Tulving, 1985).

Tulving's (1985) re-introduction of introspective methods in memory had an immeasurable impact on the psychological community. By advocating the use of subjective report, he paved the way for decades of fruitful research regarding the inextricable link between memory and consciousness. As later researchers began to understand and research cognitive processing accounts of the memory systems he proposed, this area quickly began to depart from purely theoretical debate to genuine applied research. For example, following a variety of evidence that impairments in recollection are more pervasive than familiarity in aging (Cohn, Emrich, & Moscovitch, 2008; Friedman & Trott, 2000; Java, 1996; Jennings & Jacoby, 1997; Norman & Schacter, 1997; Perfect & Dasgupta, 1997; Souchay, Moulin, Clarys, Taconnat, & Isingrini, 2007), a training paradigm that specifically targets recollective processes has shown success in increasing older adult participants' performance on an experimental task, as well as transferring performance to other tasks that rely on recollection (Jennings, Webster, Klaykamp, & Dagenbach, 2005; Jennings & Jacoby, 2003). Moreover, Tse, Balota, Moynan, Duchek, and Jacoby (2010) recently displayed that the recollective component of their experimental task (exclusion test performance, explained in Section 1.9.2.3.1) was able to reliably differentiate between healthy older adults and those with early stage Alzheimer's disease, and between healthy older adults with the presence or absence of the apolipoprotein ε4 (*APOe4*) allele, a hereditary gene known to increase the risk of earlier stage Alzheimer's disease.

Although there are relatively few studies looking at rehabilitation of recollection or its real world correlates, this is an area of research of value in TLE. The above work is pertinent to the current thesis as it shows how there is clear benefit from an applied clinical perspective in studying, and extrapolating the results of dual-process led research to memory impaired populations.

1.8 Dual-process theories

Several dual-process theories have been proposed in the literature. In the experiments presented throughout this thesis, the central tenets and corresponding measurement methods proposed by the theories of Jacoby (1991) and Tulving (1985) were adopted. Therefore, I concentrate on these in the discussion that follows. Because the model developed by

Yonelinas and colleagues (Dobbins, Kroll, Yonelinas, & Liu, 1998; Yonelinas, 2001; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996; Yonelinas, 1994, 1997, 1999, 2001a, 2001b) has had such a huge impact within this literature, and due the fact that its measurement method (the receiver operating characteristic curve; ROC) has been used alongside those of Tulving and Jacoby, I will also cover this. For the interested reader, two other earlier models proposed by Atkinson et al. (Atkinson, Hertman, & Wescourt, 1974; Atkinson & Juola, 1973, 1974) and Mandler (Mandler, 1980, 1991) are reviewed in Yonelinas (2002).

1.8.1 Tulving and the Remember/Know paradigm

The distinction between recollection and familiarity began following Tulving's (1972) suggestion that researchers had only been assessing what he called 'episodic memory'. He likened this to our autobiographical memory (AM) of singular events from our past, and contrasted it with 'semantic memory', which he considered to comprise context-free knowledge of our life and the world around us. An example of an episodic memory would be the detailed recall of a fine summer evening in the park picnicking with friends two weeks ago. In comparison, *knowing* that the United Kingdom is made up of England, Scotland, Wales and Northern Island is an example of a semantic memory, or semantic knowledge. Tulving described how typical laboratory tasks using verbal material tested episodic memory because they involved recall and recognition tests for items in a particular personal context; other tasks that were emerging at the time tapped into general knowledge (or semantic memory).

Later, Tulving (1983) introduced the idea that these two types of memory formed functionally distinct *systems* within the brain, and that each type gives rise to a qualitatively different phenomenological experience. Episodic *remembering*, he proposed, was experienced as 'autonoetic' (self-knowing) consciousness. It involves a mental reliving of a prior episode and is associated with the retrieval of specific contextual elements from that singular event. A later, and oft cited addition to this included the idea of sensory-perceptual cognitive-affective detail, to describe the integration of processing that is involved in this contextual retrieval (Conway, 2001; Conway & Pleydell-Pearce, 2000).

'Noetic' (knowing) consciousness on the other hand, is experienced simply as knowledge of something's prior occurrence, in the absence of subjective recollection of associative detail. In other words, there is mere *familiarity* for prior occurrence. In Tulving's view, these two states, Remembering and Knowing, were subjective experiences that occurred independently. For the retrieval of past events, or AMs, subjective *remembering* accompanied information from the episodic system; activation of the semantic memory system incurred a subjective sense of *knowing*.

Based on these distinctions, Tulving (1985) developed an experimental paradigm, the Remember/Know (R/K) procedure, to test his hypothesis with respect to people's anterograde recognition memory. As mentioned above, the R/K procedure relied on introspective reports by participants regarding their subjective state of awareness of 'Old' items during a recognition test. Tulving (1985) and later, Gardiner, Ramponi, & Richardson-Klavehn (1998) provided sound empirical evidence that people are reliably able to differentiate between subjective Remembering and Knowing. Following the retrieval of some kind of thought or association from the encoding phase, participants responded Remember, and in the absence of any contextual retrieval but knowledge of previous occurrence, they responded Know.

The R/K paradigm was used in three out of the four experiments in this thesis; further description of this method and findings related to its previous use are described later in Sections 1.9.1.1, 1.10.1 and 1.10.2.

1.8.2 Jacoby and the process-dissociation procedure

In 1981, Jacoby and Dallas conducted perceptual identification experiments in which words were briefly presented before a subsequent recognition phase; first, they found that Old words were more likely to be identified than New words. Further, using levels-of-processing manipulations (LOP; Craik & Lockhart, 1972; Lockhart & Craik, 1990), they found that encoding instructions that facilitated conceptual or semantic properties of words boosted recognition but not perceptual identification, where as instructions to focus on perceptual aspects of words boosted only perceptual identification. Based on these findings, Jacoby and others went on to suggest that there must be different forms or uses of memory. Specifically, it was suggested that recollection and familiarity are alternative basis for responding Old in recognition tests. By this account, recollection is viewed as an analytical controlled process that enables the retrieval of contextual information; familiarity is viewed as a more automatic process and arrives when fluent processing is attributed to prior occurrence of an item

(Jacoby, Kelley, & Dywan, 1989; Jacoby, 1991; Jacoby & Kelley, 1992; Jacoby & Witherspoon, 1982; Kelley & Jacoby, 1990; Whittlesea, Jacoby, & Girard, 1990)

Similar to other dual-process theories, Jacoby postulated that these two processes acted independently, but both contributed to performance; because of the automaticity of familiarity, this process was proposed to operate in a quicker manner than recollection. Jacoby's test of his assumptions came from work using the *process-dissociation procedure* (PDP; described in detail in Section 1.9.2.3.1) which is a theoretical framework designed to tease apart the relative contributions of recollection and familiarity to performance by putting them in *opposition* to one another.

1.8.3 Yonelinas and the dual-process signal detection model

Yonelinas and colleagues (Dobbins, Kroll, & Liu, 1998; Dobbins, Kroll, Yonelinas, *et al*., 1998; Yonelinas *et al*., 1996; Yonelinas, Kroll, Dobbins, & Soltani, 1999; Yonelinas, 1994, 1997, 1999, 2001*a*, 2001*b)* proposed an alternative to the view of recollection and familiarity as subjective states of awareness or intentional control mechanisms. Instead, they saw the two processes differing in the type of information associated with them and corresponding levels of confidence. In the dual-process signal detection model, familiarity is assumed to be a signal detection like process – a quantitative index of memory strength of items where an item is recognised if its familiarity exceeds a participant's response criterion (i.e. a participant's propensity to make a positive recognition response). Hence, the most familiar items will be accepted as having been studied. On the other hand, recollection reflects a threshold process represented by high-confidence responses whereby qualitative information is recovered (e.g. where the item was studied). If the level of contextual information does not reach the given threshold, assessments of familiarity will prevail. This is not to say that recollection is an all-or-none process; rather, a certain level of contextual detail must be present in order for recollection to succeed, and beyond this threshold, varying amounts of qualitative information are retrieved (Yonelinas, Aly, Wang, & Koen, 2010; Yonelinas & Parks, 2007). During recognition tasks that involve both processes, recollection and familiarity are postulated to be activated simultaneously but independently, with familiarity being quicker than recollection.

Estimations of the two processes are obtained by fitting receiver operating characteristic (ROC) curves to different levels of confidence responses associated with correctly recognised Old items (hits) and falsely recognised New items (false positives; FPs). The ROC method is described in more detail in Section 1.9.2.4.

1.8.4 Alternatives to dual-process models

As with any theory attempting to explain such a complex and multifaceted problem, dual-process accounts are not without criticism. A dual-process approach was adopted throughout this thesis, but it is important to acknowledge other theories of recognition memory, which are presented in the following section.

1.8.4.1 Single trace accounts

A number of researchers have suggested that a more parsimonious way of looking at recognition memory is from a single process view, where memory reflects a unitary continuum of trace strength (Donaldson, 1996; Dunn, 2004; Hirshman & Master, 1997). This view is borne out of signal detection theory (Swets, Tanner, & Birdsall, 1961) and holds that for item recognition, studied items have a greater memory strength than new, unseen items, but there is variability in overall memory strength such that the two types have overlapping Gaussian (normal) distributions. The distance between these distributions is *d*’, which reflects how much stronger studied items are than new items. A recognition decision is made when old items exceed the response criterion. Variations on this model essentially depend on how they perceive the variance of the two distributions.

In the equal variance signal detection model, the variance associated with target items is equal to new items. This model suggests that differences between R/K responses simply reflect the fact that R responses reflect stronger memories and K responses reflect weaker memories. In the alternative unequal variance signal detection model, a second memory component is added; the *difference* between the variances of the old item distribution and new item distribution (V_T). Differences in these variances will have corresponding effects on the ROC curves derived from recognition performance. Although no specific predictions are made about such differences, it has been suggested that the old item distribution may be more variable, because of encoding variability (Wixted, 2007). The unequal variance signal detection model similarly predicts that Remember judgments simply reflect high confidence recognition responses.

There are many more recent examples of signal detection approaches to recognition memory, such as the 'sum difference theory of remembering and knowing' (STREAK; Rotello, Macmillan, & Reeder, 2004), the 'source activation confusion model' (SAC; Diana, Reder, Arndt, & Park, 2006), the theory of distributed associative memory (TODAM; Murdock, 2006) and a model proposed by Wixted and Stretch (2004). It is beyond the scope of this thesis to describe these models in great detail. However, the fundamental differences between them can be summarised as follows: a) their assumptions about the distribution of old and new items; b) whether or not they include a unitary strength dimension or two to account for recollection and familiarity; c) the inclusion (or exclusion) of a threshold process to account for recollection; d) whether they include additional parameters to account for differences in associative memory rather than single item memory and; d) fundamentally, the decision rule that they adopt, i.e. exactly what leads to a positive recognition response (see Rotello & Macmillan, 2006, and Yonelinas & Parks, 2007, for reviews).

This area of research is highly complex and continues to provide knowledge about the basis of recognition memory. However, the aim of the current thesis was not to explore such issues. Although one could inevitably add to understanding about memory impairment in TLE by adopting a single trace approach, for the purposes of my aim in bridging together measures of subjective awareness and objective performance, dual-process theory was better suited. Moreover, despite differences in theoretical viewpoint, the paradigms are the same in that they ascribe subjective reports to objective memory performance.

Later in Section 1.10 I will describe the body of evidence from the TLE literature that has shown recollection and familiarity are functionally dissociable, independent processes, hence validating the methods used in the my experiments.

1.8.4.2 The Source Monitoring Framework

An alternative viewpoint is the Source Monitoring Framework (SMF; Johnson, 2006; Johnson, Hashtroudi, & Lindsay, 1993; Johnson & Raye, 1981; Mitchell & Johnson, 2009), which provides a conceptual understanding of how the construction and reconstruction of experiences is dependent on people's knowledge, beliefs, goals and metamemory assumptions (Mitchell & Johnson, 2009).

According to the SMF, complex event memories are made up from disparate features such as perceptual, spatial, temporal, semantic and emotional information. When specific *combinations* of these elements are reconstructed, the *differentiation* between them gives rise to an episodic memory. When a high degree of differentiation occurs including a number of bound specific details, the resultant subjective experience is likely to be one of recollection. However, other source attributions are relatively non-specific as they are based on relatively undifferentiated information. These will be experienced as familiarity. Further, the features involved in source attributions are *flexibly weighted* according to the demands of the task. For example, asking a participant "Do you recognise this item?" is likely to place emphasis on purely cognitive information, whereas asking "Was this item presented in red?" will lead to a heavier weighting on perceptual information. The SMF assumes that all episodic memory tasks involve some kind of source attribution (described further in Section 1.9.2.2), and the difference between them lies in the extent to which one or a number of processes are operating along with things like a person's knowledge and beliefs. It therefore predicts that there is overlap in the brain processes involved.

As mentioned, the SMF views recollection and familiarity as subjective experiences arising from attributions. However, like single trace accounts, the SMF views this as a continuous process, along the trajectory of differentiation. In other words, a memory is experienced as continuous, comprising more, and less specific information. Therefore, like the single trace accounts above, it uses behavioural evidence of *graded* recollection as support for its prediction (e.g. Simons, Dodson, Bell, & Schacter, 2004; Wais, Mickes, & Wixted, 2008).

1.8.5 Neuroanatomical models

Dissociations found in memory processes of amnesic patients led to the development of the theories of recognition outlined above. However, due to the selectivity of neuropathology in these patients, a vast literature has developed in order to understand the neurobiological basis of memory also. This has predominantly involved the study of functional specialisation in the MTL.

1.8.5.1 Dual- process neuroanatomical accounts of recognition memory

Drawing on findings from amnesics, Eichenbaum, Otto, and Cohen (1994) and Aggleton and Brown (1999; Brown & Aggleton, 2001) both suggested that the hippocampus is critical for recollection, where as the adjacent parahippocampal gyrus is responsible for familiarity. Aggleton and Brown (1999) further suggested that due to the network connecting the hippocampus to the fornix, mamilliary bodies, and anterior thalamic nuclei, these structures are also engaged during the encoding and retrieval stages of recollection. Moreover, they suggested that familiarity is supported specifically by the most anterior portion of the parahippocampal region - the PRc.

Both of these models make the prediction that hippocampal damage should affect recollection but not familiarity, and parahippocampal damage should lead to impairments in familiarity, not recollection. In support of such predictions, patients with damage restricted to the hippocampus have displayed isolated impairments in recollection through the use of the R/K paradigm and process dissociation methods (Bowles *et al*., 2010; Holdstock, Mayes, Gong, Roberts, & Kapur, 2005), and analysis of a patient with a lesion restricted to the PRc revealed impaired familiarity but intact recollection using the R/K paradigm, ROC method and response-deadline procedure (Bowles *et al*., 2007).

Later models have elaborated on the specific roles of the PRc, EC and parahippocampal cortices (PHc) due to the emergence of findings that extrahippocampal structures may be able to support associative memory when items are sufficiently unitized during encoding (e.g. Quamme, Yonelinas, & Norman, 2007). Such a departure, as Montaldi and Mayes (2010) describe, begins to view recollection and familiarity as ‘kinds’ of memory, because “each is a complex function, likely to depend on several different processes that are probably mediated by different structures that are functionally connected in a system” (p.1294).

A schematic representation of a neuroanatomical model of recognition is presented in Figure 1.1, based on Dickerson and Eichenbaum (2010) and Montaldi and Mayes (2010). In their Convergence, Recollection and Familiarity Theory (CRAFT) model, Montaldi and Mayes (2010) argue that the PRc rapidly forms weakly pattern separated[1] memories that support familiarity

[1] Pattern separation is a neurobiological process of transforming similar representations or memories into highly dissimilar, non-overlapping representations.

well, but recollection poorly, so memory *binding* will occur in the hippocampus. Further, intra-item associations can be supported by this area when unitised (e.g. the words 'ice' and 'shaft' encoded as iceshaft), but *inter*-item representations may also be formed giving rise to a *feeling* that the two were presented before (e.g. face-word pairs). The ability of the PRc cortex to support such representations is dependent on the manner in which they are encoded; intra-item associations rely on a unifying conceptual link, inter-item associations rely on a linking of components. These representations are highly inflexible and if the linked components are altered, familiarity will diminish. In recognising the similarities in cytoarchitecture between PRc and PHc, these authors further postulate that the parahippocampal cortex can also support associations, but for context-context relations. Such 'contexts', although difficult to fully define, can include visual, spatial or semantic information that is peripheral to the item that is the focus of attention (Diana, Yonelinas, & Ranganath, 2007).

Recollection, on the other hand, supports highly flexible associations and as it lies at the top of the MTL hierarchy, it alone can support between-domain associations (object-context links). Its cytoarchitecture allows rapid pattern separation (and completion), which supports recollection and not familiarity.

Whereas the CRAFT model ascribes importance to the role of the PHc in *familiarity* based context recognition through bound associations, the 'Binding of Item and Context' (BIC) model proposed by Diana et al. (2007) makes a slightly different assumption about this MTL sub region. The model by Diana and colleagues, based on a variety of neuroimaging data, similarly suggests that the PRc and PHc encode item and context information, with the hippocampus encoding representations between them. However, they suggest that because context representations support recollection in item recognition tests, the PHc is involved in recollection as well as the hippocampus.

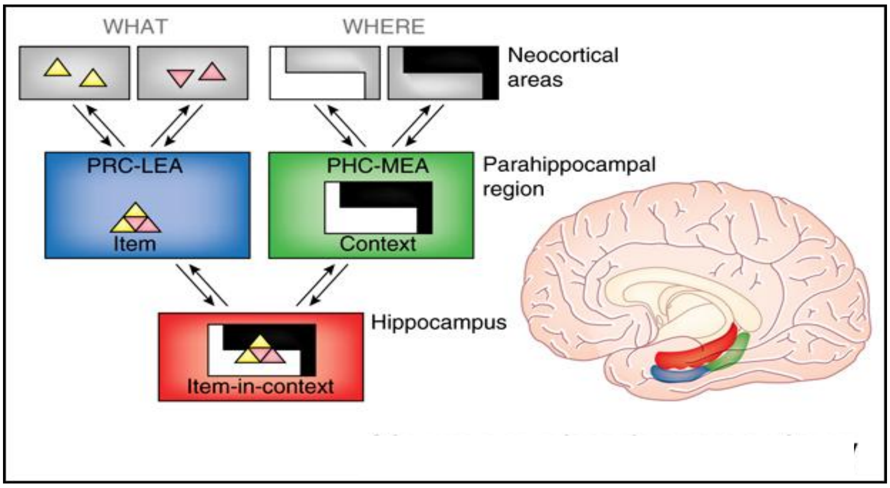

Figure 1.1 Functional organisation of the medial temporal lobe - proposed input and convergence. Taken from Dickerson and Eichenbaum (2010). Object features converge from neocortex in perirhinal cortex (PRC) and lateral entorhinal area (LEA); location and context input converge in parahippocampal cortex (PHC) and medial entorhinal area (MEA); hippocampus supports binding of complex item-in-context relations.

Another view of MTL involvement in declarative memory departs from the dual-process focus of recollection and familiarity and instead sees this brain system as fundamentally *relational* in nature (Cohen & Eichenbaum, 1993; Eichenbaum & Cohen, 2001). Relational theory posits that the hippocampus is involved in forming relations between spatial information, associative information and temporal information. This is distinguished from memory for items themselves that are bound together. Evidence for this theory is derived from the finding that patients with restricted hippocampal damage show preserved item memory, but impairments in both spatial and non-spatial relations (e.g. Kan, Giovanello, Schnyer, Makris, & Verfaellie, 2007; Mayes *et al*., 2004) and neuroimaging results that show increased activation in the hippocampus when forming new relationships among items, rather than the individual encoding of items (e.g. Davachi & Wagner, 2002; Davachi, Mitchell, & Wagner, 2003). Clearly, this relational view shares many common traits with the above CRAFT and BIC models, and all are able to use similar neuropsychological and neuroimaging results to support them.

1.8.5.2 The single trace neuroanatomical account of recognition memory

Just as cognitive single trace accounts contest the assumptions of dual-process theories, there is also opposition to the above neuroanatomical models. Squire and colleagues (Squire, Wixted, & Clark, 2007; Wixted & Squire, 2011; Zola-Morgan, Squire, & Ramus, 1994) argue that all structures within the MTL mediate recollection and familiarity equally. Their MTL Unitary Trace Strength (MUST) account suggests that functional heterogeneity does exist within the MTL, but not for recollection and familiarity. Although the theory does not question the existence of these two processes, it sees that examination of the components within the MTL cannot be illuminated by this distinction in psychological constructs; rather, the distinction is likely to benefit from findings from neuroanatomy and neurophysiology that identify attributes of memory supported by different structures (Wixted & Squire, 2011).

The MUST account criticises the interpretations gleaned from lesion and neuroimaging studies regarding the role of recollection in the hippocampus on the basis that their interpretations strongly assume that confidence and accuracy are high whenever recollection occurs. Correspondingly, all of the methods used in support of the recollection/familiarity distinction (ROC, R/K, source memory etc) also assume that familiarity is associated with low confidence and *weaker* memories. As Wixted (2007) and Wixted and Squire (2011) argue, recollection is a continuous process just like familiarity. Based on this assumption, previous work suggesting the hippocampus supports recollection equally supports the interpretation that the hippocampus is simply involved in the encoding and retrieval of *strong* memories, which may be recollection or familiarity based. In order to provide evidence for this, they suggest methods must be used that do not confound recollection and familiarity with memory strength. For example, in a source memory experiment using functional magnetic resonance imaging (fMRI), Wais, Squire, & Wixted (2010) measured hippocampal activity at retrieval after equating memory strength of recognition decisions on item-correct plus source-correct or item-correct plus source-incorrect trials. Their analysis focused only on Old/New trials where participants assigned high confidence ratings, regardless of whether the correct source was retrieved. They found that hippocampal activity was similarly elevated for both correct/incorrect source judgments, suggesting it is involved in both recollection and familiarity.

1.8.6 Consolidation theories of hippocampal function

The research discussed so far has concentrated on the functional specialisation of the MTL in anterograde recognition memory. However, similar debate exists regarding the role of the hippocampus in the encoding and consolidation of memories over longer periods of time. Hence, these structures also play an important role in autobiographical memories. The experiment presented in Chapter 6 of this thesis explores the interaction between episodic and semantic aspects of AM in TLE. Previous findings in the TLE literature regarding AM will be discussed later in Sections 1.10.2 and 1.10.4, but I will briefly outline the two neurobiological theories of consolidation here, as they extend from the above discussion.

1.8.6.1 The Standard Model of Consolidation

According to the standard model of consolidation (SMC; Bayley, Hopkins, & Squire, 2006; McClelland, McNaughton, & O'Reilly, 1995; Murre, 1996; Squire & Alvarez, 1995), MTL structures are only involved in the consolidation and retrieval of memories (both episodic and semantic) for a time-limited period. Upon encoding, these memories are presumed to be stored initially by synaptic changes in the hippocampal system, but over time, these mnemonic representations become independent of the hippocampus due to storage in neocortical structures. Although the exact period over which the links between the hippocampus and neocortex is unknown, it has been suggested to be in the order of around 5-10 years (e.g. Schmidtke & Vollmer, 1997).

Evidence for the SMC initially came from studies of amnesics who appeared to show a 'Ribot' gradient (Ribot, 1888) following MTL insult. That is, a relative preservation of remote memories in light of significant impairments in newer acquired ones (more commonly known as a *temporal gradient*). The model assumes that *retrograde amnesia* is temporally limited and directly related to the locus and extent of damage. When there is isolated hippocampal damage, the retrograde amnesia will be limited to several years, but following extended damage into other MTL areas (which are still crucially involved in the transfer of representations), the retrograde amnesia will be temporally extended backwards (Reed & Squire, 1998). Evidence for the SMC has come from studies of amnesics with either selective hippocampal damage or more diffuse MTL damage whose remote autobiographical memories are indistinguishable from healthy controls (e.g. Bayley, Hopkins, & Squire, 2003; Zola-Morgan, Squire, & Amaral, 1986).

1.8.6.2 The Multiple Trace theory

The multiple trace theory (MTT) is the alternative view to the SMC (Nadel & Moscovitch, 1997, 2001). Like the standard model of consolidation, it agrees that the hippocampal complex rapidly encodes information and binds neocortical neurons into a memory trace. However, MTT does not agree that there is a prolonged consolidation process that strengthens neocortical representations, removing the involvement of the hippocampus over time. Instead, each time memories are retrieved, MTT posits that a new hippocampally mediated trace is created so that older memories are represented by *stronger* hippocampal and MTL traces than newer memories, and become far less susceptible to disruption from neurological insult. One of the other key differences between MTT and SMC is that only the former accounts for differences in episodic and semantic memory; each autobiographical episode forms a unique trace, but the formation of multiple related traces helps retrieve neocortically mediated information that is common between them. This information is combined with pre-existing knowledge and forms semantic memories that exist independently of the MTL. MTT suggests that the prolonged consolidation account of the SMC is explained by the fact that with repeated experience, semanticization of the knowledge acquired with individual episodes occurs.

The specific predictions of each model heavily rest on the methodology employed in experimental studies (i.e. how many years in the past does the instrument measure; whether the instrument separates episodic from semantic memories) and also on the extent of lesions in patients. In recent years, support for the MTT has been garnered from studies that employed sensitive testing methods that specifically assess the difference between contextual episodic memories and those consisting of semantic knowledge, or repeated experiences (Moscovitch *et al*., 2005).

1.8.7 Summary

The discussion above indicates how there is ongoing debate within the recognition and neuroscience literatures regarding functional specialisation of the MTL. Patients with TLE provide a useful sample to test the predictions of such theories, particularly in post-operative cases where precise anatomical information is available regarding the extent of excisions. Pre-operative patient samples are also interesting , because comparisons can be made between

those with hippocampal sclerosis and those with more a more lateral epileptic focus. Obtaining precise lesion data is dependent on high resolution and costly neuroimaging, however.
The aim of this thesis was not to help delineate the individual processes that contribute to recollection and familiarity, or understand their exact anatomical nature. Rather, reflecting on Montaldi and Mayes' (2010) statement above, the experiments were aimed at shedding light on these 'kinds' of memory and their associated subjective experience as there is value in this approach also. Below, I describe the experimental measurement techniques that are used throughout this thesis.

1.9 Measuring recollection and familiarity

A useful distinction, and one that is critical for the current thesis, is between the methods that provide a *subjective* measure of recollection and familiarity and those that provide *objective* measures.

1.9.1 Subjective measures and awareness

1.9.1.1 The R/K paradigm

The R/K paradigm is a first-person approach to recognition memory which asks participants to reflect on their experiential state during recognition, or autobiographical memory retrieval. In recognition memory, a Remember response is assigned to an item if it evokes contextual detail from the encoding phase (thoughts, feelings and associations) and a Know response is assigned to items that are recognised in the absence of such context but with a feeling of 'oldness'. The proportion of items assigned a Remember response in such paradigms is thus thought to reflect the contribution of recollective experience to recognition, and this is compared to the probability of items subjectively experienced as *known.* There have been many developments in this paradigm over the years, several of which are pertinent to the current thesis. These include the addition of a Guess response, using Familiar rather than Know judgments, and the introduction of mathematical procedures in order to satisfy the independence assumption of the two processes. These theoretical considerations, as well as the boundary conditions of the PDP used in the current thesis are covered in Section 1.9.3 below.

Tulving's (1972, 1985) development of the R/K paradigm was based on his theory regarding the functional separation of the episodic and semantic memory systems. Hence, the idea of autonoetic and noetic conscious states of awareness was directly related to the phenomenology of *past* experience. Based on this distinction, and the emerging debates regarding the temporal gradient of retrograde memory loss in amnesia (see Section 1.8.6), the Autobiographical Memory Interview (AMI; Kopelman, Wilson, & Baddeley, 1990) was developed. This was the first development of a standardised tool to separately assess episodic and semantic AMs in neurological populations and involves the retrieval of event memories, or factual information, from different lifetime periods. Drawing on the phenomenological aspect of Tulving's work, Piolino and colleagues (Noulhiane *et al*., 2007; Piolino *et al*., 2003, 2005) later developed a much more detailed semi-structured interview; this requires the assignment of Remember and Know judgments to retrieved memories that are cued by themes (e.g. holdays) and lifetime periods. The resultant narratives are also scored on an episodic scale, according to their contextual richness. This method, and the equally detailed Autobiographical Interview (AI; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) have provided a large body of evidence elucidating the functional separation of these systems, and the phenomenology associated with them in a variety of neuropsychological groups.

The R/K paradigm can however, be applied in its simpler form following the retrieval of any kind of autobiographical memory. In Chapter 6 of the current thesis, the R/K paradigm was applied in the context of retrieval of specific memories that contribute to semantic knowledge of public events. AM in TLE is discussed further in Section 1.10.

1.9.2 Objective measures

1.9.2.1 Item vs. associative memory

Dual-process models argue that recollection involves a process of retrieving qualitative contextual and *associative* information from a prior episode. Therefore, when units of information are bound together, recollection is used to retrieve the relation between them. On the other hand, familiarity only discriminates between single (or, as above, unitised) representations in a quantitative fashion. One commonly used way to test this is through paradigms that incorporate both aspects; item and associative recognition. In such experiments, participants are usually presented with unrelated word pairs (although other stimuli, such as faces, or pictures may be used) that they must encode. They are later tested on recognition memory for either single items, or on the association between those items (e.g. Hockley, 1992; Hockley & Cristi, 1996). Item memory is calculated as the probability of correct discrimination between Old items and New, lure items. Associative memory is calculated as the probability of correct discrimination between pairs consisting of two originally bound items and pairs consisting of two items that were both encoded, but from different pairs (recombined pairs). Because both old and recombined pairs are comprised of previously seen information, successful discrimination between them is thought to rely heavily on recollection (i.e. qualitative information about the association is retrieved). As Cohn et al. (2008) describe, this *associative identification* is dependent on successful binding, but due to the high level of familiarity for old recombined pairs, recollection based *recall-to-reject* processes are needed to oppose this, which involve extensive memory search and post-retrieval monitoring mechanisms also. For intact pairs, recollection *supplements* familiarity by using a *recall-to-accept* mechanism to *reinstate* the pair, hence these authors name this *associative reinstatement*. Because of the contrasting influences recollection and familiarity have on these types of items, the paradigm is particularly suited for application of the PDP. This is described later in Section 1.9.3.1.

1.9.2.2 Source memory

Source memory, or source *monitoring* paradigms, involve learning a range of stimuli that differ in some contextual aspect. These differences are generally perceptual differences, such as modality (words encoded by reading vs. auditorily presented) or spatially (item presented on the top or bottom of the screen). It could also be differences in the whole context an item was learnt (different lists of words, or different test sessions). Consistent with item and associative recognition memory tests, recollection and familiarity are proposed to contribute in a similar way; simple Yes/No recognition of Old vs New items can be supported by both processes, but it is assumed that the retrieval of the correct source feature is dependent on recollection only.

As in the study cited above by Squire and Wixted (2010), estimates of the contribution of recollection and familiarity can be observed in ROC curves derived from confidence responses to correct item/source discriminations. However, the R/K paradigm has been utilised in this area to a great extent also, as the subjective state of remembering is theorised to be accompanied by retrieval of source or contextual information, where as subjective knowing, or familiarity, is not. For example, experiments have shown that 'Remember' judgments are associated with significantly better source memory than 'Know' judgments in a variety of experimental manipulations (Dewhurst & Hitch, 1999; Humphreys *et al*., 2003; Meiser & Sattler, 2007; Perfect, Mayes, Downes, & Eijk, 1996) and Remember judgments have also been found to be associated with the correct retrieval of two or more bound representations, further suggesting a relationship between the binding of context and recollective experience (Meiser, Sattler, & Weisser, 2008).

Understanding the processes by which we bind and integrate information is important as part of consciousness is inherently related to our experience of the world as a coherent set of features. Comparing the effect memory impairment has on this with healthy adults is likely to elucidate further how such conscious processes operate. Therefore, both source and associative memory are explored in detail in Chapters 3 and 5 of this thesis.

1.9.2.3 Process estimations

The PDP and ROC methods have already been mentioned above several times; both of these methods allow for an objective estimation of the *contribution* of recollection and familiarity to recognition memory.

1.9.2.3.1 Process dissociation procedure

The process-dissociation procedure (PDP) was first developed by Jacoby (1991) as a way to separate automatic and controlled uses of memory to recognition performance. Jacoby, and other researchers at this time had observed that performance on *indirect* tests of memory, such as implicit memory, were preserved in amnesics, whilst performance on direct tests that tapped declarative memory (e.g. recall) were impaired (Squire & Zola-Morgan, 1988; Tulving & Schacter, 1990). Such dissociations led to the development of dual-process theories, as they suggested there were different forms, or uses of memory. However, Jacoby acknowledged that comparing memory for implicit/explicit tests to provide evidence for a dual-process model was problematic because such tests were not *process pure*. In particular, indirect tests of memory may be particularly susceptible to the influence of explicit memory, therefore, measurement of any ‘automatic’ process is contaminated.

To overcome this problem, Jacoby’s PDP (1991) assessed the contribution of different processes within one task. Early studies examined this by the use of word-stem completion tasks (e.g. Jacoby, Toth, & Yonelinas, 1993); participants were to study a list of words under full, or divided attention and were subsequently given an *inclusion* and *exclusion* test. In the inclusion test, stems of the word were presented (e.g. fl_ _ _ for ‘flame’) and participants simply had to attempt to recall a word from the study phase to fill in the gaps. In the exclusion test, stems were again presented, but participants were instructed to complete the item without using a word from the study phase. In the inclusion test, performance is subserved by automatic (*A*) and controlled (recollection; *R*) processes, or the combined use of the two. In the exclusion test, an incorrect response (i.e. the participant fills the stem with a study word) would only occur if recollection did not overcome, or successfully *oppose* familiarity. By making the assumptions that the two processes operate independently and have similar influence in the two tests, the contribution of recollection and familiarity to performance can be derived mathematically using algebraic formulations (details of these equations are presented in the method sections of Chapters 4 and 5). In Jacoby et al’s. (1993) study, they found that dividing attention during encoding reduced recollection estimates in healthy adults to zero, whereas familiarity estimates were left unchanged; hence, the two processes were behaviourally *dissociable*.

The PDP can be applied to many different experimental paradigms. The manipulation of different encoding conditions has elucidated a range of variables that selectively effect either recollection or familiarity, hence adding to the hypothesis that they are dissociable processes (see Yonelinas & Jacoby, 2012, for a review). Of particular importance however, is the application of the PDP to populations in which memory impairments are theorised to result as a specific deficit in recollection. The procedure, or variants of it, was therefore used in two experiments within the current thesis to examine recollection and familiarity in TLE. In the first experiment presented in Chapter 4, the ‘repetition-lag’ procedure described by Jennings & Jacoby (1997) was used. This variant of the PDP was originally designed to test one of the fundamental errors of recollection commonly observed in older adults; an inability to overcome the repetition of storytelling. As Jennings and Jacoby theorised, this was a result of the fact that the automatic influences from an earlier encounter of storytelling are not opposed by recollection to determine that they had been told before. Although this may, or may not be a common feature of TLE, the repetition-lag procedure nevertheless allows a suitable means of exploring the contribution of recollection and familiarity to recognition.

As was mentioned in Section 1.9.2.3.1, the PDP can also be applied to associative recognition studies. Associative identification involves discriminating between studied and recombined pairs of items; for example, after studying pairs AB and CD, in the associative identification test, a participant would attempt to recognise AB and reject AD. Hence, relational information would have to be recollected in order to overcome familiarity for the two previously seen words in the recombined pair. In an *associative reinstatement* test, the instructions differ, in that any combination of old pairs can be accepted (i.e. both AB and AD). This does not require the explicit retrieval of the relation between items, but performance should be better for pairs that reinstate the original study context. As Cohn and colleagues discuss (Cohn *et al*., 2008; Cohn, McAndrews, & Moscovitch, 2009; Cohn & Moscovitch, 2007), these tests place varied demands on relational binding, recollection and familiarity, and strategic retrieval operations. Associative identification is dependent on intact MTL binding operations, but also strategic *recall-to-reject* strategies, which are suggested to rely on integrity of frontal-lobe functioning (Cohn *et al*., 2008). Associative reinstatement, however, is less dependent on strategic retrieval, and is a purer index of MTL relational binding operations (Cohn *et al*., 2009). By incorporating associative identification and associative reinstatement into a single task (akin to inclusion and exclusion tests), one can derive behavioural measures reflective of recollection (e.g. FPs after failure in recalling-to-reject) and familiarity (e.g. item memory) but also derive objective PDP estimates of these two processes by contrasting hit and FP rates across tests. The formula for these are described in detail in Chapter 5.

1.9.2.4 ROC method

The ROC method was not employed in the current thesis, but due to its widespread use and influence on the dual-process/single trace literature, I provide a brief overview of this objective measurement technique.

An ROC is a function that relates the proportion of hits to FPs over different variations in response bias (Yonelinas & Parks, 2007). The most common way of measuring this is to obtain a continuous confidence rating over a six-point scale for recognised items (e.g. 1 – *sure old* to 6 - *sure new*). Because this method allows one to plot a function of hits against FPs over different response criterion, it is more constraining than typical recognition tests, in which only one point, the single hit and FP rate, are obtained. The ROC is generated by plotting hit and FP pairs starting with the most confidently recognised items (hits and FPs assigned a rating of 6) and subsequently plotting items with the next highest level of confidence (i.e. hit = 6, FP = 5; FP = 6, hit =5). This is continued until all permutations of confidence are plotted. The shape of the ROC curve and area beneath it, the intercept with the y-axis, and slope of the z-ROC curve are then derived from these responses. Example ROC curves are displayed in Figure 1.2. Observing the left panel – chance performance would lie along the diagonal (as hits = FPs), but as the curve is pushed up toward the outer left quadrant, the greater area under the curve represents greater memory sensitivity or discriminability. In this example, the ‘strong’ curve represents an ROC function for a test where items were presented multiple times during encoding (versus one presentation for ‘weak’). Hence, this encoding benefit would lead to better memory discrimination performance between Old and New items.

Another way of analysing the ROC is to obtain the z-score for each point and plot these as z-space ROCs. If the z-ROC is linear, then the intercept can be used to approximate recognition accuracy, and the slope can be used to estimate the asymmetry of the ROC. In Figure 1.2, both diagonals appear to be slightly pushed up to the left hand-side, indicating that the z-slope is less than 1. Analysis of z-slope and z-intercept are the most common measures and regression analyses can be conducted on these to assess slope and intercept functions (Yonelinas & Parks, 2007). However, one can also fit theoretically based models to the ROC using signal detection algorithms. Model based analytic approaches provide estimates of model parameters; for example, in the dual-process signal detection model, one can obtain estimates for each subject of the contribution of recollection and familiarity. These estimates can then be submitted to standard quantitative statistical analyses, such as ANOVA, to compare differences.

There are numerous models that have been proposed to account for recognition memory, and the strength of the ROC method is that the ‘goodness-of-fit’ of each model can be calculated to show numerically whether one model has better explanatory power of the data than another. The dual-process signal detection model (Yonelinas, 1994) views recollection and familiarity as independent, with the former being a threshold process and the latter as continuous. Thus, familiarity is represented as a curved symmetrical ROC. Because recollection increases with high confidence hits during item recognition, the ROC becomes asymmetrical and the z-ROC will have a slope of less than 1. Based on these predictions, increasing recollection (through semantic encoding instructions, for example) should lead to a more asymmetrical ROC, whereas familiarity should be unchanged and hence symmetrical.

Each of the alternative signal detection approaches predicts different shapes to ROCs, and this is also dependent on the type of test used (e.g. item vs relational recognition). One of the strengths of the ROC method is that it can be applied to almost any recognition paradigm, and as Yonelinas (2002) discusses, the dual-process signal detection model has been used extensively to corroborate dissociations found in other methods, such as the PDP and R/K paradigm. As Yonelinas and Parks (2007) and Parks & Yonelinas (2008) review, single trace models of recognition cannot adequately account for recognition memory, and instead two processes must be responsible.

The focus of the current thesis was to make comparisons between objective measures of performance and the subjective experience associated with them in TLE and healthy adults *within-tasks*. Comparison of subjective experience with ROC data has been conducted previously in the literature with healthy adults (Kapucu, Macmillan, & Rotello, 2010; Rotello, Macmillan, Reeder, & Wong, 2005). These studies have typically evaluated how well a number of alternative mathematical models fit recognition data. However, as mentioned, the aim of this thesis was not to prove or disprove dual or single process accounts. Therefore, the ROC method was not examined.

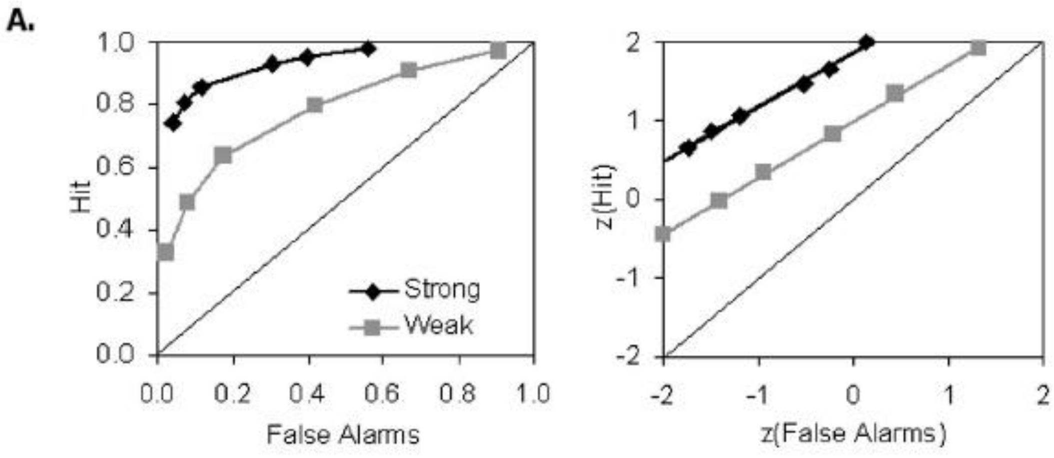

Figure 1.2 Example ROCs in probability space (left panel) and z-space (right panel) from Egan (1958), as cited by Yonelinas and Parks (2007).

1.9.3 Theoretical considerations and boundary conditions of methods

Because all dual-process accounts have the central defining feature that recollection and familiarity operate independently, their ability to display this has been the focus of most criticism. However, there are a number of careful considerations that can be adopted, in both methodology and statistical analysis, which can ensure this assumption, and others, are met. Below, I discuss some of the theoretical issues relating to the two main methods employed in the present set of experiments; the PDP and R/K paradigm.

1.9.3.1 Process Dissociation Procedure

An early criticism of the PDP came from Curran & Hintzman (1995), who argued against the independence assumption on the basis that recollection is *redundant* with familiarity, rather than independent of it. For example, redundancy would occur in the inclusion stem completion test described earlier if a word automatically came to mind, and the participant then engaged in a memory search to see if the word was originally studied ('generate-recognise' strategy). However, Jacoby (1998) displayed different patterns of responding when providing instructions that either encouraged the generate-recognise strategy, or direct retrieval. This argument led to the acknowledgment that instructions are critical to find the predicted dissociation in controlled and automatic processes. In a similar vein, as Jacoby (1998) discusses, varying instructions may have an effect on response bias in each test, such that base rate FPs differ. This would also pose a problem for the independence assumption.

Because the experiments in this thesis did not use this stem completion paradigm, the more important issue was whether participants *understood* the instructions for the inclusion and exclusion tests. To overcome this potential problem, the experiments in Chapters 4 and 5 both used the exact same instructions as the published studies on which they were based. Moreover, participants' understanding of these instructions was verified and the instructions were available throughout the testing procedure. Moreover, as robust dissociations between recollection and familiarity had been previously shown using these paradigms, this precedent provided good basis to believe that this factor should not confound the independence assumption. With respect to response bias, this was checked and analysed via ANOVA in both studies.

A further problem for the independence assumption is if recollection and familiarity are not equally used as bases for responding in both inclusion and exclusion tasks. In depth-discussion of ways to counteract such a problem are provided by Yonelinas, Kroll, Dobbins, Lazzara and Knight (1998) and Yonelinas and Jacoby (1995). The important issue relating to this for the current thesis comes down to the *type* of recollection involved in these tests. The PDP only measures the extent to which a recollective process aids performance on a specific task. Hence, there may be other more automatic forms of recollection that are present that are not captured in the PDP derived estimates. This has been termed 'noncriterial recollection' (Yonelinas & Jacoby, 1996) . For example, when having to decide whether a word pair was studied together, a participant may automatically remember that they sneezed when they saw one of the words. However, this contextual information had not originally contributed to binding the items and hence could not be used as a recollective process to correctly accept the word pair. These kind of influences may thus exert an effect across inclusion and exclusion performance and one potential way of accounting for such differences is to use subjective reports, which reflect all available recollective information. This was the approach taken in the current set of experiments.

1.9.3.2 R/K paradigm

The original R/K paradigm only permits a participant to respond either Remember or Know to a single item, which inherently carries an *exclusivity* assumption that the two cannot co-exist. Although dual-process models treat *knowing* as arising in the absence of recollection, as Yonelinas and Jacoby (1995)discuss, this does not mean that items that are recollected will not be experienced with familiarity also. Hence, the R/K procedure underestimates the contribution of familiarity. To overcome this problem and to provide a measure that satisfied the independence assumption, the *independence-remember-know* (IRK) procedure was introduced (Yonelinas & Jacoby, 1995). As well as providing a more accurate estimate of familiarity, the IRK procedure also acknowledges the problems that arise in estimates when groups differ in their response bias (i.e. FP rates differ). A number of studies have shown that the use of the IRK procedure makes comparison of data from subjective reports more consistent with the dissociations and findings gleaned from objective process estimates (Prull, Dawes, Martin, Rosenberg, & Light, 2006; Yonelinas *et al*., 1998; Yonelinas & Jacoby, 1995; Yonelinas, 2001). This is of importance for the current thesis as a direct comparison of these measures in TLE was a primary focus. The calculation of recollection and familiarity using the

IRK procedure is outlined in Chapter 3, and further discussion about comparison of subjective and objective methods is covered in Section 1.11 below.

Other methodological issues that have received attention in the literature have focused on the use of one-step or two-step procedures and the inclusion of a Guess response. With respect to the former, a question has been whether asking participants to state their subjective experience combined with the recognition decision (i.e. Remember, Know or New) would differ from when it is required *following* an Old/New decision (Old, followed by Remember/Know). A number of studies have examined this issue and compared recognition performance measures including sensitivity and response criterion, as well as accuracy associated with different subjective experience judgments (e.g. Bruno & Rutherford, 2010; Eldridge, Sarfatti, & Knowlton, 2002; Hicks & Marsh, 1999). In general, findings have suggested that recognition accuracy does not differ between one and two-step procedures. However, a consistent finding is that the one-step procedure leads to a more liberal response criterion, and Know judgments in particular appear to be assigned a higher level of hit and FPs with this method. As Hicks and Marsh (1999) discuss, this is likely due to the added difficulty of attempting to distinguish between different subjective states at the same time as recognition. For this reason, the two-step procedure was adopted in the current experiments where the R/K paradigm was utilised.

From a similar line of enquiry, the inclusion of a Guess response in the R/K paradigm has been researched as it was suggested that inconsistencies in response bias between studies using LoP manipulations may have resulted from participants using the Know category when in fact they were guessing (Gardiner, Java, & Richardson-Klavehn, 1996). Gardiner and colleagues have examined differences between Guess and no-Guess procedures and made several conclusions (Gardiner, Richardson-Klavehn, & Ramponi, 1997; Gardiner, 2008; Gardiner, *et al*., 1996; Gardiner, Kaminska, Dixon, & Java, 1996). First, results suggest that inclusion of the Guess category produces similar results to when participants are actively encouraged *not* to guess, but are not actually given the Guess response option. However, in situations where guessing is not discouraged, or is not mentioned, participants may use the Know response option occasionally when guessing. Additionally, when assessing justifications for the different subjective experience judgments, it is apparent that participants draw on inferences, judgmental strategies and unrelated mnemonic information to the study episode when making a Guess response. For example, Guess justifications often reflect familiarity for a target derived from some other external source (Gardiner *et al*., 1998). In comparison, Know and Remember justifications are reliably different from experiences of guessing, and each other. As Gardiner

(2008) summarises, the inclusion of a Guess response in the R/K paradigm is of use, as it effectively removes instances where participants use the Know judgment when they are in fact guessing. As such, guessing was permitted in the experiments presented in Chapters 3 and 4 of this thesis that used the R/K paradigm along with recognition data.

Just as the clarity and interpretation of instructions is critical in the PDP, this is also a major consideration in the R/K paradigm. The greatest problem lies in how *Know* judgments are described; published studies vary greatly in their description of what constitutes this subjective state, with some emphasising it as reflecting high confidence 'just knowing' that an item was present, some studies implying it is associated with lower confidence, and some studies using the term 'Familiarity' instead of Knowing. The present thesis aimed to compare subjective states of awareness of recollection and familiarity with their underlying cognitive processes (measured by objective process estimates), therefore it was important to ensure the instructions given to participants regarding *Familiarity* in the R/K paradigm was a close to the cognitive process of familiarity as possible.

A number of studies have explored whether the subjective states of Knowing and Familiarity are dissociable, although this has typically been in the context of learning meaningful information such as in higher education, to observe the semanticisation of knowledge over longer periods (Conway, Gardiner, Perfect, Anderson, & Cohen, 1997; Dewhurst, Conway, & Brandt, 2009; Herbert & Burt, 2001, 2004). Although not directly assessing the difference between the two states for recognition on a single test occasion, such studies have revealed that 'just knowing' reflects a state of awareness that is similar to subjective remembering in terms of accuracy, and may differ from subjective familiarity.

A recent set of experiments presented in an unpublished thesis by Williams (2011) directly compared Remember, Know, Familiar and Guess responses using recognition tasks similar to those presented throughout this thesis. The conclusion drawn from this work was that Familiar and Know responses were dissociable; many similarities were in fact found between Know and Remember responses in measures of confidence, response speed, and accuracy. Hence, 'just knowing' (Know response) reflects a different state of awareness to 'feelings of familiarity' (Familiar) response. This was a further rationale for including the Familiar judgment, rather than Know, in the present study, as I wanted a measure that was likely to dissociate recollection and familiarity as best as possible.

Moreover, a study by Geraci, McCabe, and Guillory (2009) recently showed that R/K judgments were most orthogonal to confidence (hence refuting single trace accounts) when Knowing was described as a highly confident state, in the absence of recollected details. Therefore, the instructions provided to participants in the current experiments used the word *Familiar*, but emphasised this should reflect feelings of familiarity for the word along with high confidence it was previously seen. The instructions provided to participants can be found in Appendix A.

1.10 Recollection and familiarity in TLE

Support for dual-process theories of recollection and familiarity has come from various strands in the literature. A great deal of support for the existence of these two independent processes has come through application of the different methods described above to show that they are functionally *dissociable* processes via experimental manipulations in healthy subjects; neuroanatomically through lesion studies; neuroimaging and electrophysiological work; or in special populations. A thorough examination of this extant literature is beyond the scope of this thesis; reviews can be found in Eichenbaum, Yonelinas, & Ranganath (2007); Parks & Yonelinas (2008); Skinner and Fernandes, (2007) and Yonelinas and Jacoby (2012). For single trace arguments and responses to these dual-process accounts, see Squire et al. (2007); Wais et al. (2008); Wixted (2007) and Wixted & Squire (2010). As the current thesis was concerned with examining recollection and familiarity specifically in TLE, below I present a thorough review of previous studies assessing these processes in this patient group.

1.10.1 Application of the R/K paradigm to recognition memory in TLE

A number of studies have applied the R/K paradigm to assess the subjective states of Remembering and Knowing in TLE. As mentioned in Section 1.5.1, a critical neuropsychological issue in this patient group has been the assessment of laterality and material specific deficits, so as well as attempting to display patterns of reduced remembering in TLE, studies have also used the paradigm to explore subjective states of awareness for visual and verbal material in LTLE and RTLE.

The fist study to apply the R/K paradigm to TLE came from Blaxton and Theodore (1997), who compared recognition and subjective experience for abstract designs in pre and post-surgical

LTLE, RTLE and healthy controls. They found that controls and LTLE patients' recognition was dominated by subjective Knowing, whereas the opposite pattern was found in the RTLE group; they subjectively remembered far more of the designs. This was also reflected in FP rates, where the RTLE group had significantly fewer Remember FPs to new items. In a qualifying experiment, they assessed the influence of surgical status, by comparing equal numbers of left and right pre- and post-surgical patients. The results were identical to before as the presence of widespread MTL lesions did not alter the effects. Finally, they conducted another experiment using encoding manipulations to encourage conceptual and perceptual processing. As expected, controls provided more Remember responses to items encoded under conceptual encoding conditions, and more Know responses under perceptual encoding. However, LTLE patients consistently provided more Know responses regardless of encoding instructions, and the opposite was found for RTLE patients, as they consistently made more Remember judgments. Hence, the results were supportive of a 'modes-of-processing' view of laterality that emphasises the importance of the left temporal lobe in conceptual or distinctive processing, and the right temporal lobe in perceptual or fluent processing.

Moscovitch & McAndrews (2002) conducted a follow-up study and compared visual (face) and verbal material in left and right patients under conceptual and perceptual encoding conditions. Based on Blaxton and Theodore's (1997) interpretation, LTLE patients should show global impairments in conceptual processing regardless of the type of material (i.e. more Know than Remember responses) and encoding instructions. RTLE patients on the other hand should show global impairments in perceptual processing. Instead, their evidence fully supported the material-specific view. Subjective remembering was significantly reduced for verbal material in LTLE patients, whilst non-verbal memory (faces) was associated with significant reductions in subjective Remember responses in RTLE patients. Moreover, for material processed by the hemisphere contralateral to the epileptic focus, Remember responses were increased by conceptual processing. For example, Remember responses to verbal stimuli were higher in RTLE patients after conceptual encoding. In contrast, the expected pattern was found in controls where conceptual processing enhanced Remember responses regardless of material type. Additionally, Know responses were unaffected in all groups by encoding manipulations. Moscovitch and McAndrews concluded that the results were in agreement with previous work suggesting the involvement of the hippocampus in the formation of conceptual relationships; although their patient sample included participants with excisions outside the hippocampus, they reasoned that there was good evidence indicating this was the most consistently damaged area.

Bengner and Malina (2008) sought to clarify some of the inconsistencies found between the above two studies. They assessed the impact of laterality of lesion, hippocampal sclerosis and proactive interference (PI) [2] on Remember/Know responses during face recognition. Surprisingly, they discovered that patients with hippocampal sclerosis made fewer Know responses, regardless of side of lesion. This result thus contradicted much of the previous amnesic and neuroimaging literature that has consistently suggested the hippocampus is critical for recollection and adjacent parahippocampal and rhinal cortices are responsible for familiarity (as discussed in Section 1.8.5 above). Moreover, the same result occurred with and without the influence of PI, despite the fact this manipulation was hypothesised to have an impact on Remember, not Know responses. They also found that Remember responses were significantly reduced in the RTLE group, and suggested that the combination of these results points to the involvement of a distributed network of regions involved in face recognition, located predominantly in the right temporal lobe. Because PI led to similar reductions in Remember responses in both LTLE and RTLE, the authors concluded that their results do not support the Blaxton and Theodore (1997) modes of processing account; support for this would have been evidenced in a left temporal lobe performance advantage following PI due to its hypothesised involvement in conceptual processing.

One of the key weaknesses of group studies such as the three reported above is in the variability of the patient sample in terms of clinical aetiology, neuropsychological test performance, and most importantly, the extent of lesions. Even Bengner and Malina (2008), who used strict clinical data to classify patients into groups with, or without hippocampal sclerosis, acknowledged that it could not be discounted that patients may have subtle pathology extending beyond the hippocampus. To overcome these problems, Bowles and colleagues (Bowles *et al*., 2007, 2010) presented analyses of patients with extremely well documented lesion data following selective excision of hippocampal or anterior temporal lobe structures.

In their first study, Bowles et al. (2007) presented the single case NB, who had had a lesionectomy for relief of intractable SPS, CPS and SGTC seizures. Surgical removal included her left amygdala and portions of the rhinal cortices, whilst leaving the hippocampus and PHc intact. Using the R/K paradigm, NB displayed a comparable discriminability score (*d*') to a group of matched controls, which was expected in the context of normal neuropsychological

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[2] Proactive interference is the phenomenon whereby previously learned information is detrimental to the learning of more recent information. In Bengner and Malina's (2008) study, learning a list of faces 24 hours before the next test phase was hypothesised to interfere with this subsequent material. Because PI reduces contextual distinctiveness in episodic memory, the authors predicted PI would reduce subjective levels of remembering.

evaluation. However, her recognition responses were characterised by elevated levels of Remember responses, with impaired Familiarity. Due to the precise lesion data, the results therefore argue against a unitary trace strength account because of the dissociation in the subjective experience of recollection and familiarity.

From a single trace perspective, this dissociation can still be explained by the fact the hippocampus supports strong memories, whereas surrounding areas support weaker memories (e.g. Wais *et al*., 2008). Therefore, more convincing evidence would come from a *double dissociation*, displaying the opposite pattern of performance to NB in patients with selective hippocampal lesions. This is exactly what Bowles et al. (2010) achieved in their later study. They administered a verbal R/K task to a group of left and right sided TLE patients who had undergone selective amygdalo-hippocampectomy; a surgical procedure that spares surrounding neocortical structures. They found both groups to have significantly reduced recollection scores compared to controls, and their z-transformed scores further revealed recollection to be significantly less than familiarity also. They also found patients with milder overall recognition impairments to have the most reduced recollection scores. To provide evidence of a double dissociation, the authors identified a single patient from the larger group who was well matched with patient NB for overall recognition performance and showed a corresponding impairment in recollection, with familiarity intact.

Taken together, the findings by Bowles et al. suggest a simple explanation involving differing memory strength in MTL regions is not adequate. The lack of difference between left and right patients in this verbal measure once again contrasts the results found in the studies cited above. As a possible explanation, the authors cite evidence suggesting the potential role of the right temporal lobe in imagery, which may be closely involved in the 're-experiencing' aspect of hippocampally dependent recollection (e.g. Maguire, Valentine, Wilding, & Kapur, 2003; Viard *et al*., 2007).

Another critical point addressed by these authors centres on the relationship between overall memory performance and selectivity of recollection impairments. As noted above, better overall recognition ability was associated with *reduced* recollection impairments, which supports findings from other documented cases of hippocampal amnesia where isolated recollection impairments were found in the context of normal recognition performance (Bird & Burgess, 2008). Variations in recollection impairments appear in groups of patients even when there is documented evidence of selective hippocampal pathology, and this is likely to be due to variations in extent of hippocampal damage and functional integrity of remaining tissue (Holdstock *et al*., 2008). Clearly, when evaluating differences in recollection, it is important to consider the impact varying levels of memory strength may have. This is approached in Chapter 3, where qualitative differences in Remember responses are assessed between patients and controls after matching recognition performance.

Attempting to bring some resolution to the above material specificity debate, Martin, Bowles, Mirsattari, and Köhler (2011) conducted further assessment of patient NB with a variety of material types to see if her selective familiarity impairment was exclusive to verbal stimuli. Three recognition tests were administered involving aurally presented non-words, unfamiliar faces and abstract designs. These were all selected on the basis that performance could not be enhanced, or influenced, by pre-existing semantic relationships; it has been suggested that lateral temporal structures in the left temporal lobe in particular are crucial for verbal tasks that require the use of such semantic representations (Saling, 2009). Therefore, using these difficult stimuli, any effect of damage to lateral areas in NB was predicted to be attenuated. Martin et al. (2011) found a selective impairment in the verbally presented stimuli, which manifest as a significant reduction in subjective familiarity. These results, along with other similar studies (Aly, Knight, & Yonelinas, 2010; Cohn *et al*., 2009) suggests that familiarity processes and not recollection, operate in a material-specific manner.

As mentioned in Section 1.2, the experience of déjà vu is a common manifestation of SPS in TLE; this experience is characterised by inappropriate *feelings of familiarity* in the context of an assessment of novelty. In an extensive review of the TLE literature, Illman et al. (2012) assessed evidence from brain stimulation, neuroimaging and subjective report data in an attempt to clarify the underlying neurobiological bases of different forms of this phenomenological experience. Their conclusion focused on the suggestion of a separation between a hippocampal based *recollective* error (termed 'déjà vecu') and the more typically experienced familiarity error experienced in TLE, which is likely due to irregular neuronal firing of extrahippocampal structures. Martin et al. (2012) recently conducted a vital empirical study in this area by assessing both subjective and objective measures of recollection and familiarity in TLE patients who did and did not experience déjà vu as part of their habitual seizures. Recognition of visually categorised scenes was impaired in both groups compared to controls, and further analysis displayed the patient group with déjà vu to have selective impairments in assessments of familiarity, whilst the group without déjà vu had impairments in both recollection and familiarity. Moreover, volumetric analyses showed a trend for the déjà vu group to have more focal ipsilateral reductions in rhinal cortices, compared to more widespread MTL reduction in the non-déjà vu group. Thus, these authors displayed for the first time in an experimental setting that the existence of this nebulous state during seizures can be linked to underlying pathology in line with the predictions of dual-process theories.

1.10.2 Application of the R/K paradigm to autobiographical memory in TLE

AM impairments in TLE have recently received much attention in the literature; clinically, this is relevant due to the devastating impact these can have on daily life and theoretically, the study of such a breakdown in memory systems is useful for exploring long-term consolidation processes (as covered in Section 1.8.5). Although this literature continues to grow, only two studies to date have applied the R/K paradigm to specifically address AM in TLE. Noulhiane et al. (2007) used the TEMPau task (Piolino *et al*., 2003) with left and right resected TLE patients in comparison to controls. This semi-structured interview requires the retrieval of thematically cued AMs from four lifetime periods, followed by R/K judgments to indicate the subjective experience associated with recall of events. An objective episodic score was derived from participants' narratives according to specificity and richness of details, and participants were asked to justify Remember responses with factual, spatial and temporal contents of memories. Their findings revealed that both patient groups had temporally extensive impairments in objective episodic scores, matched by reduced levels of subjective remembering also. Correlations between MTL regions and their AM measures further revealed that the right temporal lobe is crucial for reliving the encoding context of memories throughout the lifespan.

In a recent single case study, Illman et al. (2011) assessed AM and the self in a patient with transient epileptic amnesia (TEA), a late onset syndrome of TLE (see Butler & Zeman, 2007, for a review). They combined the R/K paradigm with the IAM task (Rathbone, Moulin, & Conway, 2009, 2008) – a measure that has previously illustrated how AMs cluster around the emergence of different perceptions in identity (e.g. I am a husband). Illman et al. (2011) displayed the patient to have reduced levels of subjective remembering for critical self-defining memories from his past, but a preserved *sense of self*, presumably supported by intact semantic and conceptual knowledge of his life (see also, Rathbone *et al*., 2009, for a similar discussion).

Many other studies have assessed AM in TLE and have found impairments especially in episodic components; although relying on the verbal reports of patients, these all use more objective scoring criteria to determine the episodic and semantic content of memories and therefore will be mentioned further in Section 1.10.4 below.

In summary, there are a number of studies that have utilised the R/K paradigm in TLE for both anterograde and retrograde memory. The findings from the patient samples, and the effect encoding manipulations have on controls, have provided consistent support for the functional dissociation of recollection and familiarity as states of conscious awareness. Although this research has done much to provide support for dual-process theories, and neuroanatomical theories of MTL functioning, the lack of group studies in this area means there are still potential avenues to explore. This was one of the main motivations for the present thesis; as will be described below, one gap in the literature is the extent to which patients' metamemory judgments of their underlying recognition impairment (i.e. R/K judgment) is consistent with objectively measured indices of recollection and familiarity.

1.10.3 Objective measurement of recollection and familiarity in TLE

Studies have shown that whereas explicit measures of recall and recognition are impaired in TLE, implicit memory is often intact (e.g. Billingsley, McAndrews, & Smith, 2002; Zaidel, Oxbury, & Oxbury, 2006). In a recent review, Leritz, Grande, and Bauer (2006) summarised this literature, and concluded that results suggest that tasks that are more dependent on intentional and controlled uses of memory (i.e. they require explicit memory) are more reliant on the integrity of the hippocampal complex, whereas more automatic tests of priming are achievable with a non-functional hippocampal complex. As discussed in Section 1.9.2.3.1, the problem with the comparison of explicit and implicit tasks is that each process may be contaminated by the other. Therefore, using tasks that are able to dissociate these forms of memory is more useful. Only a handful of such studies exist in the TLE literature.

Del Vecchio, Liporace, Nei, Sperling, & Tracy (2004) borrowed the verbal stem completion PDP from Jacoby (1991) to assess recollection and familiarity in LTLE (the method of which is described in Section 1.9.2.3.1). They found patients to be impaired in their use of recollection to complete the task, whilst estimates of familiarity were intact. Building on this work, Hudson, Flowers, and Roberts (2009) conducted a similar stem completion paradigm with inclusion and exclusion tests but included a RTLE group for further comparison and used a 'guided procedure' with visual prompts to ensure participants' understanding of instructions. These authors displayed a significant reduction in recollection estimates in the left temporal group only, whereas familiarity was comparable between both patient groups and controls. Thus, these two studies both illustrated with one version of the PDP that recollective processes are significantly impaired in TLE, and this has a material specific basis at least for verbal stimuli in the LTLE group.

The studies cited in the above section by Bowles et al. (2007) and Martin et al. (2011, 2012) both incorporated objective assessments of recollection and familiarity as well as the R/K paradigm. For example, Bowles et al. (2007) displayed comparable selective reductions of familiarity in patient NB using the ROC method, and Martin et al. (2011) further used this method to support the material specific basis of this impairment. In their assessment of familiarity in patients experiencing déjà vu, Martin et al. (2012) used an exclusion task involving the repetition of visual scenes, similar to the repetition-lag procedure of Jennings and Jacoby (1997). They found that whereas both patient groups had equal impairments compared to controls in discriminating between Old and the first presentation of New items, only the group who did not experience déjà vu showed impairments in excluding repeating lures at all lag intervals. Therefore, the results converged with the R/K paradigm and suggested the presence of déjà vu in patients was related to more isolated impairments in familiarity, whilst leaving recollection intact and allowing patients to exclude repeated items on the basis of this process.

As discussed in Section 1.9.2.1, associative recognition tests are accepted as a relatively reliable measure of recollective or relational memory and have been used extensively in the amnesia literature along with item recognition tests to compare familiarity and recollective dependent processing (Giovanello, Verfaellie, & Keane, 2003; Gold *et al*., 2006; Kan *et al*., 2007*a*; Kan, Giovanello, Schnyer, Makris, & Verfaellie, 2007b; Quamme *et al*., 2007) . Empirical studies have also explored associative recognition impairments in the general TLE population.

For example, Weniger, Boucsein, and Irle (2004) administered object and face associative tests to pre- and post-operative TLE patients and obtained detailed structural data regarding MTL lesions. They found that patients with large lesions in the hippocampus, PHc and amygdala performed worse than patients with smaller lesions and controls. Moreover, regression analyses revealed that increasing size of rhinal cortex lesions was significantly associated with worse performance on the associative task, whilst size of hippocampal and amygdala lesions provided no extra explanatory power. Thus, their results were consistent with the recent neuroanatomical models of MTL function discussed in Section 1.8.5.1 that propose the rhinal cortices can support binding of intra-item associations (Diana *et al*., 2007; Montaldi & Mayes, 2010).

In the context of neuropsychological assessment, impairments in arbitrary associations for verbal stimuli are often used as lateralising evidence for LTLE during neurosurgical assessment (McAndrews & Cohn, 2012; see Saling, 2009, for a critical discussion of this). Other studies have, however, displayed preferential impairments in the formation of associations in non-verbal stimuli in RTLE, such as musical tones (Wilson & Saling, 2008) and abstract design and symbols (Smith, Bigel, & Miller, 2011).

Although this work provides further understanding of hemispheric specialisation in associative learning and helps elucidate the division of labour within MTL sub regions, only one study has specifically addressed the contribution of recollection and familiarity to item and associative memory in TLE (Cohn *et al*., 2009). In this study, the authors aimed to compare different forms of associative memory (associative identification and associative reinstatement, as described in Section 1.9.2.3.1) with item memory, and assess the contribution of recollection and familiarity to performance in post-operative TLE patients. They had two specific aims; first, to make a novel comparison between the different associative measures in TLE, and second, to assess the contribution of laterality and language dominance to these processes. Their results showed that associative identification, associative reinstatement and recollection measures for both dominant and non-dominant patient groups was significantly below that of controls. As was item memory, which although runs *contra* to other findings in the literature, the authors suggest that the pair recognition task they used to estimate item memory is influenced by recollective processes. Addressing their second aim, they found familiarity estimates to be significantly reduced only in the dominant TLE group, providing further evidence that familiarity processing, more so than recollection, has a material specific basis.

1.10.4 Objective measurement of dual-processes in autobiographical memory in TLE

Although the R/K paradigm has had limited use in AM studies in TLE, a number of studies have used other methods that specifically aim to fractionate episodic and semantic , or recollective and familiarity processes in retrograde memory (e.g. Addis, Moscovitch, & McAndrews, 2007; Herfurth, Kasper, Schwarz, Stefan, & Pauli, 2010; Lah, Grayson, Lee, & Miller, 2004; Lah, Lee, Grayson, & Miller, 2006, 2008; Manes, Graham, Zeman, de Luján Calcagno, & Hodges, 2005; Manes, Hodges, Graham, & Zeman, 2001; Park, St-Laurent, McAndrews, & Moscovitch, 2011; St-Laurent, Moscovitch, Levine, & McAndrews, 2009; Viskontas, McAndrews, & Moscovitch, 2000). These studies have found impairments in both episodic and semantic aspects of AM in

TLE, but an examination of the interaction between the two, and a comparison of subjective and objective measures has not yet been explored. Chapter 6 addresses this gap in the literature by utilising a novel public events task that incorporated an objective measure of dating accuracy alongside several subjective measures that provided an index of recollective experience associated with the retrieval of memories for events.

1.11 Comparisons of methods

1.11.1 Convergence of subjective and objective dual-process methods

As discussed in Section 1.8, the underlying assumptions about how recollection and familiarity operate differ somewhat between the dual-process theories proposed by Tulving (1985), Jacoby (1991) and Yonelinas (1994). For example, as Gardiner et al. (1996) and Gardiner (2001) discuss, the R/K procedure provides a first-person experiential account of the subjective experience associated with different recognition processes, whereas the PDP adopts an objective, third-person approach as it sees the two processes as differing in uses of intentional control in inclusion and exclusion tests. Further, as Yonelinas (2001*a*) describes, the ROC method assesses the two processes in terms of their contribution to the shape of a response confidence curve.

Despite these apparent differences, a large body of evidence has accumulated suggesting a *convergence* between them. The most robust evidence for this has mainly come from studies investigating recollection impairments in memory impaired groups. For example, Yonelinas et al. (1998) compared the PDP, R/K paradigm and ROC method in amnesics and found comparable reductions in both recollection and familiarity for all methods. Further, Jacoby, Debner, and Hay (2001) assessed the influence of PI, study duration and divided attention on recollection and familiarity in the context of aging; they found similar effects on the two processes using both the PDP and R/K paradigm, and reported significant correlations between subjective reports of remembering and objective process estimates. Yonelinas (2001*a*) carried out a comprehensive assessment of the three methods to assess the influence of divided attention and levels-of-processing on recollection and familiarity. His set of experiments assessed the R/K paradigm and ROC together, and he also provided a separate examination of all methods in a between-subjects design. Yonelinas (2001*a*) concluded, “The current results...showed that these three characterisations of recollection and familiarity are quite compatible and that the measurement procedures associated with these theories lead to converging conclusions about the two processes" (p. 373). Subsequent studies in the amnesic literature have provided similar results (e.g.Turriziani, Serra, Fadda, Caltagirone, & Carlesimo, 2008; Vann *et al*., 2009) as did the study by Bowles et al. (2007) investigating the post-operative TLE patient, NB.

The comparability between these subjective and objective measures suggests the R/K paradigm is a viable means of assessing the consciousness associated with the underlying cognitive processes that contribute to human memory. Something that is lacking from this literature, however, is within-task comparisons of such measures. Although the ROC method of acquiring confidence ratings can, and has been used in conjunction with the R/K paradigm and PDP (Kapucu *et al*., 2010; Rotello *et al*., 2005; Yonelinas, 2002), there still exist other ways of exploring subjective experience with the objective indexes of memory performance within single tasks. One of the central aims of the current thesis was to broaden this literature further by using TLE as model to understand the relationship between subjective and objective forms of recollection.

1.11.2 Comparison of dual-process methods with neuropsychological tests

A similar comparison of methods has been conducted quite extensively in the aging literature in order to better understand the neurobiological and cognitive basis of age-related memory decline. Recollection impairments in this group have been linked to compromised medial-temporal and frontal-lobe integrity through the comparison of subjective and objective tasks with neuropsychological test performance (Clarys, Bugaiska, Tapia, & Baudouin, 2009; Glisky, Rubin, & Davidson, 2001; Henkel, Johnson, & De Leonardis, 1998; Prull *et al*., 2006) and findings from the neuroimaging literature suggest that frontal and medial temporal lobes are most affected by aging (Buckner, Head, & Lustig, 2006). Such results are consistent with other neuroimaging data showing that recollection is dependent on a network of these areas (Skinner & Fernandes, 2007); specifically, the medial-temporal lobe being involved in the binding and integrating of information, and the frontal lobes involved in the elaboration of strategic encoding and retrieval operations (Wheeler, Stuss, & Tulving, 1997).

A neuropsychological test approach was also used in a recent meta-analysis by McCabe, Roediger, McDaniel, and Balota (2009), who compared the relationship between Remember hits and FPs in the R/K paradigm to neuropsychological test performance in older adults over a range of studies. Their analysis revealed that whereas medial-temporal lobe functioning (in tests such as paired-associate recall and list learning) was related to Remember hits, age and frontal-lobe functioning (such as mental arithmetic and verbal fluency) was related to Remember FPs. Familiarity, however, was uncorrelated with neuropsychological test performance or age.

As discussed in Section 1.6, discrepancies between TLE patients' subjective report of memory and neuropsychological test performance have been consistently observed in the literature, and the causes of this still need investigating. No studies to date have incorporated a direct comparison between measures of recollection and familiarity, standardised test performance and subjective perception of memory in TLE. Because these measures all reflect the different aspects of consciousness to memory, a combined approach is likely to be both theoretically interesting as well as providing useful data for clinical practice. This was thus the clinical theme of this thesis.

1.11.3 Self-awareness of memory: Metamemory

The convergence found between subjective and objective measures of recollection and familiarity in MTL damaged patients suggests that these people have *insight* into the basis of their memory problems. For example, reduced levels of subjective remembering in the context of poor discriminatory performance, or corresponding low objective measures of recollection in the PDP suggest a person can reflect appropriately on their underlying cognitive processing. Thus, Remember/Know judgments can be seen as a form of *metacognitive assessment*. However, there is a vast literature that has examined *metamemory*, which also compares subjective reports of participants regarding their memory functioning with objective measures of performance.

In the TLE literature, assessments of metamemory have typically come in the form of questionnaire based assessments of patients' perception of their memory functioning, which are subsequently compared to objective neuropsychological test performance (as described in Section 1.6). Although providing mixed results, the general finding has been one of overestimation of memory difficulties in this group. However, an alternative assessment of metamemory is through the application of laboratory tasks to see how standard metacognitive measures match up with objective recall or recognition performance. Such tasks tap into *monitoring* and *control* aspects of metacognition, following the influential model proposed by Nelson and Narens (1990).

A handful of these experimental metacognition studies exist in the TLE literature. Early studies suggested that patients were inaccurate in monitoring memory performance measured by judgments-of-learning accuracy (JOL; Nelson & Dunlosky, 1991) and found impairments in their ability to predict subsequent recognition success for currently unrecallable information, evidenced in feeling-of-knowing (FOK; Hart, 1965) accuracy (Prevey, Delaney, Mattson, & Tice, 1991; Prevey, Delaney, & Mattson, 1988). However, the results of these studies were dismissed on several methodological and statistical grounds by Howard et al. (2010*a*), who in a more tightly controlled experiment involving purely episodic materials displayed no impairment in memory monitoring in TLE patients (using JOL and FOK judgments), despite their lower overall memory ability. Moreover, another study from the same group found TLE patients memory predictions following study of material was accurately upgraded compared to predictions made before study, reflecting intact metacognitive control processes (Howard *et al*., 2010*b*). The conclusions of these two recent investigations suggest like the R/K literature, that although TLE patients have underlying recall and recognition deficits, their conscious assessment of memory accurately reflects this.

Although the papers by Howard et al. (2010*a*, 2010*b*) suggest monitoring and control is intact in TLE, patients' metacognitive awareness has never been examined in the context of more demanding tasks where successful performance is dependent on recollection. Therefore, although these previous studies have assessed whether a metacognitive impairment drives *general* impairments in recall and recognition, they have not drawn attention to the specific processes underlying these measures of memory. Associative recognition paradigms involve a complex interaction of recollection and familiarity processes so the experiment in Chapter 5 further tested metacognitive accounts of memory impairment in TLE with the use of a novel measure of awareness – confidence judgments. This allowed a comparison of how subjective confidence judgments would differ between item types more, or less dependent on recollection. Moreover, monitoring has also only been examined in the context of anterograde memory tasks; a metacognitive account of AM impairment has not been explored before in TLE. Thus, a simple but informative measure of monitoring was included in the public events task in Chapter 6.

1.12 Aims of this thesis

The overall aim of this thesis was to better understand the nature and extent of memory impairments in TLE using dual-process theory as an empirical framework. To this end, a variety of experimental paradigms are presented in the experimental chapters, each assessing recollection and familiarity in different ways. Based on previous findings, the general prediction was that patients would be impaired across all measures.

Beyond this underlying aim, two broad themes were addressed. The first was *theoretical* in nature – although recollection impairments have previously been found in TLE, I wanted to provide a novel assessment of the relationship between subjective experience (in terms of remembering, familiarity and metacognitive awareness) and objective performance that is dependent on the cognitive use of these processes. As well as adding to our understanding about memory impairment in TLE, this theme ultimately contributes to the distinction between how different dual-process theories conceptualise recollection. The second theme was of a *clinical* nature and is discussed below.

Recollection and familiarity were assessed in *anterograde* recognition memory in Chapters 3-5. This was achieved through the use of a contextual source memory paradigm (Chapter 3), a repetition-lag paradigm with the PDP (Chapter 4) and an associative recognition task, also involving a variant of the PDP (Chapter 5). The objective measurement of recollection varied in these. In the source memory task, recollection was operationalised by the amount of contextual information successfully retrieved during recognition; in the repetition-lag procedure recollection estimates were derived from the ability to successfully discriminate single items from alternative lists; and in the associative recognition experiment, recollection is measured as the ability to recapitulate originally bound relationships between two items. The R/K paradigm was used as a subjective measure of recollection and familiarity along with the objective tasks in Chapters 3 and 4, and confidence ratings of perceived accuracy of recognition was the subjective measure in Chapter 5.

Having examined recollection and familiarity in laboratory tasks (Chapters 3-5), the experiment in Chapter 6 took a more naturalistic approach and assessed these processes in *retrograde* memory of prominent public news events. Although the objective measure (accuracy of dating events) diverged from the objective measures in the other experiments, the paradigm allowed an assessment of the extent to which recollective processes contribute to the retrieval of what is typically assumed to be a product of the semantic memory system. As well as the R/K paradigm, a further metacognitive measure was included in this task to assess awareness.

The synthesis of subjective and objective measures throughout these experiments afforded the opportunity to assess how patients have ‘on-line’ insight into their memory. Although important as stand-alone experiments, a natural progression was to examine these together in a more holistic approach.

Thus, a correlational analysis of some key measures is presented in Chapter 7. This provides an appreciation of the extent to which different indices of recollection are comparable. The inclusion of neuropsychological assessment data of patients in this analysis helps draw conclusions of a *clinica*l nature. For example, it helps understand whether dual-process led tasks reveal similar patterns of impairment to standardised tests; if differences are found, then it calls to question the scope and specificity of standardised instruments. By taking into account such a diverse range of subjective and objective measures, Chapter 7 aimed to elucidate the long-standing question of, what factors contribute to perceived memory impairment in TLE?

2 Sample Characteristics

2.1 Overview

In this chapter, I present a detailed summary of the sample recruited for my research. Although many empirical TLE studies have presented rather homogenous groups of patients (such as operative status or laterality, for example), from the outset, this was not my aim. This was due to the difficulty with recruiting a large, pure sample in the absence of an established clinical infrastructure. More importantly, the aim of this work was to provide a *novel* comprehensive assessment of recollection and familiarity in a more naturalistic, heterogeneous group of TLE patients. Although this approach allows a generalisability of findings, it is limited in that patients are likely to have differing degrees of impairment. Moreover, it is difficult to establish precisely which neuroanatomical areas deficits derive from. However, the fact that nearly all patients and controls completed every task throughout afforded the opportunity to make a large scale comparison of measures, as will be presented in Chapter 7.

Below I present an outline of all stages of the recruitment process, a summary of each patient's clinical data, and finally, the results of the full neuropsychological assessment carried out with participants.

2.2 Ethical approval

NHS ethical approval was granted for recruitment and testing of TLE patients by Leeds Central Research Ethics Committee. Separate institutional ethics was granted by the Institute of Psychological Sciences, University of Leeds. The NHS approval covered recruitment and testing of patients at NHS sites and at their homes. Institutional ethics then further covered the recruitment of control participants and non-NHS TLE participants, and allowed testing at home or within the University.

2.3 Recruitment process

After gaining NHS ethical approval, I began recruiting patient participants with the help of a Consultant Neurologist and Consultant Clinical Neuropsychologist, both of whom have a special interest in epilepsy. To ensure a large enough sample was recruited, I later decided to advertise my research in a bi-monthly magazine published by Epilepsy Action (EA) charity. Following this advert, I was approached by a number of people with TLE wanting to take part.

Control participants were recruited from various sources; some were patients' spouses or friends and others were my own friends or family. The majority of control participants were recruited after I had completed testing with patients, as this allowed me to select people who would be well matched demographically.

2.4 Summary of patient data

2.4.1 Further recruitment summary

Table 2.1 displays a summary of all clinical information for patients, with the first column indicating how each was recruited. The majority of patients were recruited through NHS sites. Most participants attended Leeds General Infirmary or St James' University Hospital for normal treatment and hence lived in West Yorkshire; two lived in Greater Manchester; one lived in South Yorkshire and one participant who was a friend's relative, lived in Surrey (denoted as 'Other' in column 1).

For NHS patients, medical records were available along with the consultant neurologist/clinical psychologist's opinion during or after a routine appointment. For EA participants, some patients kept letters from their consultant neurologists regarding diagnostic information, in which case, this evidence was used to ensure they had TLE. This was combined with information obtained during a semi-structured intake interview I carried out with each person. In other cases, with the patient's permission, I requested their medical records from the hospital they had, or were being treated at.

2.4.2 Diagnostic information

Diagnosis of TLE and laterality of epileptic focus was determined by standard methods in patients (electrophysiological recordings, neuroimaging, seizure semiology and neuropsychological assessment). As can be seen in the 'Evidence' column of Table 2.1, some patients had identifiable structural abnormalities following MRI scans (patients 1-5, 14-16, 20-23,27) – this was the case for all patients who had undergone, or were being prepared for resective surgery. Patient 19 developed SGTC seizures following a bout of herpes simplex encephalitis (HSE) in the late 1980s before the advent of modern MRI, but a right temporal lesion was evidenced through a CT scan. In the case of standard EEG, patients' diagnosis was based on temporal abnormalities during recording and supporting information during clinics regarding seizure semiology (patients 8, 17, 18, 25, 26). A diagnosis was aided in three patients using video-EEG (1, 8, 12) and three using intracranial EEG (6, 12, 27). A clinician's report regarding neuropsychological assessment (NPA in Table 2.1) supplemented laterality diagnosis in certain surgical cases. Although my own neuropsychological assessment occasionally provided supporting evidence for a left or right sided diagnosis, this is not counted as the testing was carried out for research, and not clinical purposes.

Based on the above information, the sample consisted mainly of patients with LTLE (N = 12). Of these, three had undergone resective surgery (patients 3, 20, 21). Of the nine patients with RTLE, three of these had also had surgery (patients 2, 14, 23). The post-surgical patients had all undergone their resections at least seven years prior to testing. Two of the remaining patients had a diagnosis of probable BTLE (patients 10 and 24) based on equivocal evidence from repeat MRI and EEG analyses. The other four patients (patients 6, 16 and 26-27) had more reliable evidence of a bilateral diagnosis through bihemispheric seizure onset during EEG or intracranial EEG (patients 6, 26 and 27) and structural abnormality as evidenced by MRI in both MTL (patient 16).

The remarks in the 'Lesion status' column Table 2.1 reflect a summary of the information available to me for each patient. 'Unknown' in this column represents patients where MRI scans revealed no discrete abnormality. Although I made best efforts to obtain as detailed information as possible regarding the site and extent of resection in the surgical patients, surgical reports were not always available. Therefore, the information I *was* able to obtain is presented. For example, for patient 3, I was only able to ascertain that she had a 'resection of the left temporal lobe'. In comparison, patient 14's notes specifically described a 'right hippocampectomy'. Although there were clearly differences in location and extent of excisions in these patients, the most important factor for the present thesis was that any damage was limited to the temporal lobes.

Table 2.1. Summary of clinical characteristics in TLE group.

Patient	Recruited?	Diagnosis	Evidence	Lesion status	Onset (yrs)	Duration (yrs)	Seizure type	No. AEDs
1	NHS	RTLE	MRI/V-EEG/Sem/NPA	MTL DNET	52	3	SPS	1
2	NHS	RTLE	MRI/EEG/Sem/NPA	Resection in 1999	16	38	Seizure free since 2002	1
3	NHS	LTLE	MRI	Resection in 2005	18 mnths	46	Seizure free since surgery	1
4	NHS	LTLE	MRI	MTL DNET	16	17	CPS – none for nine months prior to testing	2
5	NHS	LTLE	MRI/EEG/Sem	Left lesion	17	13	SPS/CPS/Tonic phase	3
6	NHS	BTLE	Bilateral discharge IC-EEG	Unknown	4	22	CPS/SGTC	4
7	NHS	LTLE	Sem/NPA	Unknown	20	14	SPS	1
8	NHS	RTLE	EEG/V-EEG/Sem	Unknown	17	9	SPS/CPS	3
9	NHS	LTLE	MRI	MT sclerosis	5	43	SPS/CPS/SGTC	2
10	NHS	BTLE	EEG/MRI/CT all normal	Unknown	14	24	SPS/nocturnal TC	1
11	NHS	LTLE	EEG/Sem, MRI normal	Unknown	4	38	SPS/CPS	2
12	NHS	LTLE	V-EEG/IC-EEG/Sem	Left posterior TL	16	29	SPS/CPS	4
13	NHS	RTLE	EEG/Sem/MRI	Probable right lesion	44	2	SPS/CPS/SGTC	1
14	EA	RTLE	MRI	Right hippocampectomy 2002	23	22	Seizure free since surgery	1
15	EA	LTLE	MRI	Left HS	14	33	CPS/SGTC	3
16	EA	BTLE	MRI	Right posterior H atrophy; Left anterior H atrophy	0	38	CPS/SGTC	2
17	EA	LTLE	EEG/Sem	Unknown	21	18	SPS/CPS	2
18	EA	RTLE	EEG/Sem	Unknown	14	4	SPS/CPS	2
19	EA	RTLE	CT/Sem	RTL damage secondary to HSE	25	5	Seizure free since successful treatment of HSE in 1993 and introduction of AEDs	1
20	EA	LTLE	MRI	Resected left posterior temporal cavernous angioma in 1997	23	15	SPS	2
21	NHS	LTLE	MRI/NPA	Left hippocampectomy 2001	6	22	Seizure free since surgery in 2001	0
22	NHS	LTLE	MRI	Possible LGA in left temporal horn	40	3	SPS	2
23	EA	RTLE	MRI	Right resection following benign meningioma SURGERY 2001	33	11	SPS/TC	3
24	EA	BTLE	MRI/EEG normal	Unknown	51	6	SPS/SGTC	1
25	EA	RTLE	EEG/Sem	Unknown	21	2	Nocturnal TC	1
26	Other	BTLE	EEG/Sem	Unknown	5	25	SPS/CPS/SGTC	2
27	NHS	BTLE	MRI/bilateral discharge IC-EEG	Left side unknown; high signal lesion in right MTL	28	8	CPS/SGTC	2

Note: TLE = temporal lobe epilepsy, NHS = National Health Service, EA = Epilepsy Action, RTLE = right temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy, MRI = magnetic resonance imaging, V-EEG = video-electroencephalography, Sem = semiology, NPA = neuropsychological assessment, IC-EEG = intracranial electroencephalography, CT = computed tomography, MTL = medial temporal lobe, DNET = dysembryoplastic neuroepithelial tumour, H = hippocampus, HS = hippocampal sclerosis, HSE = herpes simplex encephalitis, LGA = low grade astrocytoma, SPS = simple partial seizure, CPS = complex partial seizure, SGTC = secondary generalised tonic-clonic seizure.

2.4.3 Epilepsy onset, duration and seizure types

Mean age of onset in the sample was 20.25 years (*SD* = 13.51) and mean duration of TLE was 18.77 (*SD* = 13.01).

Almost all patients were suffering from seizures at time of recruitment. Patients 3, 14 and 21 were completely seizure free following surgery. Patient 2 was seizure free for three years following surgery, but experienced a single, prolonged SGTC in 2002. This caused further memory difficulties and although no confirmatory notes were available, the patient informally told me that the specialist opinion was that the lack of oxygen to his MTL had caused this. Therefore, it seems he suffered from mild hypoxic damage. He had remained completely seizure free since this episode, however. Patient 4 had had a seizure free period of nine months prior to testing (although he had frequent CPS before this for a period of 17 years); patient 19 had been seizure free for approximately 15 years following treatment for HSE (as described above).

The number of patients experiencing SPS (80%) was roughly consistent with other estimates in the literature (e.g. 90% in Gloor *et al*., 1982). Subjective manifestations were like those described in Section 1.2 of the main Introduction. For example, patient 5 reported that “a tingling sensation rises through my body”. In his case, SPS almost always evolved into CPS and TC seizures. Therefore, he identified the strange tingling sensation as a warning, and would make sure he located himself somewhere safe in case he lost consciousness. For patient 8, her SPS often involved an intense feeling of déjà vu, coupled with “a funny gustatory feeling”. She reported a variety of emotions associated with these experiences; a kind of warmth and embrace of the bodily sensation, but slight anxiety associated with the inappropriate familiarity that was part of the déjà vu experience. Her SPS would always evolve into a CPS with impaired consciousness, so she similarly described these feelings as an ‘aura’ or warning sign.

There were ten patients who experienced CPS, and these either followed an initial SPS (patients 5, 7-9, 11-13, 17, 18 and 26), or occurred spontaneously with no warning or aura (patients 4, 6, 15 and 16 and 27). Approximately one-third of patients experienced SGTC seizures (patients 5, 6, 9, 13, 15, 16, 24, 26 and 27). The frequency of these varied somewhat, however. For example, patient 6 could suffer up to twenty convulsive seizures each week. This was the most extreme case however, and most of these patients rarely had SGTC seizures. For instance, patients 9 and 15 only had one or two each year, and these were directly related to periods of stress, or unrelated illness such as flu.

The sample was thus comprised mainly of patients who were *medically refractory*. Disregarding those who were seizure free at time of testing, six patients were currently on monotherapy (patients 1, 7, 10, 13, 24 and 25) and the remaining 17 were on polytherapy. Three of the bilateral patients (16, 26 and 27) also had vagus-nerve stimulator implants; all of which reported that the device seemed ineffective in significantly reducing seizures over and above their medication. AEDs being taken by patients included: Leviteracetam, Carbamazepine, Phenobarbital, Topiramate, Zonisamide, Lacosamide, Oxcarbazepine, Pregabalin, Lamotrigine, Primidone, Retigabine and Clobazam (all patients who used this was in case of clusters of particularly bad seizures). Additionally, two patients (24 and 26) were taking Citalopram for mood disturbances. This will be discussed further in Section 2.5.3, which covers levels of anxiety and depression in the whole sample.

2.4.4 Subjective memory complaint

Patients were asked during the initial intake interview and through informal discussion whether they experienced any subjective memory problems. Notably, all patients (apart from patient 6 – see below in Section 2.5.1) reported having some sort of memory difficulty. This varied considerably in terms of type of memory and the level of perceived impairment. For example, patient 1 simply reported having a generally poor memory; patient 7 reported difficulty with prospective memory and planning and patient 5 specifically stated his topographical memory for new places was very poor, and following a seizure, he felt that his memory of events for the preceding couple of weeks was affected. Problems with autobiographical memory were expressed quite frequently in the group as a whole, with most describing a loss of recent information (often following seizures) but there were two patients who reported more severe impairments encompassing remote periods of their life (patients 2 and 17). Another common subjective complaint appeared to be with remembering people's names. Perceived memory function is explored further in the experiment in Chapter 6, where participants were administered a self-report questionnaire.

2.5 Neuropsychological assessment

Both patients and controls were administered a battery of standardised neuropsychological tests. These data, as well as demographic information, are presented in Table 2. Most participants completed all measures, but missing data is discussed further in Section 2.5.1 below. The test battery included the Hospital Anxiety and Depression scale (HADs;Zigmond & Snaith, 1983), the National Adult Reading Test (NART; Nelson, 1982), the Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999), the figure, word list and story learning components of the BIRT Memory and Information Processing Battery (BMIPB; Coughlan, Oddy, & Crawford, 2007), the Warrington Recognition Memory Test (WRMT; Warrington, 1984), digit span (forward and backwards) and the verbal (FAS) and category (animal names) fluency components of the Delis-Kaplan Executive Function Scale (D-KEFS; Delis, Kaplan, & Kramer, 2001). Scores presented are either raw scores, or the z-score derived from the normative data associated with that specific test. In Table 2.2, Chi-square tests were used to compare gender and handedness distributions and one-way ANOVAs compared scores on all other measures. Statistical test value, significance level and effect sizes are presented for the comparison between the TLE group as a whole and controls. Further one-way ANOVAs assessing laterality differences are presented in the right section; if a main effect of group was found, the associated *p* value is reported. Alpha was set at $p < .05$ for all analyses. Following significant main effects in the laterality analysis, subgroup differences were assessed using Bonferroni post-hocs, where the *p* value was adjusted to account for comparison of four groups (.05/4 = .013). Each participant's individual scores for selected neuropsychological tests are presented in Appendix B.

2.5.1 Attrition and missing data

Patient 4 requested to end the project before completing the neuropsychological assessment; this was due to a lack of free time as he started a new demanding job. He did however complete the contextual source memory task (Chapter 3) and associative recognition task (Chapter 5).Because detailed diagnostic information had been obtained alongside his age and years of education, his data was included in analyses of results for those experiments.

Patient 6 was completely removed from all analyses because she was non-compliant with certain parts of the neuropsychological memory assessment. She also showed an apparent lack of understanding of instructions on other tasks.

Patient 7 did not complete the WRMT, fluency measures or digit span, as her assessment session had to be cut short. The results of the measures she did complete are included in the analyses in Table 2.2. Following this session, the patient dropped out of the project for unknown reasons. She did carry out the contextual source memory task, however, so her data for this is included in the analysis in Chapter 3.

Patients 11 and 13 were having detailed investigation for possible resective surgery, so the Consultant clinician preferred his assistant to conduct assessments with these patients. Because of this, slightly different tests were conducted. Instead of the WASI, both patients were administered the Wechsler Adult Intelligence Scale- Fourth Edition (WAIS-IV; Wechsler, 2009). The subtests differ in the WAIS-IV, meaning the same verbal and performance IQ measures cannot be derived. However, because it yields a standardised predicted full-scale IQ (PFSIQ), this data was used in the analysis presented in Table 2.2. Additionally, for clinical reasons, patient 11 was administered the Wechsler Memory Scale-Fourth Edition (WMS-IV; Wechsler, 2010) rather than the BMIPB. Her scores on all measures of the WMS-IV were within the normal range (auditory memory; $z = -0.47$, visual memory; $z = 0.2$, visual working memory; $z = 0.6$, immediate memory index; $z = -0.13$, delayed memory index; $z = -0.27$).

Patient 27 was initially recruited as part of a separate research project being conducted by myself but agreed to take part in some further memory testing. In an initial session, he completed the contextual source memory task presented in Chapter 3, and in the following neuropsychological assessment session he was only able to complete a number of measures. He found the story learning component of the BMIPB too taxing and wished not to continue with this. He completed the full WASI, word list learning and figure recall, but wanted to end the session following these. After this testing occasion, the patient had a particularly bad bout of seizures and subsequent hospitalisation; it was therefore decided to discontinue further testing. The data that were obtained from him are included in the analysis in Table 2.2 and in the experiment in Chapter 3.

A summary of the numbers of participants included in each of the analyses in Table 2.2 can be found in Appendix C.

Table 2.2 Demographic and neuropsychological assessment of patient and control group.

Variable	Controls	TLE combined	Test value	*p*	Effect size (η^2)	LTLE	RTLE	BTLE	Sig.?	Group diff.
Demographics										
Age	38.63 (14.10)	40.88 (10.46)	*F* = 0.38	.54	.01	41.00 (7.12)	41.22 (14.86)	40.00 (10.07)	n.s	
Gender (Male:Female)	11:8	6:20	χ^2 = 5.66	.02	n/a	3:9	2:7	1:4	n.s	
Yrs. Education	13.16 (1.68)	12.85 (2.29)	*F* = 0.25	.62	.01	13.08 (2.27)	12.22 (1.72)	13.40 (3.36)	n.s	
Handedness (Right:Left)	18:1	20:6	χ^2 = 1.85	.17	n/a	9:3	7:2	5:0	n.s	
Mood: HADscale (raw score/21)										
Anxiety	5.79 (3.38)	8.48 (4.16)	*F* = 5.21	.03	0.11	8.45 (3.85)	8.17 (4.93)	9.25 (4.19)	n.s	
Depression	3.42 (2.80)	4.95 (3.15)	*F* = 2.76	.10	0.06	5.18 (2.75)	5.09 (3.90)	4.00 (2.94)	n.s	
IQ (standard scores)										
NART pred. FSIQ	109.05 (9.24)	107.33 (10.25)	*F* = 0.33	.57	.001	104.73 (9.46)	106.78 (10.58)	115.75 (9.39)	n.s	
WASI VIQ	105.47 (14.54)	103.10 (15.94)	*F* = 0.25	.62	.001	97.53 (10.45)	104.75 (17.81)	111.60 (20.56)	n.s	
WASI PIQ	109.84 (13.32)	101.94 (12.24)	*F* = 4.01	.05	.09	101.06 (10.11)	99.88 (15.87)	107.00 (10.51)	n.s	
WASI FSIQ	108.89 (13.27)	103.21 (13.82)	*F* = 1.89	.18	.04	100.21 (9.63)	103.00 (17.20)	110.20 (15.35)	n.s	
Memory: BMIPB (z-scores)										
Figure Imm %	-0.02 (1.02)	-1.38 (1.24)	12.99	.001	0.24	-1.29 (0.93)	-1.39 (1.54)	-1.52 (1.48)	*p* =.01	No
Figure Del %	0.33 (0.91)	-0.98 (1.10)	17.64	.001	0.30	-0.99 (1.00)	-0.71 (1.00)	-1.47 (1.46)	*p* =.001	L/BTLE<Ctrl
List A1-5	0.27 (1.13)	-0.54 (1.55)	3.67	.06	0.08	-0.84 (1.63)	-0.35 (1.47)	-0.28 (1.76)	n.s	
List 6	0.14 (0.93)	-0.86 (1.44)	6.83	.01	0.14	-1.14 (1.41)	-0.84 (1.21)	-0.33 (2.00)	n.s	
Story Imm	-0.01 (0.79)	-1.32 (1.39)	13.56	.001	0.25	-1.94 (1.22)	-0.79 (1.45)	-0.81 (1.23)	*p* =.001	LTLE<Ctrl
Story Del	0.15 (0.91)	-1.44 (1.30)	20.39	.001	0.33	-2.09 (1.26)	-0.87 (1.22)	-0.93 (0.90)	*p* =.001	LTLE<Ctrl
WRMT (raw score/50)										
Words	47.74 (2.66)	44.00 (4.47)	*F* = 10.24	.003	.20	42.10 (3.63)	44.33 (5.17)	48.00 (1.41)	*p* =.001	LTLE<Ctrl
Faces	43.16 (4.18)	39.35 (6.17)	*F* = 5.25	.03	.12	41.10 (5.28)	36.67 (6.89)	41.00 (5.77)	*p* =.04	RTLE<Ctrl
Working memory (raw scores)										
Digits forward	6.95 (1.03)	6.91 (1.03)	*F* = 0.01	.91	.001	6.90 (0.99)	6.63 (1.41)	7.50 (1.29)	n.s	
Digits backward	5.74 (1.15)	5.14 (1.32)	*F* = 2.38	.13	.06	5.00 (1.05)	5.13 (1.73)	5.50 (1.29)	n.s	
Fluency (z-scores)										
FAS	-0.14 (0.94)	-0.65 (1.08)	*F* = 2.63	.11	.06	-1.05 (1.04)	-0.25 (1.19)	-0.57 (0.75)	n.s	
Categories	-0.04 (0.88)	-0.44 (1.00)	*F* = 1.82	.19	.04	-0.54 (0.86)	-0.72 (1.05)	0.45 (0.92)	n.s	

Note: HADs = Hospital Anxiety and Depression rating scale (Zigmond & Snaith, 1983), NART = National Adult Reading Test (Nelson, 1982), FSIQ = Full-scale IQ, WASI = Wechsler Abbreviated Scale of Intelligence (Psychological Corporation, 1999), VIQ = Verbal IQ, PIQ = Performance IQ, BMIPB = BIRT Memory and Information Processing Battery (Coughlan *et al*., 2007), WRMT = Warrington Recognition Memory Test (Warrington, 1984). TLE = Temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

2.5.2 Demographics

All participants were aged between 18 and 58 years of age, and as shown in Table 2.2, this was well matched across all groups. The significant effect of gender was due to the fact that the control group comprised relatively equal numbers of males and females, whereas the TLE group was predominantly female. Unfortunately, this reflects a comparative lack of willingness to take part in research by males with TLE; many more men turned down the research project than women during recruitment in the hospital, and many more women volunteered through EA. Gender differences were not examined in this thesis. Importantly, the two groups were well matched on other key characteristics – years of education, for example. Handedness was also well matched, with the expected higher proportion of right, compared to left handed people. Handedness and *language dominance* are commonly used in assessments of laterality. Language dominance is only however determined by the intracarotid-amobarbital procedure (WADA test; Wada, 1949), or more recently, using fMRI paradigms. This information was not available for the patients recruited here.

2.5.3 Mood scores

For the majority of participants, a single administration of the HADs was used as all testing was completed within a short space of time (approximately one month). For participants whose testing took place over an extended period, the HADs was repeated in case of mood variations. For these participants, the average anxiety and depression score was used in analyses. Notably, mood scores in these participants had little fluctuation. As the data in Table 2.2 show, anxiety levels were significantly higher in the TLE group compared to controls, where as depression was better matched. There were no differences between subgroups. As discussed in Section 1.4 of the main Introduction, anxiety is a common psychosocial consequence of TLE, therefore this result is relatively unsurprising. The impact of this increase in anxiety on memory is explored further in Chapter 7.

2.5.4 IQ

Levels of predicted premorbid intelligence estimated by NART scores suggested patients and controls were very well matched; patient subgroups were also, with the BTLE group having higher, but non-significant IQ on this measure.

Every patient and control had a WASI predicted FSIQ > 73. The PIQ subscale differed significantly between patients and controls, whereas VIQ was well matched. Importantly, FSIQ was matched between groups.

2.5.5 BMIPB memory

Comparison between patients and controls revealed significant differences in both visual (immediate/delayed complex figure) and verbal (delayed word list and immediate/delayed story) memory. This suggests that compared to the control sample recruited here, the patients as a whole were impaired on these measures. Taking the z-scores of patients in isolation however, only immediate figure memory and immediate/delayed story recall were more than 1 standard deviation lower than the normative data from the BMIPB. This is a value that is generally taken to suggest some level of impairment is present compared to the general population.

The assessment of laterality revealed a mixture of results. The LTLE group performed poorly on both verbal tests, with story recall being the most impaired; both immediate and delayed performance differed significantly from controls. In contrast, there was no evidence of a lateralised impairment in figural memory in the RTLE group. In fact, it was the LTLE and BTLE groups that differed significantly to controls on both immediate and delayed performance on this measure.

2.5.6 WRMT

Significant group differences were found between patients and controls on both the word and face subtests of the WRMT; this was larger for words, however. Whereas the BMIPB analysis did not reveal a preferential impairment in figural memory in the RTLE group, the WRMT did indeed show evidence of lateralised impairments. For the face task, right sided patients had the lowest raw score, and the difference between this and controls reached significance. Similarly, the low score of the

LTLE group for the word version was significantly different from controls. Bilateral patients on the other hand, had performance comparable to controls for both tasks. These results provide some support for the material-specificity hypothesis of laterality.

2.5.7 Working memory and fluency

No difference was found between controls and patients (or patient subgroups) on the maximum number of digits recalled in forward, or backward order, or verbal and category fluency. Because these tasks are generally considered to tap into executive functioning, the results provide some evidence that frontal lobe functioning is intact in the patient group.

2.6 Summary

The results presented above suggest that the patient and control groups were well matched on a number of important demographic and neuropsychological variables (age, education level and IQ). Overall, memory was impaired on these standardised measures compared to controls, suggesting that the epileptic syndrome has resulted in identifiable deficits in MTL functioning in the patient group. Further, there is some evidence of lateralised impairments, especially with respect to the left temporal group. As outlined in the main Introduction, an important clinical and theoretical question concerns the extent to which standardised neuropsychological test performance relates to other measures of memory. Therefore, the relationship between recollection, subjective perception of memory and these test scores is examined in Chapter 7.

3 An assessment of the contributions of contextual knowledge to subjective experience

3.1 Introduction

As discussed in Chapter 1, dual-process models of recognition memory posit that hippocampally mediated recollection is a reconstructive process involving the retrieval of contextual and associative information of a prior study event (Yonelinas, 2002). These complex types of information, including perceptual, temporal and spatial details, are what differentiates events in memory and makes them episodic in nature. As well as subsuming these contextual elements under the term of recollection, we can also view them as being the *source* of mental experiences. The source monitoring framework (SMF; Johnson, 2006; Johnson, Hastroudi & Lindsay, 1993; Johnson & Raye, 1981, 2000) has provided an understanding of how differences in representations lead to attributions about memory. It has provided important contributions regarding the influence of metamemory, knowledge and beliefs to the monitoring of source information.

Although the SMF outlined by Johnson and colleagues disagrees with certain aspects of dual process accounts of recollection and familiarity, importantly for the current chapter, it converges on the idea that these are two distinct states of subjective awareness associated with different responses during recognition; standard old-new paradigms can be accomplished through a simple familiarity heuristic whereas Remember/Know tasks may involve a more systematic evaluation of the specifics of the encoding context, as this is what participants are oriented toward (Mitchell & Johnson, 2009). More specifically, source information is presumably monitored in these tasks, even though it is not always explicitly required. Therefore, tasks employing the R/K procedure include an element of source monitoring, albeit not as explicitly as those that require a participant to report the encoded colour or position of an item, for example.

Within the source monitoring literature, one of the biggest debates has centred on the respective role of the frontal and temporal lobes in this type of memory. This is not an aim here, but importantly, the various studies reported in Section 1.10 showing recollection deficits in TLE provide evidence to suggest that at least some aspects of source memory are clearly reliant on the MTL. Surprisingly, there are few studies that have assessed source memory explicitly in this patient group, and these have all used post-operative patients or those with extensive focal damage. Kopelman, Stanhope and Kingsley's (1997) early study displayed that frontal and diencephalic lesions led to impaired temporal context judgments, but not in temporal lesion patients. On the other hand, only temporal lesions led to impairments in spatial context. Schwerdt and Dopkins (2001) found that temporal lobectomy patients were impaired in both content and source memory in a paradigm where participants had to recall an action performed with a small object (content) and whether it was performed by the experimenter, self, or imagined (source). More recently, Thaiss and Petrides (2003) directly addressed the contention that pre-frontal areas are more responsible for source monitoring by comparing a group of frontal and temporal excision patients with controls in a source memory task. Subjects viewed two different trivia game shows and were tested on the trivia answers (content), who provided the answer, and when (source). They found the temporal excision group to be impaired on both fact and source information, with no such impairments seen in the frontal group. Therefore, previous studies in TLE that have assessed source memory have either done so with a primary focus on assessing the extent of subjective or objective impairments in recollection, or aimed to clarify the respective roles of the frontal or temporal lobes. Moreover, with current advances in functional neuroimaging, this literature is generally directed toward shedding light on the contributions of specific medial temporal areas to source memory. In particular, studies have often attempted to resolve the issue as to whether the hippocampus is responsible for source memory alone, or if it also supports item memory (e.g. Gold *et al*., 2006; Slotnick, 2010).

The present study diverged from the common aim of delineating the neuroanatomical substrates of item and source memory and instead adopted a more direct behavioural approach. Drawing on the previous TLE literature, it was apparent that although evidence exists for both recollection and source memory impairments, no study has specifically compared the level of contextual (or source) information available to patients following different subjective states during retrieval. The only relevant example of this in the literature comes from Noulhiane et al.’s (2007) study looking at AM in temporal lobectomy patients, where the contextual information for a memory following remember and know responses was specifically analysed.

Previous studies outside of the context of TLE have investigated the types of contextual source information that drive post-recognition Remember/Know judgments. Pertinent to the present experiment, studies have revealed that Remember judgments are associated with better source memory for the previously encoded perceptual features of words (Meiser & Bröder, 2002; Perfect *et al*., 1996) and Remember judgments are particularly diagnostic of the successful binding and retrieval of a number of contextual source elements (Dudukovic & Knowlton, 2006; Meiser & Bröder, 2002; Meiser & Sattler, 2007; Meiser *et al*., 2008; Starns & Hicks, 2005). Conclusions gleaned from this research suggest that subjective Remember judgments are characterised by binding processes that preserve the specific configuration of contextual features, whereas Know judgments involve residual memory for less integrated information.

A critical issue that has also been examined in the R/K source monitoring literature that is of relevance here has been to examine the different cognitive bases of Remember judgments between younger and older adults. A study by Comblain, D'Argembeau, Van der Linden, and Aldenhoff (2004) found younger and older adults based Remember judgments on perceptual details equally often, but there were differences in the type of other qualitative information used to make them. For example, older adults reported basing Remember judgments on the emotional features of items and younger adults reported making these judgments on the basis of memory for thoughts or associations of items. Additionally, Boywitt, Kuhlmann, and Meiser (2012) demonstrated that the retrieval of perceptual source features does not distinguish between older adults subjective Remember and Know responses, whereas younger adults recollective experience is consistently driven by retrieval of experimentally manipulated perceptual elements of items. Therefore, in this group who share a common deficit in associative binding to TLE, the cognitive basis of subjective Remembering is different to healthy younger adults. Hence, the key aim of the current experiment was to examine the cognitive basis of Remember judgments in TLE.

In this chapter, the methodology adopted by Perfect, Mayes and Downes (1996) was deployed. Like the other studies cited above, they aimed to examine the level of contextual knowledge available for Remember and Know judgments. In five experiments using the R/K procedure, they displayed that recollection was consistently associated with above-chance levels of spatiotemporal contextual retrieval. However, they also found evidence that under some conditions, above-chance levels of spatial information were supported by familiarity judgments. Moreover, in their final experiment, although they found Remember judgments to be accompanied by higher overall levels of contextual detail in general, contextual detail was available in approximately one third of Know responses. They concluded that their results were in line with dual process accounts, with the possibility that Know responses might not solely reflect pure, context-free familiarity. In any case, Perfect et al.'s methodology is suitable for testing the relationship between subjective experiences of memory and their basis in contextual and source information available to participants.

Several modifications were made to their procedure; first, a number of contextual elements (item location, temporal order and colour) were incorporated into a single encoding trial to enable a within-subjects design (Perfect's original study presented different types of contextual information to different participants in a between-subject design). These contextual features were then tested in a four-alternative forced choice format for ease of administration and scoring. Second, participants were *explicitly* instructed that the source information would later be tested – this was done because evidence suggests that incidental encoding of source information requires higher cognitive demands at test in the form of strategic retrieval operations (Johnson *et al.*, 1993; Thaiss & Petrides, 2003). Hence, in the TLE group, presumably at least some level of contextual information was successfully encoded. Additionally, 'familiar', rather than 'know' judgments were used and the 'guess' response option was included, the reasons for which were described in the previous chapter.

There were thus several aims. First, was the replication of previous TLE studies showing impairments in both recognition memory and the subjective experience of remembering. In controls, a similar pattern of performance was expected for contextual detail as found by Perfect et al. That is, successful retrieval of source information should generally only be above chance for Remember judgments. Although a lower level of Remember responses were expected in the TLE group, a motivation was to see whether subjectively remembered items could still be accompanied by appropriate source information. Despite differences in materials and methodology, it was predicted that like Schwerdt and Dopkins (2001) and Thaiss and Petrides (2003), the TLE group would show impairments in source memory. Any differences found between controls and TLE in the type and level of source information retrieved would imply a qualitatively distinct recognition experience between the two groups. To foreshadow the results, to provide a more convincing test of this account, data were re-analysed after equating recognition memory performance. Furthermore, following recognition of a target, participants were asked if they had made associations with other items, or made more personal external associations with that item. This allowed the comparison of objectively measured contextual information with subjectively experienced associations for Remember and Familiar responses. In sum, the aim was to explore whether impairments in subjective remembering in TLE reflect deficits in the underlying cognitive retrieval processes responsible for the reconstruction of the contextual elements of a memory trace.

3.2 Method

3.2.1 Participants

All patient and control subjects described in Chapter 2 participated in the present study. One patient's data (patient 14) was not included due to an administrative error with the testing protocol and another patient's data (patient 16) was not included due to an equipment error during the testing session.

3.2.2 Materials

A list of 48 nouns was selected, with a range of 5-118 per million based on SUBTLEX word frequency data (Brysbaert & New, 2009). All words were between 4 and 10 letters in length. These stimuli were then split into two frequency matched lists of 24 words: one to be used at study and the other as test items.

3.2.3 Procedure

Participants were tested individually with study items presented on a 15" laptop computer screen using Microsoft Powerpoint. Onscreen instructions explained that participants were about to be shown 24 words which they were to try to remember for a later test. They were instructed that each word would appear in one of four locations of a grid, which was displayed below. They were also told that each word would appear in one of four colours: blue, green, yellow or red. None of the participants reported colour blindness. Words were presented in capitalised size 24 Times New Roman font for 2s each, followed by a 1s ISI. Participants were asked to read each word aloud. During the study phase instructions, it was stressed to participants that in the recognition test that would follow immediately, they would be asked to attempt to recognise the above source information, as well as discriminating old from new words. Hence, participants were told to encode the words with whatever strategy suited them, but location, colour, and temporal order information would be tested.

The list of 24 study words was rotated resulting in four versions of the task, which were counterbalanced across participants. Following the study phase, the experimenter read through instructions for the recognition test. The instructions explained that participants had to distinguish between old and new items, and for each old item recognised, they must first judge whether the item was Remembered (R response), Familiar (F response) or if they had guessed the item was previously studied (G response). They were instructed to give an R response if they could consciously recollect some form of contextual or associative information from the time of studying the item, including thoughts and feelings evoked by the word. An F response was given if participants were certain they recognised the item but in the absence of any conscious recollection about its prior occurrence. G responses were given if participants neither recollected nor found the item familiar (see APPENDIX A for exact wording of definitions). The rest of the instructions were not explained until the experimenter was confident in each participant's understanding of these subjective experience judgments.

Participants were also instructed that for each recognised item, they would be asked which location they thought the item was in at study, which colour it was displayed in and which temporal quartile of the list it appeared in (1^{st}, 2^{nd}, 3^{rd} or 4^{th}). This allowed for a four alternative forced choice for each category, and participants were forced to guess when they were unsure of the correct information. A prompt sheet was provided which displayed the four colours, a picture of the same grid used in the study phase with quadrants labelled A, B, C and D and a diagram of how the list could be separated into quartiles (see APPENDIX D). Finally, participants were asked to describe if they had recognised the item by making associations with other items in the list (Item association), if they had made external associations (External association), if they had formed a mental image of the item (Imagery) or provide any other contextual information (Other). The order in which this information was asked was kept constant for each recognised item (i.e. colour, quadrant, quartile). Following the provision of these instructions, each participant was presented with the same test sheet, which had the study words and lures randomly intermixed. For each word judged as old, the participant provided the information about their recognition in the order described above. The experimenter noted responses by hand.

3.3 Results

There were four main strands to the analyses. First, standard recognition memory scores were analysed focusing on signal detection measures of discriminability (*A'*) and bias (B''_D). Second, differences in subjective experience judgments between the two groups were compared for recognised items using process estimations. Third, to assess source memory, conditionalised probability that participants would correctly report the required contextual information for responses classified as remembered and familiar was compared; finally, the extent to which alternative contextual information (i.e. item and external associations) was available during retrieval was assessed in both groups. As discussed in the Introduction, a comparison of the TLE group as a whole with controls was the main objective, but analysis of laterality subgroups is also presented at the end of each section.

3.3.1 Recognition memory

Recognition memory scores are presented in Table 3.1. As the means suggest, the control group had better recognition performance; one-way ANOVAs showed this was reliably higher for hits-FPs, $F(1, 42) = 6.96$, $p = .01$, $\eta^2 = .15$ and *A'*, $F(1, 42) = 12.60$, $p = .001$, $\eta^2 = .23$, but not for B''_D, $F(1, 42) = 0.46$, $p = .50$, $\eta^2 = .01$. Therefore, the TLE group have significantly poorer discrimination ability than controls, but share a comparable level of conservative bias in their recognition. Further one-way ANOVAs were conducted on each measure to assess differences in the laterality subgroups. Significant group differences were found for the hit-FPs and *A'* measures; $F(3, 42) = 3.17$, $p = .04$, $\eta^2 = .20$; $F(3, 42) = 4.29$, $p = .01$, $\eta^2 = .23$. Bonferroni post-hocs revealed the effect for hits-FPs was due to a trend between the difference in LTLE and controls ($p = .03$), whereas this difference was significant for the *A'* measure ($p = .01$) when taking into account multiple comparisons. No other significant differences were found between groups. The recognition memory results are consistent with previous literature suggesting a material specific deficit in verbal recognition memory in LTLE.

Table 3.1 Mean (*SD*) recognition memory scores for study items.

	Hits	Hits - FPs	*A'*	B''_D
Controls	.69 (.17)	.58 (.15)	0.88 (.05)	0.42 (0.52)
TLE	.60 (.18)	.44 (.19)	.81 (.07)	.52 (.43)
LTLE (*N* = 12)	.54 (.20)	.39 (.18)	.80 (.07)	.59 (.28)
RTLE (*N* = 8)	.68 (.14)	.51 (.21)	.82 (.08)	.40 (.51)
BTLE (*N* = 4)	.59 (.18)	.43 (.18)	.82 (.08)	.54 (.70)

Note: FP = false positive, TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

3.3.2 Subjective experience

To calculate recollection and familiarity from the R/K task, the IRK procedure was adopted, which takes into account variations in response bias (FP rates) and allows an estimation of the contribution of familiarity to recollected items also (Yonelinas & Jacoby, 1995; Yonelinas *et al.*, 1998). Using the IRK procedure, true recollection is measured either by a) subtracting remember FPs from remember hits or b) subtracting the probability of making a false remember response from the probability of making a true remember response, then dividing by the opportunity to observe a true remember response: $R = (R_{old} - R_{New})/(1 - R_{New})$. Although these two calculations provide similar results, both are presented below. Similarly, familiarity can be computed in several ways. To take into account responses that are both recollected and familiar, the number of familiar responses (F) is divided by the opportunity one has to make a familiar response (1 – R): F = F/(1-R). To account for differences in base rate FPs, one can then subtract the FP rate from this value to obtain a corrected F value. Moreover, as the IRK procedure views familiarity as a signal like threshold process, a more precise discriminability score can be calculated taking into account the probability of accepting an old item as familiar and contrasting this with the probability a new item will be familiar: For old items, familiarity is defined as $F_{old} = p(\text{familiar}_{old})/[1 - p(\text{remember}_{old})]$. For new items, familiarity is defined as $F_{new} = p(\text{familiar}_{new})/[1 - p(\text{remember}_{new})]$. The difference between these is typically expressed as *d*', with larger values indicating better use of familiarity to discriminate old and new items. As with the recognition scores above, for consistency, *A*' was used. Similarly, following Macmillan and Creelman (2004) and Prull et al. (2006), proportions of 0 and 1 were converted to 0.02 and 0.98, respectively. Table 3.2 displays all of the above IRK derived recollection and familiarity estimates for patients and controls.

One-way ANOVAs displayed significant differences between the TLE and control group on the Remember hits-FP and Remember IRK measures, $F(1, 42) = 8.87$, $p = .005$, $\eta^2 = .18$; $F(1, 42) = 4.87$, $p = .03$, $\eta^2 = .11$. In contrast, no difference was found in the Familiarity IRK, Familiar correct or Familiarity *d*' measures, $F(1, 42) = 0.76$, $p = .39$, $\eta^2 = .02$; $F(1, 42) = 1.64$, $p = .21$, $\eta^2 = .04$; $F(1, 42) = 0.23$, $p = .63$, $\eta^2 = .01$. Thus, the data for the subjective experience judgments are also consistent with previous TLE literature suggesting this patient group has a selective reduction in the ability to consciously remember previously studied items, whilst familiarity based recognition is left intact.

One-way ANOVAs were conducted on all of these measures, using Bonferroni post-hocs to compare subgroup differences. A significant effect of group was found for Remember hits-FPs, *F*(3, 42) = 3.46, *p* = .03, η^2 = .21. The lower score in the LTLE group compared to controls approached significance (*p* = .05). There was no difference between RTLE, BTLE and controls, or between any of the patient subgroups. The effect of group on Remember IRK estimates was of borderline significance, *F*(3, 42) = 2.75, *p* = .06, η^2 = .18. Again, post-hocs suggested the low score in the LTLE group compared to controls was driving this near significant difference (*p* =.06). No significant effects were found for the Familiar IRK and Familiar corrected measures (*F*s < 1). However, as would be expected from the means in Table 3.2, a significant group effect was found for the Familiarity *d'* measure, *F*(3, 42) = 3.66, *p* = .02, η^2 = .22. Post-hocs displayed a significant difference between the LTLE and BTLE groups (*p* = .01) but not between any other subgroup. This result must be interpreted with caution, because the groups were highly comparable in the other familiarity measures, and there was large variation in scores seen in the small number of BTLE patients for the *d'* value.

In sum, the data suggest that patients with left epileptic foci have a reduced ability to engage in subjective remembering (although the difference was non-significant); patients with RTLE also display lower levels of Remember responses to controls, but it seems from the small number of patients included here that BTLE is more resistant to reductions in recollective experience. Subjective familiarity, on the other hand, is largely intact in the TLE group.

Table 3.2 Mean (SD) estimates of recollection and familiarity.

	R Hits-FPs	R IRK	F IRK	F Corrected	F *d'*
Controls	.69 (.22)	.58 (.27)	.94 (.14)	.83 (.22)	1.83 (2.68)
TLE	.42 (.35)	.36 (.37)	.90 (.16)	.74 (.23)	1.43 (2.74)
LTLE (*N* = 12)	.38 (.29)	.26 (.26)	.88 (.20)	.74 (.25)	0.33 (0.79)
RTLE (*N* = 8)	.39 (.47)	.40 (.52)	.90 (.12)	.72 (.23)	1.29 (2.95)
BTLE (*N* = 4)	.59 (.23)	.59 (.23)	.94 (.13)	.78 (.20)	4.98 (3.64)

Note: R = remember, FP = false positive, IRK = independence remember-know, F = familiarity, TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BLTE = bilateral temporal lobe epilepsy.

3.3.3 Source judgments

The above evidence is consistent with previous studies showing recognition memory and recollective impairments in TLE. The novel aim of the current experiment was to assess the extent to which patients would successfully be able to retrieve contextual information, given this deficit.

Table 3.3 presents the proportions associated with correct retrieval of contextual features following *successful* target recognition. As the means suggest, on the whole, the source element of the task was highly difficult, with both groups only achieving overall successful contextual retrieval between 30-40%. One-way ANOVAs displayed no significant differences in retrieval of the three individual contextual elements, or in the overall proportions (*F*s < 2.82). Analysis of laterality also revealed no significant effects of group. Therefore, despite patients achieving lower recognition performance of individual study items, they were comparable to controls in their retrieval of the contextual features This result diverges from those found in the previous TLE studies mentioned in the Introduction that have found impairments in source memory in this group. However, the main focus of the analysis was to assess the types of contextual information available during qualitatively different recognition experiences. Because of this, source judgments for incorrectly recognised items are not presented.

Table 3.3 Proportion of successfully retrieved contextual features.

	Prop. Location	Prop. Order	Prop. Colour	Overall Prop.
Control	.39 (.15)	.36 (.15)	.36 (.10)	.37 (.10)
TLE	.35 (.19)	.34 (.13)	.30 (.13)	.33 (.11)
LTLE (*N* = 12)	.30 (.10)	.29 (.11)	.29 (.13)	.29 (.06)
RTLE (*N* = 8)	.36 (.24)	.34 (.12)	.32 (.15)	.34 (.14)
BTLE (*N* = 4)	.48 (.27)	.47 (.14)	.29 (.08)	.41 (.14)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, Prop = proportion.

3.3.4 Accuracy of source judgments according to subjective experience

Differences were assessed in the accuracy of source judgments according to subjective experience between groups. These data are presented in Figure 3.1[3]. A 2 (group) x 2 (subjective experience) x 3 (source type) repeated measures ANOVA was conducted with group as a between subjects factor. As above, there was no effect of group. However, there was an effect of subjective experience, $F(1, 38) = 11.83$, $p = .001$, $\eta_p^2 = .24$, with the source judgements being more correct for Remember than Familiar responses. Most importantly, subjective experience interacted significantly with group, $F(1, 38) = 5.36$, $p = .03$, $\eta_p^2 = .12$;

[3] Guess responses were also recorded but were at very low levels for both the TLE group (*Mean proportion* = 0.05, *SD* = 0.08) and controls (*Mean proportion* = 0.03, *SD* = 0.06), i.e. around 5% of all responses made were assigned to the guess category. Initial analyses revealed guess responses in both groups to be at, or below chance level on all source measures, hence I focus the analysis on Remember and Familiar responses.

such that for controls, there was a large difference between the proportion of correctly reported source information for Remember (*Marginal Mean* = .42, *SE* = .04) and Familiar (*Marginal Mean* = .23, *SE* = .04) judgments, but for patients the combined means across the three types of source information were comparable between subjectively remembered (*Marginal Mean* = .36, *SE* = .03) and familiar items (*Marginal Mean* = .32, *SE* = .03). Further analysis with paired sample t-tests showed Remember judgments to have significantly higher accuracy compared to Familiar judgments for both location and order in the control group, $t(16) = 3.79$, $p = .002$; $t(16) = 2.80$, $p = .01$ but not colour, $t(16) = 1.71$, $p = .12$. Paired-samples t-tests also showed no significant differences in source accuracy between Remember and Familiar responses for location, order and colour (*p*s > .12). No other main effects or interactions were found in the ANOVA analysis (*F*s < 2.20).

The same repeated measures analysis was conducted but including all laterality subgroups within the group factor. There was no main effect of subgroup and it did not interact with the other factors (*F*s < 2.00). Therefore, there was no evidence to suggest that Remember and Familiar responses differed between these groups in terms of the contextual features retrieved.

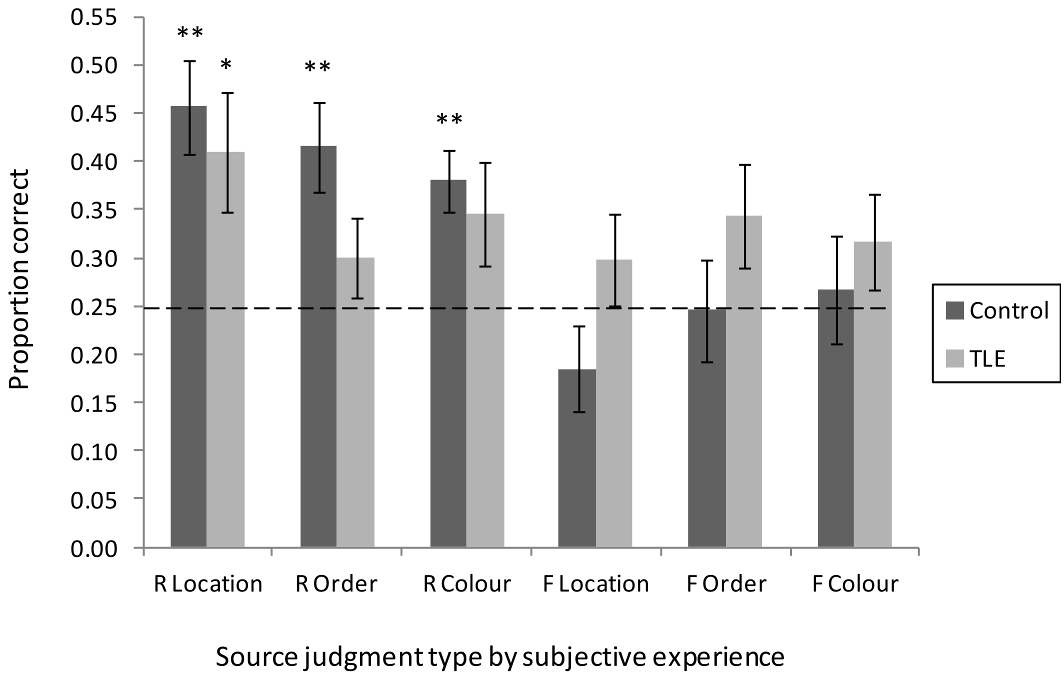
After finding differences between the patient and control group in information retrieved during Remember and Familiar responses above, the next analysis checked whether performance was above chance for each of the source types. The dotted line in Figure 3.1 represents chance performance (.25 due to four-alternative forced choice format) and significance levels following one-sample t-tests are indicated, where the test value was set at 0.25.

As expected, the control group were able to successfully retrieve the correct source information significantly above chance levels following Remember responses to old items. In contrast, the patient group only successfully retrieved location information above chance levels. Moreover, the accuracy of source information retrieved following Familiar responses was at chance in both groups[4].

One-sample t-tests were also computed in the same way for each type of response for all laterality subgroups. In these analyses, the left and right TLE groups did not display performance significantly above chance for any measure (*t*s < 1.668). However, the BTLE group's accuracy for the order of stimuli following a Remember response (*M* = 0.52, *SD* = 0.07)

[4] Although the performance of location information for Familiar judgments appears to be lower than chance in the control group, this difference was non-significant.

was significantly higher than the 0.25 level, $t(3) = 7.35$, $p = .01$. Again, given the small sample size, the relevance of this result must be interpreted cautiously.



Note: R = Remember response, F = Familiar response, TLE = temporal lobe epilepsy, ** = $p < .01$, * = $p < .05$, dotted line indicates chance performance level.

Figure 3.1 Accuracy of source judgments conditionalised by Remember and Familiar responses.

In summary, the above analyses first displayed that the TLE group provided significantly lower levels of subjective Remember responses for study items. Further, the retrieval of experimentally manipulated contextual information during recognition did not reliably differentiate Remember and Familiar responses to the same extent as controls. For the TLE group, the ability to report the appropriate source was limited to the location of the target word in the grid, whereas controls were able to successfully generate all three types of source information above chance levels for Remember responses.

However, subjectively remembering a target word in this experiment did not necessarily indicate that only the to-be-encoded source information would be retrieved; recollection can involve the retrieval of other item or associative information. Following source judgments, participants were asked to note if they had recognised an item along with information linked to other items in the test (item association), with other more personal external associations (external association) or if the item created any mental images at the time of encoding/retrieval. Table 3.4 displays the proportion of hits associated with this information[5].

As predicted, the means suggest that Remember responses are characterised much more by the retrieval of external associations in addition to the experimental source information. Item associations were low, but higher for Remember responses. These data were entered into a 2 (group) x 2 (association type) x 2 (subjective experience response) repeated measures ANOVA, with group as a between subjects factor. There was no effect of group, $F(1, 38) = 0.05$, $p = .83$, $\eta_p^2 = .001$, but significant main effects were found for both association type, $F(1, 38) = 40.26$, $p = .001$, $\eta_p^2 = .51$ and subjective experience, $F(1, 38) = 50.96$, $p = .001$, $\eta_p^2 = .57$ and the interaction between these was significant, $F(1, 38) = 7.10$, $p = .011$, $\eta_p^2 = .16$. The data suggest that there was a higher incidence of external associations in general, but this increased to a greater extent for Remember responses. There was no interaction between group and association type, $F(1, 38) = 1.08$, $p = .30$, $\eta_p^2 = .03$. A significant interaction was found however between group and subjective experience type, $F(1, 38) = 4.17$, $p = .05$, $\eta_p^2 = .10$, suggesting that whereas both groups had lower rates of external association for Familiar responses, the difference between these and for Remember responses was significantly greater for patients. Finally, the three-way interaction between group, association type and subjective experience type was statistically non significant, $F(1, 38) = 0.12$, $p = .74$, $\eta_p^2 = .003$.

To assess laterality, the same ANOVA was conducted as above, but with the group factor including LTLE, RTLE and BTLE as well as controls. The missing cells in Table 3 for the RTLE and BTLE groups reflect the fact that none of these participants made item associations along with Familiar judgments. The ANOVA displayed no significant interactions, suggesting comparable levels of item and external association for Remember and Familiar responses across these subgroups.

Taken with the above findings, these results suggest that despite decreased levels of subjective remembering and retrieval of experimentally manipulated contextual information, patients nevertheless report a comparable level of external associative detail accompanying these judgments compared to controls. The results were in the expected direction when assessing Remember and Familiar judgments overall; that is, Remember judgments were driven by more associative detail in general for both groups. However, the difference in available external associations between Familiar and Remember responses was larger for patients. Because

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[5] Imagery was omitted from analyses because only one patient and two controls reported this recall feature, and at very low levels.

detailed information was not obtained regarding the content of such associations, it is difficult to know whether these were diagnostic of the items on which they were based.

Table 3.4 Proportion of Remember and Familiar responses to hits accompanied by item and external associations.

	R + Item Association	R + External Association	F + Item Association	F + External Association
Control	.12 (.25)	.37 (.29)	.02 (.05)	.21 (.33)
TLE	.12 (.15)	.43 (.30)	.01 (.05)	.11 (.17)
LTLE (*N* = 12)	.16 (.18)	.54 (.33)	.03(.08)	.09 (.17)
RTLE (*N* =8)	.11 (.11)	.23 (.20)	-	.10 (.20)
BTLE (*N* =4)	.04 (.08)	.52 (.14)	-	.17 (.15)

Note: R = remember, F = familiarity, TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BLTE = bilateral temporal lobe epilepsy.

3.3.5 Subjective experience and source memory after equating recognition performance

To investigate the influence of overall memory strength on subjective experience and source memory, the sample was modified to include groups of patients and controls who were matched on recognition performance. After removing the eight lowest performing patients and five high performing controls, *A'* scores were matched in a new sample of 16 patients (*Mean* = .85, *SD* = .04) and 14 controls (*Mean* = .86, *SD* = .04), $F(1,29) = 0.24$, $p = .63$. For subjective experience judgments, there was now no statistical difference found in either recollection score between the two matched groups (*F*s < 1.75) and no difference in familiarity scores (*F*s < 0.10). Therefore, in the current experiment, the ability to subjectively remember old items seems to be associated with increased memory performance.

Source accuracy conditionalised by Remember and Familiar judgments was again assessed with a 2 (group) x 2 (subjective experience) x 3 (source type) repeated measures ANOVA as above, to test for differences between groups. The same pattern of results as earlier was found, except this time subjective experience interacted significantly with source type, $F(2, 52) = 3.33$, $p = .04$, $\eta_p^2 = .11$. To assess differences in accuracy rates for source information between the two subjective experience types, paired samples t-tests were conducted on the data set. With this subsample combined, only location information was significantly more accurate for Remember responses, $t(27) = 3.41$, $p = .002$. However, after splitting the data set, this difference was not evident in the patient group, and now temporal order was significantly more accurate for Remember, rather than Familiar responses in controls also, $t(12) = 2.48$, $p = .03$. Finally, the proportion of Remember and Familiar responses that were accompanied by item and external associations in the subsample were analysed. The 2 (group) x 2 (association type) x 2 (subjective experience response) repeated measures ANOVA returned the same results as in the original analysis.

One-sample t-tests for the proportion of Remember responses to old items accompanied by the correct source information revealed the exact same pattern as before; controls recalled the location, colour and order of items significantly above chance levels (ps < .005) and the high performing patient sample only recalled the location of items above chance levels ($p = .01$). Therefore, despite subjective remembering now being comparable between these two groups, patients were still less accurate in the objectively measured recollection aspect of the task.

The accuracy of source judgments accompanying Familiar responses changed slightly. Controls were now significantly below chance levels for location judgments ($p = .015$), providing further evidence that the specific location of a studied item is a unit of contextual information specifically indexed by recollective processes. In patients, the accuracy of temporal order was now significantly above chance levels for Familiarity responses ($p = .02$). I return to this point in the Discussion below.

3.4 Discussion

The present study aimed to build on previous TLE research that has demonstrated impairments in the ability to subjectively remember previously studied information; the novel contribution was to assess the extent to which recognition responses based on recollection or familiarity were accompanied by contextual and associative source information. A number of important findings emerged. First, evidence was found to support studies that have displayed recognition memory in TLE to be characterised by reduced levels of phenomenological remembering using the R/K paradigm (Bengner & Malina, 2008; Blaxton & Theodore, 1997; Bowles *et al.*, 2010; Moscovitch & McAndrews, 2002). Second, the results from the source component of the task revealed that patients were just as able as controls to successfully retrieve contextual features of items. However, controls were able to recall the spatiotemporal and item colour information at above-chance levels following Remember judgments whereas patients on the other hand, were only able to retrieve spatial information at above-chance levels for Remember judgments. Because source memory was at chance for Familiar judgments in controls, the results suggest the retrieval of contextual information reliably differentiated these two qualitative recognition experiences. Finally, both patients and controls reported comparable levels of item and external associations, further suggesting a qualitatively distinct recognition experience between the two groups. In a subsample of participants matched for recognition performance and subjective levels of remembering, differences were still found in the quantity of objective contextual information retrieved.

To date, there have only been a handful of studies assessing recollection and familiarity with the R/K paradigm in TLE. The present results are consistent with this previous work, in that all have displayed recollection deficits for either visual or verbal material. However, these previous studies, as discussed in the main Introduction, have all aimed to test material specificity accounts or modes of processing views of the temporal lobes in remembering and knowing. Unlike these, the sample here did not consist of equal numbers of left and right TLE patients, or have detailed structural information regarding the extent of MTL lesions; therefore the aim was not to specifically assess laterality differences or to provide any comprehensive input into debate surrounding the functional roles of specific neuroanatomical structures in the MTL. However, a preferential impairment in verbal memory was found in the larger LTLE group and the means suggested these patients also had the lowest levels of subjective remembering. There were no apparent laterality differences in the level of contextual information retrieved, however. An obvious extension of this study would be to replicate the procedure using non-verbal stimuli. This would provide a more concrete test of the material specificity hypothesis.

Encouragingly, the results in the control sample for the source component of the task are supportive of Perfect et al.’s (1996) original paper, which the current study was based upon. The above-chance levels of retrieval for spatiotemporal and colour information for Remember, but not Familiar responses, provides evidence that indeed, more contextual information is available during recollection. In the present task, the spatial location of targets in the grid seemed to be the most salient contextual feature retrieved, as performance was numerically highest for controls, and this was the only to-be-encoded contextual information that was recalled at above-chance levels in patients. Despite showing an intact ability to successfully retrieve this spatial contextual information following Remember responses, the significant group x subjective experience response interaction suggested that overall, patients were no more likely to correctly retrieve contextual information after subjectively remembering than after recognising information based on familiarity. This was in contrast to controls, whose source accuracy for contextual information was significantly increased for Remember responses, as dual process theory would predict. These results are thus in line with a number of other studies that have found source memory to be more accurate following subjective Remember responses (Dudukovic & Knowlton, 2006; Meiser & Bröder, 2002; Starns & Hicks, 2005).

Although memory for contextual source features was not impaired *per* se in the present study, the results build on the two previous studies that have assessed source memory in TLE, due to the differences in the kind of information and the conditions under which this was required from participants. Schwerdt and Dopkins (2001) found impairments in memory for the source of who had performed an action, and Thaiss and Petrides' (2003) task similarly involved retrieving *who* had provided certain trivia facts after watching two videos of gameshows; they too found impairments in both source and factual memory in TLE. These studies used a *source identification* paradigm, where the information being tested could have come from one of a number of distinct study contexts. In the present study, the analogous source component to the task was the participant's decision that an item was from a prior study phase, or new to the test phase. This successful source identification could be achieved by subjectively remembering the word, or simply through a feeling of familiarity. The findings thus build on the source identification deficits already observed in TLE and suggest that other contextual or feature information about items from that source do not become more available even when the participant subjectively experiences recollection for the word.

One criticism of neuropsychological studies assessing memory performance in patients with MTL damage has typically been that lower rates of recognition performance (and also recollection) may simply be a by-product of initial encoding deficits. Clearly, in a task of this kind, to make any firm conclusions about the underlying basis of an impairment in contextual and source retrieval of item information, it is essential that both patients and controls are matched as far as possible at the encoding stage where such information is initially bound together. Therefore, the results of the re-analysis in which patients and controls were matched on recognition performance are less susceptible to scrutiny from this perspective. It was found in this subsample that subjective recollection, as measured by the IRK procedure, was now comparable in patients and controls. This finding is unsurprising given the diverse range of neuropsychological profiles within the whole sample. It is also consistent with recent work suggesting that high performing older adults (in terms of overall recognition ability) show similar levels of recollection to young controls (Duarte, Ranganath, Trujillo, & Knight, 2006).

Moreover, as Bowles et al. (2010) and Holdstock et al. (2008) discuss, variations in the selectivity of recollection impairments are apparent in this patient group, and there is no single agreed upon cause for this. Importantly, even in this subsample with intact subjective remembering, controls' accuracy for correct contextual retrieval following Remember responses was sill significantly higher than for Familiar responses; in patients, again only spatial information was above chance for Remember responses and no overall difference was found in accuracy between Familiar and Remember judgments. As with other studies in this area that have assessed relational and associative memory in TLE, questions still remain as to what causes these impairments in binding and retrieval of contextual information. More pertinent to the topic of this thesis however is that it appears different types of information are driving the subjective experience of remembering in these groups.

The SMF (Johnson *et al.*, 1993) offers a possible interpretation of the present results. This framework suggests that the retrieval of source information involves a *monitoring* component following recognition. Hence, it has been argued that the source memory impairments seen in patients with frontal lobe damage and older adults with age-related decrements in frontal functioning may result from the requirement to use strategic, frontally mediated, retrieval operations following successful recognition (Castel & Craik, 2003; Cohn *et al*., 2009; Incisa della Rocchetta & Milner, 1993; Jetter, Poser, Freeman, & Markowitsch, 1986; Petrides & Milner, 1982). Because recollection is thought to be dependent on a distributed network of fronto-temporal connections (*for a review, see* Skinner & Fernandes, 2007), a plausible reason for the current patient group's impairments may be that it is not the memory trace *per se* that is disrupted, but the integrity of the post-retrieval monitoring mechanism needed to search for extra contextual information is damaged. However, as mentioned earlier, participants were explicitly instructed that the contextual information would be tested later – a method advocated by Thaiss and Petrides (2003) in order to reduce task demands at retrieval, in comparison to when participants are given a 'surprise' test for source information. In a similar vein, Mitchell and Johnson (2009) discuss how the encoding of contextual features of items is *flexibly weighted* depending on goals and metacognitive beliefs participants hold about the task. From this perspective, lower performance on the contextual elements of items in the task would be explained by the fact that patients may simply have assigned less cognitive resources to encoding them, as they may have seen them as too difficult to encode, or simply unimportant. The above-chance performance for spatial information may suggest this feature was given a high flexible weighting by both groups. However, there is no evidence to suggest that patients did not try as hard, or assigned less importance to other features. In any case, this still would not explain why, in the matched subsample, patients still made an equal number of Remember responses in the absence of a recollection advantage for contextual retrieval.

The results are perhaps better explained as a recollection deficit mediated by selective damage to hippocampal areas, as outlined by similar previous TLE studies in Section 1.10. The fact that the smaller subsample of patients made a comparable number of Remember responses brings to question the quality and quantity of contextual or associative information that is needed during retrieval in order to subjectively experience recollection for a word. Given that that the data suggest less of the *objectively* measured contextual information was available for Remember responses (i.e. location, order, colour), it could be that differences in other kinds of associative information retrieved were driving the patients' Remember responses. Unlike Perfect et al. (1996), who asked participants to note all the kinds of contextual and associative information available after making R/K judgments, participants in the current study were only asked a Yes/No question. In this format, the results displayed a similar number of items assigned a Remember response to be accompanied by external associations in both groups. Although dual process theories traditionally conceptualise recollection as an all-or-none process (i.e. one can either be recollecting, or not), recent evidence has suggested under certain circumstances it can be graded (Parks & Yonelinas, 2008; Yonelinas & Parks, 2007). Therefore, it could be that the quality of patient's more personal external associations was sufficient to recollect items, and hence assign them a Remember response. During the contextual source recognition component of the task, this external information is presumably of little relevance, and therefore one could argue this to be an example of non-criterial recollection (*see* Yonelinas & Jacoby, 1996; Parks, 2007).

The SMF account of this would be that the *differentiation* created by the individual contextual elements of study items was not sufficient to distinguish their retrieval through different states of awareness. Instead, other external information (such as thoughts or feelings, for example) may have created the differentiation necessary for this recollection. Because the main point of controversy within this literature revolves around the extent to which the hippocampus supports source, rather than item memory, as Kurilla (2011) points out, future studies in this area will benefit from manipulating a variety of different contextual features in order to better understand the basis of recollection and familiarity judgments. Drawing on the present study, a simple follow up could involve varying the to-be-remembered contextual features, whilst also asking participants for detailed information regarding the quality of the external associations retrieved; the mental experiences that may contribute to recollection presumably have different strengths, such as the vividness of the scene from a participants own personal holiday that is conjured after studying the word 'holiday'. Comprehensively assessing this would no doubt illuminate further any differences in the subjective aspects of retrieval between TLE and healthy adults.

The views above make a common assumption that participants are basing their subjective experience of recollection on veridical information. We must, however, take into account the actual raw performance data for both groups. Although controls showed significantly better performance for contextual information following Remember responses as compared to Familiar responses, overall performance was only 37% across the three contextual features. It would therefore be valuable to try and replicate the results of the current study with higher levels of source accuracy; using fewer contextual features would be a suitable approach. Because participants had to make a forced choice decision regarding source information, there may have been a number of occasions where participants confidently selected an *incorrect* option following a Remember judgment. Accordingly, the reconstructive nature of memories means they can be influenced by similarities between certain events, and hence retrieved with information from alternative representations (Lyle & Johnson, 2006).

Returning to the idea of *differentiation*, it could be then that patients have disordered recollective processing, which leads them to make incorrect attributions about contextual information in this task. Unfortunately, it was not recorded whether participants believed the response to be correct, or how confident they were in that response. Obtaining confidence data for this would be particularly instructive, as it may inform the various theories that exist to account for source monitoring in the literature. For example, the SMF itself suggests that a high confidence 'old' response could be based on recollected, but erroneous information, as mentioned above. Alternatively, some single trace theorists (e.g. Kirwan, Wixted, & Squire, 2008) assume incorrect source judgments are based on a strong familiarity response. Given the present two step-procedure for determining subjective experience and retrieved contextual information, assessing the confidence with which the source information is retrieved during these two states of awareness would be highly interesting. This, in fact, is a topic that is developed later in Chapter 6, where recollection and familiarity are assessed in the context of an associative recognition task, as well as corresponding confidence levels. It must be noted again though, that the overall aim of this thesis is not to resolve the dual process/single trace debate, rather to use TLE as a model to shed light on the differences and similarities in subjective and objective recollection and familiarity.

The performance data following familiarity judgments in the matched subsample also provided interesting results. It was found that temporal order information was above chance following patients' Familiar judgments, but not for Remember judgments. Interestingly, in one of Perfect et al.'s (1996) experiments, they too found above-chance performance in temporal information for Know responses. These authors also found that about one-third of Know judgments were accompanied by some kind of associative information, suggesting that familiarity, as measured by the R/K paradigm, may not reflect the context-free process outlined by early proponents of dual process theories (e.g. Mandler, 1980; Gardiner, 1988, Rajaram, 1993). In the present study, it too was found in both groups that familiarity judgments were accompanied by a certain degree of external association (11% vs 21% in patients and controls, respectively), albeit not as frequently as Perfect et al. At the time, these authors had provided one of the first demonstrations that conflicted with the idea of a context-free familiarity process (*see also* (Conway & Dewhurst, 1995). However, it has subsequently been shown that highly accurate source judgments can be done so on the basis of the partial information retrieved along with familiarity (Hicks, Marsh, & Ritschel, 2002). Moreover, recent neuropsychological, electrophysiological and neuroimaging work has displayed that familiarity can support source memory, especially under conditions in which the information is unitised, or is formed from intra-domain associations, such as word-word pairs (Diana, Yonelinas, & Ranganath, 2008; Haskins, Yonelinas, Quamme, & Ranganath, 2008; Jäger, Mecklinger, & Kipp, 2006; Quamme, Yonelinas, & Norman, 2007; Rhodes, Castel, & Jacoby, 2008; Rhodes & Donaldson, 2007; Speer & Curran, 2007; Yonelinas, Kroll, Dobbins, & Soltani, 1999). Although we cannot be sure as to what kind of external information was available to participants during the familiarity process, at least the results are in partial agreement with this recent work. As for the finding that temporal information was above-chance in the higher performing patients for Familiar responses, this result can also be accommodated within dual process theory. As Yonelinas (1999*a*) states, familiarity "is assumed to be a relatively fast process that reflects the global familiarity or strength of an item'' (p. 1416). Therefore, the recency with which an item was presented may be experienced more as *fluency*, rather than a subjectively recollected detail. Any item above a certain criterion would be judged as familiar and old, and items that are processed more or less fluently may represent a subjective interpretation of recency. Moreover, the 4-AFC recognition format for temporal position would have placed fewer demands on recollecting information about the study phase than a serial order format (e.g. what word came after or before this one?). It is unclear though, why this would occur for patients, and not in healthy adults, especially in the context of invariant familiarity responses measured by the IRK procedure. This could be further evidence that subtle differences in the underlying processes within medial temporal areas give rise to qualitatively different subjective experiences in TLE. Recent work that has been able to utilise precise structural information regarding lesion size and extent in TLE patients (Bowles *et al.*, 2007; 2010) has helped, and will continue to aid the process of understanding exactly what drives such differences in recollection and familiarity in these patients.

In summary, the present study has highlighted how the subjective state of conscious awareness experienced in TLE may be qualitatively and quantitatively distinct from the healthy brain. One of the overarching aims of this thesis was to explore whether the phenomenological experience of remembering truly reflects a parallel underlying cognitive process of recollection. Using TLE as an example, the experiment in this chapter provides some interesting data on this topic.

4 Comparing subjective and objective recollection with a repetition-lag procedure

4.1 Introduction

In the previous chapter, subjective states of awareness were compared with the amount of information consciously available to participants during recognition. As well as demonstrating significant reductions in the likelihood TLE patients would subjectively *remember* studied items, the results also suggested that the basis for the Remember responses they did give was qualitatively different to healthy controls. The experiments presented in the following chapter aimed to build on these findings by assessing recollection and familiarity using the PDP (Jacoby, 1991), as described in Section 1.8.2.

The objective measure of recollection used in the previous experiment was the level of contextual or associative information provided by participants during recognition. In this paradigm, after matching subjects on recognition performance (and thus assuming similar item encoding success), the extent to which a participant will engage in recollective processes during recognition can be assumed to be directly related to the functional integrity of the neuroanatomical regions involved in this cognitive process. In other words, participants will use the process that is available to them during recognition. A useful extension of this then is to engage participants in a task that *directs* or *forces* them to use one process over the other. The PDP does exactly this, as it requires participants to overcome the automatic influences of memory (familiarity) with controlled, effortful processing (recollection). The first aim of the following experiments was thus to build on the TLE literature by using a variant of this paradigm to tease apart the separate contributions of recollection and familiarity to task performance.

The main attraction of the PDP is its ability to provide uncontaminated, process-pure estimates of recollection and familiarity (Jacoby, 1991; Jacoby *et al*., 1993). It is therefore surprising that given the increasing body of evidence that suggests TLE is associated with relatively selective recollection deficits, there have only been four previous studies using the PDP to investigate these impairments further (Cohn *et al*., 2009; Del Vecchio *et al*., 2004; Hudson, Flowers, &

Roberts, 2009; Martin *et al*., 2012 – these studies are discussed in Section 1.10.3). This seems to be due to a focus on studying amnesics in the literature, as when there is gross pathology in an identifiable neuroanatomical area, results of such neuropsychological studies are highly useful for informing theoretical models of memory processing. However, as Yonelinas and Jacoby (2012) discuss in their recent review, because of the sensitivity of the PDP in its measurement of these dual-processes, it has a potentially more applied utility in the diagnosis of memory disorders. Because the PDP has had limited application to studying the TLE population at large, my first motivation was to explore the contribution recollection and familiarity to performance in this group using a novel variant of this paradigm.

To this end, Jennings and Jacoby's (1997) repetition-lag procedure was used in the following two experiments. In their original study, the authors compared inclusion and exclusion test performance in young and older adults to add weight to then developing argument that aging is associated with significant impairments in recollection, whilst familiarity is intact. After studying a list of words, each test condition involved the presentation of half the study items, as well as new items, which were presented twice, with the second presentation varying between two and 48 intervening items. Under inclusion instructions, participants were told to respond 'Yes' to any item they had previously seen (study item or repetition of new item). Under exclusion instructions, they were told to only respond 'Yes' to items that were initially studied, and reject new items and repetitions of those new items. Under inclusion instructions then, successful recognition of a target or repeated item is not dependent on the retrieval of the source of that item. Conversely, under exclusion instructions, participants must utilise recollection to determine whether an item was previously studied, or if it was presented for the first time in the test phase. Because of this difference in the way recognition can be supported for repeated items in each condition, estimates of recollection and familiarity can be calculated at each lag interval (explained in more detail below).

As well as replicating this verbal repetition-lag procedure, a further motivation of the present study was to explore recollection and familiarity in this patient group with different types of materials. As such, it was decided to construct an identical task using facial stimuli. As discussed in Section 1.5.1, the material specific basis of the right temporal lobe in non-verbal forms of memory is a more contested issue than that of the verbal memory functions of the left temporal lobe. It has been suggested that lack of hemispheric group differences is dramatically influenced by the form of 'visual' test used (Helmstaedter, Pohl, & Elger, 1995; Vaz, 2004). However, recent work indicates that face recognition in particular is a non-verbal cognitive function that, under certain conditions, lateralises well to the right temporal lobe

(Bengner *et al*., 2006*c*; Bengner & Malina, 2010; Coleshill *et al*., 2004; Gainotti, 2007). For example, testing after delayed intervals has greater sensitivity in detecting face recognition deficits in RTLE, and differences are found between subgroups of patients with and without MRI evidence of focal lesions (Bengner *et al*., 2006*c*). For practical reasons, the 24 hour delay used in the above mentioned study was not possible, but instead a 10 minute filled interval was incorporated into the present experiments to overcome the potential problem of simply using an immediate recognition paradigm.

As well as conducting visual and verbal variants of the repetition-lag paradigm to explore laterality differences in PDP estimates, the most important novel addition to the task was the requirement for participants to make subjective experience judgments during recognition. As discussed in Section 1.11, there has been some attempt in the literature to compare subjective and objective measures of recollection. Most notably, Prull et al. (2006) compared three measures of recollection and familiarity (inclusion/exclusion performance; R/K paradigm; ROC method) with neuropsychological test performance in young and older adults. These authors found that all measures of recollection (subjective and objective), converged on the finding of an impairment in older adults. As the authors note, this is despite the differences in how recollection is defined in each task. Another more recent study by McCabe et al. (2011) used inclusion and exclusion tasks and subjective experience judgments to provide evidence that free recall is partially influenced by automatic memory processes. Therefore, these two studies suggest that the different methods of estimating recollection and familiarity can be used synergistically to test both neuropsychological and more theoretical hypotheses. By requiring participants to report on their experiential state during inclusion and exclusion tasks in the present experiments, the aim was to compare the extent to which any significant reduction in objective process estimations of recollection were paralleled by a reduction in the subjective experience of remembering items in TLE also. To my knowledge, this is the first example of an intra-task comparison of this type in this patient group.

Based on the results of the previous chapter and those provided elsewhere in this literature, several hypotheses were generated. First, performance in the exclusion condition was predicted to be worse in the patient sample in both experiments. As mentioned above, committing FPs to repeated exclusion items is thought to rely on a failure to recollect the source of that item (Jennings & Jacoby, 1997). Therefore, this is the first behavioural measure of recollection to be observed. Moreover, an increase in the number of FPs was expected as the lag intervals between items increased, as after the processing of more interfering information, recollection should be required to a greater extent as the task becomes more difficult. This difference was expected to be greater in patients, however. Turning to objective PDP estimates, these were expected to be characterised by significantly lower levels of recollection in the TLE sample, with familiarity left intact. In previous studies using this repetition-lag methodology, the familiarity estimate has been found to increase over intervals (and thus in line with the explanation above regarding FPs), so it was hypothesised that this pattern should be evident in both groups. As described later, IRK calculations were computed for the subjective experience judgments associated with old study items. These data were expected to show that controls' experiential state during recognition of these items was predominantly one of *remembering*, where in comparison, TLE patients would rely more on feelings of familiarity. Although the absolute values of the various estimates of these two processes were not predicted to be directly comparable, the main expectation was that all of the evidence would converge on a consistent recollection impairment.

During the testing session, all participants carried out the face version of the task first, followed immediately by the word version. However, because the previous chapter hinted toward laterality effects in the LTLE group, I present the word version as Experiment 4.1, as this seemed to be a logical transition. With regard to the face task (Experiment 4.2), despite the modest number of participants in the RTLE group, it was predicted that there would be at least some evidence of lateralised deficits, either on performance measures, recollection estimates, or both. Importantly, despite the use of a visual and verbal task, the overriding aim of the present study was more to comprehensively explore the subjective-objective comparisons of recollection and familiarity in TLE.

4.2 Experiment 4.1: Word task

4.2.1 Participants

All patient and control participants described in Chapter 2 completed the experiment with the exception of patients 4, 6, 7 and 27. Additionally, patient 23's data was lost due to a system fault during testing.

4.3 Method

4.3.1 Materials

The stimuli consisted of 100 nouns, which were drawn from the $SUBTLEX_{US}$ word frequency corpus (Brysbaert & New, 2009). All words were between four and eight letters in length. Imageability and concreteness values were separately obtained for each word from the MRC psycholinguistic database (Coltheart, 1981*b*). Four of these words served as buffer items, with two presented at the beginning and end of study and test cycles in the same fixed order. The remaining 96 words were split into two sets of 48 items, A and B, which were matched on the above psycholinguistic variables (*Mean* $SUBTLEX_{WF}$ = 63.11, *Mean concreteness*= 479.04, *Mean imageability* = 517.72, *Mean number of letters* = 5.77). The presentation of these sets as study and test items was counterbalanced across participants. Within the study set, half of the words were assigned to each of the inclusion and exclusion conditions. These were presented in random order to each participant. In the test phase, the order of inclusion and exclusion conditions was also counterbalanced between participants. The lags used were 2, 4, 8 and 16. The running order of new items forming the lags and number of intervening old or new items was kept constant, however, the six item groupings that formed each lag were rotated across participants. Thus, each set of 6 items was used as often in each lag and in study/test inclusion and exclusion trials.

4.3.2 Design and Procedure

There were two within subjects manipulations: 2 (test type: inclusion vs exclusion) x 4 (lag interval: 2, 4, 8 and 16). Participants were instructed that they were about to be shown a series of words to learn, which would be followed by a ten minute filler task and finally a test phase consisting of two recognition tests. In the encoding phase, words were presented at a rate of 3 seconds per item, with an ISI of one second during which a fixation cross was displayed in the centre of the screen. Participants were also instructed to verbalise how pleasant they judged each word to be, on a scale of 1 (very unpleasant), 2 (unpleasant), 3 (neutral), 4 (pleasant) and 5 (Very pleasant). The pleasantness judgment options always appeared on the right side of the screen and the experimenter keyed participants' responses. This instruction was included to ensure participants encoded items on a relatively conceptual level. Although it should be noted that previous literature has shown conceptual encoding of stimuli leads to an increase in the number of Remember responses in the R/K paradigm in healthy subjects, but not for TLE patients (Moscovitch & McAndrews, 2002).

After encoding, participants completed ‘spot-the-difference’ problems for approximately ten minutes. In the following test phase, participants were told they were about to see the old studied words and new words, which would be repeated at varying intervals. The inclusion instructions explained that they were to respond ‘yes’ to any word that had been seen previously (old studied words and repetitions of new words) and ‘no’ to the first presentation of new words. The exclusion instructions asked participants to respond ‘yes’ only to words from the study phase and respond ‘no’ to new words and repetitions.

They were then told that if they had responded ‘Yes’, indicating they recognised a word (based on inclusion or exclusion instructions), they must then report their subjective experience for that item (R/K procedure: Tulving, 1985). At this point, they were directed to an information sheet in front of them which gave definitions of Remember, Familiar and Guess responses, which were identical to those in Chapter 2. The instruction sheet also provided examples of daily situations in which one might report these states of awareness (e.g. finding a person’s face familiar in the absence of remembering where you know them vs. remembering what happened in the last film you watched). The study did not proceed until the experimenter was satisfied the participant correctly understood each definition.

Following instructions for the R/K procedure, the experimenter completed a walked-through practice with the participant to ensure they understood the test procedure. This was completed for both the inclusion and exclusion conditions. Participants verbalised all responses in the test phases and the experimenter entered these by a mouse click. During the test phase, the Yes and No options were presented in boxes to the right of each word; if the participant responded No, the word would disappear and was followed by a fixation cross for one second before the next word appeared. If they responded Yes, the word disappeared and a message asking ‘What was your subjective experience of the word?’ appeared, as well as three boxes with the letters R, F and G, corresponding to Remember, Familiar and Guess. Following completion of one test phase (inclusion/exclusion), the participant was immediately given the instructions for the remaining test and the above procedure was repeated.

4.3.3 Process estimations

The combination of inclusion/exclusion conditions and the instructions to report subjective experience for recognised items allowed the calculation of the contribution of recollection and familiarity to performance in two ways. As described by Jennings and Jacoby (1997), participants will make a FP to a repeated item in the exclusion condition if it is familiar (F) and its source (i.e. the test phase) is not recollected ($1\text{-}R$). Therefore, false alarming in the exclusion condition is explained by the equation: Exclusion = $F\,(1\text{-}R)$.

Conversely, the instructions to respond Yes to any previously seen item in the inclusion means that successful performance can be achieved through the use of both recollection and familiarity. Therefore, the probability of a Yes response to a repetition on the inclusion test can be calculated as Inclusion = $R + F\,(1\text{-}R)$.

Recollection can then be computed by subtracting the FP rate for the exclusion condition from the hit rate for the inclusion condition: R = Inclusion – Exclusion. Finally, familiarity can be calculated by dividing the FP rate in the exclusion condition by the inverse of the recollection estimate: F = Exclusion/($1 - R$).

Subjective experience responses derived from the Remember/Know procedure can also be used to calculate process estimations in a similar way using the independence remember-know procedure (IRK: Yonelinas & Jacoby, 1995). In the present study, estimates of recollection and familiarity were calculated in the same way as the previous chapter, using the hit rate to old study items and FP rate to the first presentation of new items.

4.4 Results

4.4.1 Recognition performance

The proportions of each item type that were assigned a Yes response in each condition for controls and the TLE group are presented in Table 4.1. Old items represent studied words and FP 1^{st} represents the false alarm rate to each lag item on its first presentation in the test phase. For the lag intervals, a Yes response in the inclusion condition represents a hit to a repeated item, whereas in the exclusion condition it represents a false alarm, as participants were instructed to reject any items other than those studied initially.

Overall recognition of study items was high in both groups for each condition. A 2 (group) x 2 (hit vs. FP1st) x 2 (condition) repeated measures ANOVA was conducted to assess differences in recognition performance, with group as a between subjects factor. There was no main effect of group or condition, $F(1, 39) = 0.21$, $p = .65$, $\eta_p^2 = .01$; $F(1, 39) = 0.96$, $p = .33$, $\eta_p^2 = .02$. Condition did not interact with any other variable (*F*s < .13, *ps* > .72), suggesting performance was comparable across inclusion and exclusion tasks in both groups for old and new items. However, the item type x group interaction reached significance, $F(1, 39) = 5.38$, $p = .03$, $\eta_p^2 = .12$, displaying that across conditions, the difference between controls' FP rate and hit rate was greater than patients, suggesting better overall recognition performance.

The same analysis as above was repeated but with the group factor including separate left, right, bilateral and control participant groups. No effect of subgroup was found, $F(1, 37) = 0.41$, $p = .75$, $\eta_p^2 = .03$ but the interaction between subgroup and item type was significant, $F(3, 37) = 2.92$, $p = .05$, $\eta_p^2 = .19$. The means suggested that as well as the result discussed above, an increased hit rate without correspondingly low FP rate in the bilateral group was also driving the interaction.

Table 4.1 Mean (SD) probability of responding 'yes' to old, new and repeated items at each lag interval in Experiment 4.1.

			Lag interval			
Test	Old	FP 1st	2	4	8	16
Inclusion						
Control	.85 (.21)	.09 (.09)	.81 (.06)	.96 (.09)	.95 (.10)	.96 (.09)
TLE	.79 (.19)	.18 (.15)	.77 (.12)	.90 (.12)	.94 (.13)	.92 (.14)
LTLE (N=11)	.78 (.12)	.22 (.16)	.74 (.15)	.88 (.13)	.95 (.08)	.89 (.17)
RTLE (N=7)	.75 (.29)	.13 (.16)	.76 (.09)	.90 (.13)	.88 (.21)	.95 (.08)
BTLE (N=4)	.92 (.09)	.14 (.08)	.83 (.00)	.96 (.09)	1.00 (.00)	.92 (.17)
Exclusion						
Control	.83 (.15)	.07 (.10)	.01 (.04)	.07 (.10)	.10 (.04)	.18 (.16)
TLE	.78 (.16)	.15 (.15)	.07 (.11)	.14 (.19)	.26 (.29)	.30 (.30)
LTLE (N=11)	.75 (.13)	.14 (.17)	.08 (.11)	.20 (.22)	.32 (.29)	.41 (.33)
RTLE (N=7)	.78 (.22)	.16 (.14)	.05 (.08)	.05 (.08)	.24 (.30)	.22 (.27)
BTLE (N=4)	.90 (.08)	.15 (.15)	.08 (.17)	.17 (.19)	.13 (.25)	.17 (.19)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy, FP 1st = false positives to first presentation of new items.

4.4.2 Repeated lag item performance

Inclusion task performance on the repeated lag items was assessed with a 2 (group) x 4 (lag interval) repeated measures ANOVA, with group as a between subjects factor. No effect of group was found, $F(1, 39) = 2.56$, $p = .12$, $\eta_p^2 = .06$, suggesting TLE patients were unimpaired in the ability to correctly recognise words that had recently been presented once already in the test phase; this result is consistent with the thesis that familiarity alone can support recognition of these items . Somewhat surprisingly, a significant effect of lag was found, $F(3, 117) = 23.56$, $p = .001$, $\eta_p^2 = .38$, due to lag 2 items achieving significantly poorer performance than other repeated items in both groups; we return to this finding in the discussion below. An ANOVA looking at laterality revealed no effect of subgroup, or interaction with lag, $F(1, 37) = 1.56$, $p = .22$, $\eta_p^2 = .11$; $F(9, 111) = 0.73$, $p = .65$, $\eta_p^2 = .06$.

Exclusion task performance on repeated lag items is where differences were expected between groups, and lag intervals. As discussed earlier, this is because correct rejection of repeated items on this task requires the use of recollection. Moreover, as past research has shown, as lag intervals increase, the demands on recollection also increase, as one must oppose the sense of familiarity created by the first presentation of a word. Consistent with these hypotheses, a 2 (group) x 4 (lag interval) repeated measures ANOVA on the data revealed a significant effect of group, $F(1, 39) = 6.75$, $p = .01$, $\eta_p^2 = .15$ and a significant effect of lag, $F(3, 117) = 17.35$, $p = .001$, $\eta_p^2 = .31$ but no interaction group and lag ($F < 1$). Bonferroni post-hoc comparisons assessing the lag effect revealed that lag 8 FPs were significantly higher than lag 2 (*Mean difference* = .14, $p = .001$) and lag 4 (*Mean difference* = .09, $p = .02$); lag 16 FPs were also higher than lag 2 (*Mean difference* = .20, $p = .001$) and lag 4 (*Mean difference* = .15, $p = .001$) but lag 2 and 4 did not differ from one another (*Mean difference* = .05, $p = .12$), nor did lags 8 and 16 (*Mean difference* = .06, $p = .27$). Therefore, the results suggest that both groups made more FPs to items at the longer intervals, but this failure to oppose the experimentally manipulated familiarity was more evident in the TLE group.

This analysis was repeated to assess the contribution of laterality and a significant effect of subgroup was found, $F(1, 37) = 3.55$, $p = .02$, $\eta_p^2 = .22$. Bonferroni post-hocs displayed a significant difference between the control group and LTLE (*Mean difference* = .17, $p = .01$), but not between the other patient subgroups, or other patient subgroups and controls (*p*s > .63). Therefore, the results provide evidence that the LTLE group is capable of completing a test where recognition is achievable solely by familiarity (inclusion condition), but when recall-to-reject recollective processes are needed (exclusion condition), performance is impaired.

4.4.3 Objective process estimations

The results from the above analysis implied that the behavioural marker of recollection in this task was preferentially impaired in the LTLE group (i.e. FPs to exclusion items). The objective process estimates of recollection and familiarity outlined earlier were this computed to examine this further.

Table 4.2 displays the recollection and familiarity estimates for patients and controls for each lag interval on the task. A 2 (group) x 2 (process) x 4 (lag interval) repeated measures ANOVA was conducted on this data, with group as the between subjects factor. No overall effect of group was found, $F(1, 39) = 2.81$, $p = .10$, $\eta_p^2 = .07$. However, an effect of process was found, $F(1, 39) = 30.78$, $p = .001$, $\eta_p^2 = .44$ and central to the experimental hypothesis, this interacted significantly with group, $F(1, 39) = 4.79$, $p = .04$, $\eta_p^2 = .11$. This was qualified with follow-up one-way ANOVAs, where a significant difference was revealed between the collapsed mean recollection estimate for controls (*Mean* = .81, *SD* = .06) and patients (*Mean* = .67, *SD* = .21), $F(1, 39)= 8.61$, $p = .01$, $\eta^2= .18$, but not between familiarity estimates for controls (*Mean* = .46, *SD* = .16) and patients (*Mean* = .51, *SD* = .20), $F(1, 39)= 0.82$, $p = .37$, $\eta^2= .02$.

Of further interest was the significant process x lag interval interaction, $F(3, 117) = 29.02$, $p = .001$, $\eta_p^2 = .43$. The means suggest this is a result of recollection estimates remaining relatively stable with no clear pattern of increase or decrease across intervals, in comparison to familiarity estimates which increased in a uniform fashion with increasing intervals in both groups. As such, the group factor did not interact with lag interval, $F(3, 117) = 0.77$, $p = .52$, $\eta_p^2 = .02$, and the three-way interaction between group, process and lag interval was also non-significant, $F(3, 117) = 0.11$, $p = .95$, $\eta_p^2 = .003$. The results of the process estimate analysis are thus supportive of the recognition performance data; poorer performance on the components of the task that are theoretically reliant on recollective processes is supported by a reduction in objective estimations of the contribution of recollection to the task as a whole in TLE. Familiarity, on the other hand, is invariant between patients and controls, and is presumably utilised in exactly the same way as controls as the difficulty of the repeated lag intervals increases.

Given that the recognition findings above showed the LTLE group to be preferentially impaired on the recollective component of the task, the process estimation analyses were re-ran and looked specifically at individual patient subgroups. There was no significant effect of subgroup or interaction between this factor and the other variables (*F*s < 2.81, *p*s < .10). Therefore, although LTLE was associated with the lowest recollection based recognition performance (exclusion FPs), when taking into account both conditions with PDP estimates, the significantly lower contribution of recollection to the task is better explained by the performance of the TLE group as a whole.

Table 4.2 Mean (SD) recollection and familiarity process estimations from performance on inclusion and exclusion lag items in Experiment 4.1.

	Recollection				*Familiarity*			
	Lag 2	Lag 4	Lag 8	Lag 16	Lag 2	Lag 4	Lag 8	Lag 16
Control	.78 (.07)	.90 (.09)	.82 (.11)	.76 (.15)	.12 (.09)	.48 (.25)	.57 (.34)	.68 (.30)
TLE	.68 (.18)	.74 (.20)	.66 (.31)	.59 (.34)	.21 (.19)	.51 (.30)	.64 (.28)	.69 (.28)
LTLE (*N*=11)	.65 (.23)	.66 (.21)	.61 (.28)	.47 (.34)	.20 (.16)	.52 (.35)	.70 (.29)	.72 (.35)
RTLE (*N*=7)	.70 (.07)	.83 (.16)	.62 (.38)	.71 (.33)	.20 (.21)	.42 (.27)	.57 (.31)	.69 (.18)
BTLE (*N*=4)	.73 (.16)	.77 (.23)	.84 (.24)	.73 (.30)	.25 (.28)	.65 (.21)	.62 (.23)	.61 (.22)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

4.4.4 Subjective experience

The novel adaptation of the repetition lag procedure adopted in the present study was to ask participants to provide subjective experience ratings for any item accepted as old. The IRK estimates are presented in Table 4.3[6]. Recollection estimates are higher in controls compared to patients in both conditions[7], and scores across conditions appear to be relatively balanced in both groups. Separate 2 (group) x 2 (condition) repeated measures ANOVAs were conducted on all four of the estimates, with group as a between subjects factor. There were significant group differences for the R hit-FP and R IRK estimates, $F(1, 39) = 5.69$, $p = .02$, $\eta_p^2 = .13$; *F*(1,

[6] Data for guess responses are not presented as they were low in both groups: Collapsed across inclusion and exclusion conditions controls *mean* = .02, *sd* = .04 and patients *mean* = .03, *sd* = .07.
[7] The R IRK estimate for controls in the inclusion condition represents the mean and SD after removing one outlying control participant whose remember FP rate was much larger than remember hit rate, resulting in an IRK estimate of -9.00. With this score included, the mean of the control group was .25 (*SD* = 2.26). In the repeated measures analysis of this estimate, this participant's score was substituted with the new group mean of .76 and used with their original exclusion R IRK score so as not to lose a data point.

39) = 4.77, p = .04, η_p^2 = .11. No effect of condition, or interaction between group and condition was found in these analyses (Fs < .32, ps > .58). Therefore, control participants were more likely than patients to subjectively remember old study items and the differing demands of each the conditions did not affect the likelihood of participants assigning these items Remember judgments. For the F IRK and F corrected familiarity estimate analyses, no significant difference was found between groups or condition, and no interactions were found between condition and group (Fs < 1.48, ps > .23).

Finally, ANOVA analyses were used to assess differences in laterality. For R hits-FPs, the subgroup factor only approached significance, $F(3, 37)$ = 2.67, p = .06, η_p^2 = .18, but for the R IRK estimate a reliable effect was found, $F(3, 37)$ = 3.02, p = .04, η_p^2 = .20. However, Bonferroni post-hoc comparisons following both analyses revealed no significant differences between patient subgroups and controls (ps > .14). The same analysis for both familiarity estimates revealed no evidence of difference in subgroups. Therefore, similar to the above findings for objective recollection estimates, it appears that the significant reduction in subjective remembering in the TLE sample is not a result of a preferential impairment in one particular laterality group.

Table 4.3 Mean (SD) Independence Remember-Know estimates of recollection and familiarity associated with old and new responses in Experiment 4.1.

Test	R Hit-FP	R IRK	F IRK	F Corrected
Inclusion				
Control	.67 (.36)	.76 (.30)	.77 (.36)	.67 (.37)
TLE	.46 (.24)	.52 (.48)	.69 (.26)	.52 (.33)
LTLE (*N*=11)	.43 (.27)	.41 (.63)	.66 (.28)	.54 (.31)
RTLE (*N*=7)	.47 (.28)	.62 (.24)	.72 (.27)	.52 (.40)
BTLE (*N*=4)	.53 (.31)	.62 (.34)	.75 (.23)	.52 (.40)
Exclusion				
Control	.65 (.29)	.73 (.30)	.70 (.33)	.62 (.37)
TLE	.52 (.33)	.57 (.43)	.73 (.29)	.58 (.37)
LTLE (*N*=11)	.48 (.31)	.55 (.26)	.76 (.25)	.66 (.32)
RTLE (*N*=7)	.59 (.41)	.51 (.71)	.72 (.35)	.54 (.44)
BTLE (*N*=4)	.52 (.34)	.73 (.18)	.68 (.35)	.45 (.41)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy, R = remember, FP = false positive, IRK = independence remember-know, F = familiarity.

The analysis presented above of PDP derived recollection and familiarity estimates was able to provide information regarding the relative contribution of these two processes to completing the task as a whole at each lag interval. Taking into account both inclusion hits and exclusion FPs, this revealed that familiarity was used progressively more as lag intervals increased, whereas the contribution of recollection remained more stable (with controls' score being significantly higher). By obtaining subjective experience ratings for repeated items in the inclusion condition, a different assessment was possible; instead of estimating the contribution of the cognitive processes used to solve the task as a whole based on recognition performance, the phenomenology with which participant's recognised items as the interval between initial presentation and repeat increased was directly measurable. These data are presented in Table 4. These were submitted to a 2 (group) x 2 (subjective experience) x 4 (lag interval) repeated measures ANOVA, with group as a between subjects factor. There was no effect of group[8], $F(1, 39) = 0.86$, $p = .36$, $\eta_p^2 = .02$, nor any effect of lag, $F(3, 117) = 0.86$, $p = .46$, $\eta_p^2 = .02$. As would be expected from the means, a significant effect of subjective experience was found, $F(1, 39) = 209.86$, $p = .001$, $\eta_p^2 = .84$, with Remember responses assigned to significantly more repeated inclusion items. Further, a significant interaction was found between group and subjective experience, $F(1, 39) = 9.57$, $p = .004$, $\eta_p^2 = .20$, confirming that control participants gave significantly more Remember responses than patients. Subjective experience also interacted significantly with lag, $F(3, 117) = 7.88$, $p = .001$, $\eta_p^2 = .17$, which resulted from the overall decrease in Remember responses and increase in Familiar responses as lag intervals increased. This result therefore provides support for the PDP data that suggested familiarity processes are utilised to a greater degree with longer lag intervals. No interaction was found between lag interval and group, $F(3, 117) = 0.86$, $p = .46$, $\eta_p^2 = .02$. However, the three-way interaction between group, subjective experience and lag reached significance, $F(3, 117) = 3.36$, $p = .02$, $\eta_p^2 = .08$. As we can see from Table 4.4, this appears to be in line with the objective process estimation data: Controls' recognition responses are consistently judged to be remembered more than familiar, whereas patients show a highly uniform linear decrease and increase in Remember and Familiar judgments over lag intervals, respectively. The strength of this pattern is evidenced by the fact that the overall subjective experience x lag interaction reported above was still significant, despite controls not showing the same profile.

[8] Guess responses are again not presented here due to low numbers; control participants did not make any guess judgments and the mean patient proportion was just .01 (*SD* = .02). The group effect was thus expected to be non-significant as the proportions in each both add to 1.

Table 4.4 Mean (SD) proportion of subjective Remember and Familiar judgments assigned to repeated inclusion lag items at each interval in Experiment 4.1.

	Remember				*Familiar*			
	Lag 2	Lag 4	Lag 8	Lag 16	Lag 2	Lag 4	Lag 8	Lag 16
Control	.99 (.04)	.93 (.11)	.96 (.12)	.94 (.13)	.01 (.04)	.07 (.11)	.04 (.12)	.06 (.13)
TLE	.88 (.19)	.81 (.22)	.78 (.26)	.69 (.28)	.12 (.19)	.18 (.22)	.22 (.26)	.30 (.29)
LTLE (*N*=11)	.83 (.25)	.77 (.26)	.70 (.32)	.63 (.30)	.17 (.25)	.21 (.25)	.30 (.32)	.34 (.32)
RTLE(*N*=17)	.93 (.09)	.82 (.20)	.83 (.19)	.68 (.30)	.07 (.09)	.18 (.20)	.17 (.19)	.32 (.30)
BTLE(*N*=4)	.96 (.09)	.91 (.11)	.91 (.10)	.86 (.19)	.04 (.09)	.09 (.11)	.09 (.10)	.14 (.20)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

These analyses were repeated on laterality subgroup data and the three-way interaction reported above was no longer significant (F = 1.18, p = .31). However, the subgroup x subjective experience interaction was again significant, $F(3, 37) = 5.94$, $p = .002$, $\eta_p^2 = .33$. A follow up one-way ANOVA was conducted on the marginal means for proportion of Remember responses for LTLE (*Marginal mean* = .78, *SD* = .16), RTLE (*Marginal mean* = .89, *SD* = .10), BTLE (*Marginal mean* = .63, *SD* = .41) and the control group (*Marginal mean* = .95, *SD* = .07). Using the Bonferroni correction method, only the difference between BTLE and controls was significant (p = .004). However, the LTLE group showed evidence trending toward a significant difference with controls, also (p = .04). The finding that the BTLE group had the lowest level of Remember responses is surprising given this group showed no evidence of lower performance on any of the other measures reported above.

4.4.5 Experiment 4.1 Summary

The results from Experiment 4.1 provide consistent evidence that the recognition impairment seen in the TLE group is a direct result of an inability to use recollection in a comparable way to healthy controls. This was displayed through three complementary strands of analysis. In the exclusion condition - a behavioural measure of recollection – patients made more FPs to repeated items. At longer intervals, these FPs are expected to increase in all participants, as the longer time interval and additional intervening information being processed mean that more demands are put on recollection to retrieve the source of the recognised information and correctly reject the item. In line with predictions, TLE patients committed more of these errors, with the left temporal group performing worst. The second line of evidence came from the objective PDP estimates, which took into account performance in both conditions of the task. These data suggested that the TLE group, as a whole, used recollection significantly less than controls to complete the repeated item lag component of the experiment. Critically, there was a corresponding increase in familiarity estimates with longer lag intervals in both groups, suggesting that this process is intact and engaged in the task in the same way as healthy adults. The comparable performance on repeated inclusion items adds further support to this, as this part of the test is solvable by familiarity alone. The final supporting evidence came from the assessment of subjective experience ratings following recognition. For study items, the IRK measures displayed a clear reduction in subjective remembering in patients; for inclusion lag items, patients' responses mirrored those of the PDP estimates as recollection decreased and familiarity increased over intervals. Controls, on the other hand, consistently reported remembering these items. These group differences in subjective experience ratings were not however driven by significantly worse performance in the left temporal group, as was predicted.

The main finding presented in Experiment 4.1 then is that recollection impairments are detectable in this TLE patient group when using multiple measures within a single task. The inconsistent findings with regard to the left temporal group shed further light on the conditions under which this reduction in recollection is observable, and for which type of material. The left temporal group showed significantly impaired performance on exclusion FPs and a tendency to provide fewer Remember responses for recognised inclusion repeated items; they did not however, show worse overall recognition performance on study items or provide significantly fewer Remember responses for these items. These results are in line with those of the previous chapter, which suggest more of a *disorder* in recollection, rather than a complete *absence*. Interestingly, Moscovitch and McAndrews' (2002) classic study with this patient group suggested that patients with left or right TLE were unable to benefit from conceptually based encoding (in terms of increase in Remember responses) for verbal and visual material, respectively. Although a comparison was not made here between different encoding conditions, the fact that the LTLE group showed equivalent performance and subjective experience profile to the other subgroups for study items suggests that they may have benefited from the encoding manipulation. Repeated lag items, on the other hand, are presented quickly, and encoding of these is incidental in the sense that participants are not directed towards trying to remember new items. Taken together then, the results confirm

Yonelinas and Jacoby's (2012) position that the PDP may be a sensitive tool for the measurement of recollection impairments.

4.5 Experiment 4.2: Faces

The same task was conducted with participants using facial stimuli to explore the contribution of subjective and objective recollection further with alternative testing materials. To reiterate, the hypotheses for this task were identical to that of Experiment 4.1: significant reductions were predicted in all measures of recollection in patients, whilst familiarity was expected to be intact. A reduction in measures of recollection was expected to be more salient in the RTLE group however, due to the findings of similar neuropsychological research.

4.5.1 Participants

All participants described in Section 4.2.1 completed the task; participant 23's data was included also.

4.6 Method

4.6.1 Materials

The stimuli consisted of 100 black and white facial photographs of male and female faces drawn from Minear & Park (2004). All faces were frontal view, with neutral expressions and aged between 18 and 55 years of age. The original colour photos from this database were converted to greyscale and cropped to a resolution of 350 x 400 pixels. Photos of people wearing glasses, or unusually distinctive facial hair were not included. Distinguishable jewellery, predominantly ear rings, were removed using Corel Paint Shop Pro software (example of a face can be found in APPENDIX E). The photographs were split in the same way as items in Experiment 4.1, whereby two lists were created that were matched for number of males and females and had comparable numbers of black, white and Asian faces within them. Moreover, the six-item lag groupings were matched as far as possible in this way also.

4.6.2 Design and Procedure

The design was identical to Experiment 4.1, as was the procedure, with the exception that the delay between study and test was filled by the completion of basic numerical problems.

4.7 Results and Discussion

As the tasks were identical except for the type of stimuli, the results follow the same structure as Experiment 4.1. Comparisons between the two tasks will be addressed in the Discussion below, and in more detail in Chapter 7, where a correlational analysis of participants' scores across all tasks within this thesis is presented.

4.7.1 Recognition performance

The proportion of items that were assigned a Yes response in the face task are presented in Table 4.5. A 2 (group) x 2 (hit vs. FP 1st) x 2 (condition) repeated measures ANOVA was conducted with group as a between subjects factor. There was no effect of group or condition, $F(1, 40) = 1.49$, $p = .23$, $\eta_p^2 = .04$; $F(1, 40) = 1.22$, $p = .28$, $\eta_p^2 = .03$. Hits to old items were significantly higher than FPs to new items, as expected, $F(1, 40) = 306.80$, $p = .001$, $\eta_p^2 = .89$. Condition did not interact significantly with the other two variables (*F*s < 1.84, *p*s > .18), implying performance on study items was not influenced by the differing task instructions between conditions for lag items. The item type x group interaction was significant, $F(1, 40) = 17.58$, $p = .001$, $\eta_p^2 = .31$, such that overall recognition performance was better in controls.

This repeated measures analysis was conducted again in order to assess laterality. There was no effect of subgroup or condition (Fs < 1.21, *p*s > .32). An effect of item type was found as expected, $F(1, 38) = 175.49$, $p = .001$, $\eta_p^2 = .82$. The item type x subgroup interaction reached significance, $F(3, 38) = 6.17$, $p = .002$, $\eta_p^2 = .33$. Follow up one-way ANOVAs were conducted on the marginal means of the two conditions and no statistical difference was found between subgroups for FP rates to new items, $F(3, 41) = 1.15$, $p = .34$, $\eta^2 = .08$. An effect of hit rate was found, however, $F(3, 41) = 4.84$, $p = .006$, $\eta^2 = .28$. Bonferroni post-hocs were conducted and although the left and right patient groups showed evidence of statistically lower hit rates to controls (LTLE, $p = .03$; RTLE, $p = .02$), these values did not reach the $p < .01$ criteria for multiple comparisons. All other main effects and interactions were non-significant (*Fs* < 1.21, *p*s > .32).

In sum, analysis of subgroups in the face task suggests FPs to new items were not different to controls, but hit rates to study items were lowered in left and right sided patients, with BTLE performing the best.

Table 4.5 Mean (SD) probability of responding 'yes' to Old, New and repeated items at each lag interval in Experiment 4.2.

			Lag interval			
Test	Old	FP 1st	2	4	8	16
Inclusion						
Control	.68 (.18)	.14 (.09)	.78 (.16)	.92 (.16)	.92 (.14)	.93 (.16)
TLE	.51 (.20)	.21 (.14)	.65 (.15)	.88 (.16)	.83 (.18)	.86 (.19)
LTLE (*N* =12)	.53 (.18)	.21 (.14)	.64 (.16)	.82 (.18)	.82 (.18)	.79 (.23)
RTLE (*N* =7)	.51 (.17)	.21 (.10)	.65 (.06)	.93 (.13)	.83 (.19)	.90 (.09)
BTLE (*N* = 4)	.61 (.19)	.24 (.20)	.71 (.25)	.96 (.09)	.86 (.19)	1.00 (.00)
Exclusion						
Control	.62 (.16)	.15 (.12)	.09 (.17)	.22 (.23)	.26 (.28)	.26 (.24)
TLE	.50 (.15)	.21 (.13)	.16 (.14)	.30 (.22)	.26 (.16)	.38 (.23)
LTLE (*N* =12)	.49 (.15)	.19 (.10)	.17 (.16)	.35 (.25)	.29 (.19)	.38 (.19)
RTLE (*N* =7)	.45 (.14)	.21 (.15)	.14 (.11)	.26 (.19)	.24 (.09)	.45 (.30)
BTLE (*N* = 4)	.62 (.10)	.24 (.19)	.17 (.13)	.21 (.21)	.21 (.16)	.29 (.21)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy, FP 1st = false positives to first presentation of new items

4.7.2 Repeated lag item performance

Performance on repeated lag items in the inclusion condition was assessed via a 2 (group) x 4 (lag interval) repeated measures ANOVA with group as between subjects factor. Controls were found to have significantly better performance on these items compared to patients, $F(1, 40) = 5.80$, $p = .02$, $\eta_p^2 = .13$. A significant effect of lag was also found, $F(3, 120) = 16.52$, $p = .001$, $\eta_p^2 = .29$, with Bonferroni post-hocs displaying that performance on lag 2 was significantly different to all other lags ($p = .001$), whereas these did not differ from one another (*p*s > .46). No interaction was found between group and lag ($F < 1$). Therefore, as with the word version of the task, participants were less accurate in accepting the shortest interval repeated lag item as previously seen. The effect of group suggests that despite the ability to use familiarity alone to solve this part of the task, patients had difficulty in recognising faces they had recently seen.

Another ANOVA was performed to assess laterality on these data. The effect of lag remained, and an effect of subgroup was also found, $F(3, 114) = 16.00$, $p = .001$, $\eta_p^2 = .30$; $F(1, 38) = 3.24$, $p = .03$, $\eta_p^2 = .20$. Bonferroni post-hoc comparison revealed unexpectedly that only the LTLE group differed significantly from controls ($p = .005$).

The same 2 (group) x 4 (lag interval) repeated measure ANOVA was conducted on the proportion of FPs to exclusion lag items. No difference was found between groups in overall FP rates to these items, $F(1, 40) = 2.14$, $p = .15$, $\eta_p^2 = .05$. The lag effect was again significant, $F(3, 120) = 10.00$, $p = .001$, $\eta_p^2 = .20$, with the reverse pattern of the above analysis, as this time lag 2 repeated items had significantly lower FP rates compared to all other items (ps < .001), which did not differ from each other. Combined with the results above, this is indicative of a highly conservative response bias at the shortest lag. Group and lag did not interact with each other ($F < 1$). Analysis of laterality did not reveal an effect of subgroup or interaction with lag (Fs < 1).Taken together then, these results show that whereas controls are more accurate in their recognition of repeated faces in the inclusion task, both groups made a similar amount of FPs in the exclusion task. As this component of the experiment is heavily reliant on recollection, the lack of difference between groups is interesting and suggests controls found the task challenging. Below we present a formal analysis of the contribution of objective and subjective recollection to performance.

4.7.3 Objective process estimations

Objective estimates of the contribution of recollection and familiarity to performance on the face task were computed in the same way as Experiment 4.1. These data are presented in Table 4.6. A 2 (group) x 2 (process) x 4 (lag interval) repeated measures ANOVA was carried out with group as a between subjects factor. The lag effect and lag x process interaction were statistically reliable, $F(3, 120) = 18.14$, $p = .001$, $\eta_p^2 = .31$; $F(3, 120) = 15.17$, $p = .001$, $\eta_p^2 = .28$, with all other main effects and interactions failing to reach significance (Fs < 3.44, ps > .08). Therefore, these process estimations are supportive of the exclusion FP data in that TLE patients did not show evidence of reduced recollection. The effect of lag and interaction with process can be explained by the relatively consistent recollection scores across intervals, whilst familiarity was significantly lower in lag 2 compared to longer lags. Theoretically, this makes sense, as items that have just been viewed will presumably have much more chance of being recollected, with familiarity contributing less to the recognition process.

Laterality subgroup analysis on the data provided the same pattern of results as above, but the subgroup effect reached significance, $F(1, 38) = 2.99$, $p = .04$, $\eta_p^2 = .19$. Bonferroni post-hoc did not display any significant differences between groups, although notably, the LTLE group showed the lowest overall combined recollection and familiarity estimates, with $p = .05$.

Table 4.6 Mean (SD) recollection and familiarity process estimations from performance on inclusion and exclusion lag items in Experiment 4.2.

	Recollection				*Familiarity*			
	Lag 2	Lag 4	Lag 8	Lag 16	Lag 2	Lag 4	Lag 8	Lag 16
Control	.68 (.24)	.68 (.30)	.64 (.28)	.65 (.25)	.27 (.24)	.67 (.24)	.63 (.33)	.73 (.29)
TLE	.49 (.18)	.56 (.28)	.56 (.27)	.47 (.23)	.30 (.20)	.70 (.31)	.64 (.25)	.72 (.29)
LTLE (*N*=12)	.47 (.18)	.46 (.28)	.52 (.31)	.41 (.19)	.30 (.22)	.60 (.33)	.64 (.26)	.68 (.30)
RTLE (*N*=7)	.49 (.13)	.65 (.28)	.59 (.21)	.44 (.25)	.27 (.16)	.84 (.15)	.64 (.30)	.71 (.32)
BTLE (*N*=4)	.54 (.28)	.73 (.17)	.64 (.31)	.69 (.20)	.37 (.26)	.71 (.40)	.63 (.20)	.84 (.22)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

4.7.4 Subjective experience

Data for IRK estimates of the contribution of subjective recollection and familiarity to old items are presented in Table 4.7.[9] Individual 2 (group) x 2 (condition) repeated measures ANOVAs were carried out on all four estimates. A significant effect of group was found for R hit-FP, $F(1, 40) = 6.68$, $p = .01$, $\eta_p^2 = .14$ but no effect of condition, or interaction between condition and group was found, $F(1, 40) = 1.93$, $p = .17$, $\eta_p^2 = .05$; $F(1, 40) = 0.01$, $p = .93$, $\eta_p^2 = .001$. For R IRK estimates, a significant effect of group was again revealed, $F(1, 40) = 4.75$, $p = .04$, $\eta_p^2 = .11$. In both estimations, controls provided significantly more Remember responses than patients. In

[9] As with the word task, there were instances where participants' IRK recollection estimates were extremely negative, skewing the initial results. Therefore, the scores represent the mean after removal of one control participant's inclusion R IRK estimate and two separate patient's R IRK scores for inclusion and exclusion conditions, respectively. As before, these scores were substituted with the group mean in ANOVA analyses in order to maximise the *N* in these calculations.

this analysis however, R IRK estimates were found to be significantly higher across all participants in the inclusion condition, $F(1, 40) = 4.40$, $p = .04$, $\eta_p^2 = .10$. There was no interaction between condition and group, however ($F < 1$).[10]

For the F IRK estimate, there was a trend for controls to have higher scores, but this did not reach significance, $F(1, 40) = 3.57$, $p = .07$, $\eta_p^2 = .08$. There was no effect of condition or interaction between group and condition (*F*s < 1). The results for the corrected Familiar score were similar, except the group effect was now significant, $F(1, 40) = 5.29$, $p = .03$, $\eta_p^2 = .12$. This measure takes into account base rate FPs to new items, which as presented in 4.7, were numerically higher in patients.

In the laterality analysis, the effect of subgroup for R hit-FPs approached significance, $F(1, 38) = 2.64$, $p = .06$, $\eta_p^2 = .17$. Post-hocs were carried out to explore this and the LTLE group was found to have the lowest value compared to controls, at $p = .02$. No other effect or interaction was found ($F < 1$). For the R IRK, F IRK and F corrected measures, no effects or interactions were found (*Fs* < 2.21, *p*s > .10).

In summary, the subjective experience data for study items presents a mixed picture. Recollection estimates were reliably lower in TLE patients, but familiarity estimates also displayed evidence of a reduction. Differences in task difficulty likely explain the disparity in results between them. For example, the average hit rate was considerably higher in the word task (TLE *Mean* =.79, *SD* =.16; Control *Mean* = .84, *SD* = .17) as compared to the face task (TLE *Mean* =.52, *SD* =.17; Control *Mean* = .65, *SD* = .13). The finding that the R IRK estimate was increased in the inclusion test despite any difference in performance between conditions, or reliable effect of test order, is difficult to reconcile. One potential explanation of this could be to do with participants' response bias and interpretation of the contextual information they retrieve in recognition. In this condition, participants are making many more 'Yes' responses, which can be based on recollection or familiarity. Faces, unlike words, are complex arrays of features which may have a high degree of overlap. Therefore, participants in the inclusion condition may initially recognise a study item based on familiarity, but similarity in features with items just presented may lead to a feeling of recollection, subsequently followed by a Remember response. In the exclusion condition, where participants know they must truly recollect the source of the item, this interaction between familiarity for features is presumably

[10] Because this result may have been due to testing order, another repeated measures ANOVA was conducted on the IRK scores with a 2 (condition) x 2 (group) x 2 (test order) structure, with group and test order as between subjects factors. Although R IRK estimates in the inclusion condition were numerically higher in both groups who completed this first, there were no significant effects or interactions with test order.

relied upon less. Although this is just a hypothesis, if it were true it would be interesting as it provides further suggestion that despite lower levels of subjective remembering in TLE, the cognitive processes driving this phenomenological experience act in a similar way to healthy adults.

Table 4.7 Mean (SD) independence Remember-Know estimates of recollection and familiarity associated with old and new responses in Experiment 4.2.

Test	R Hit-FP	R IRK	F IRK	F Corrected
Inclusion				
Control	.42 (.37)	.53 (.28)	.76 (.26)	.62 (.30)
TLE	.23 (.30)	.28 (.36)	.67 (.25)	.45 (.29)
LTLE (*N* = 12)	.21 (.37)	.28 (.44)	.64 (.34)	.44 (.33)
RTLE (*N* = 7)	.23 (.24)	.25 (.28)	.72 (.20)	.51 (.25)
BTLE (*N* = 4)	.28 (.18)	.32 (.15)	.54 (.20)	.30 (.34)
Exclusion				
Control	.34 (.26)	.36 (.33)	.79 (.19)	.64 (.28)
TLE	.16 (.28)	.21 (.40)	.68 (.22)	.47 (.30)
LTLE (*N* = 12)	.10 (.31)	.22 (.45)	.56 (.27)	.37 (.29)
RTLE (*N* = 7)	.14 (.23)	.10 (.37)	.77 (.28)	.56 (.35)
BTLE (*N* = 4)	.35 (.22)	.38 (.19)	.79 (.19)	.64 (.28)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy, R = remember, FP = false positive, IRK = independence remember-know, F = familiarity.

The objective scoring methods have suggested that the TLE group utilise recollection in a comparable way to controls in this task. Above, there was some evidence of reduced levels of subjective remembering for old study items in patients. The final analysis, as with Experiment 4.1, looked at the subjective experience associated with recognition of repeated lag items in the inclusion task (see Table 4.8). A 2 (group) x 2 (subjective experience) x 4 (lag interval) repeated measures ANOVA was conducted on the data. A significant group effect was found, $F(1, 40) = 7.20$, $p = .01$, $\eta_p^2 = .15$, resulting from the fact that patients made more guess responses across lags (*Mean* = .03, *SD* = .01) compared to controls, who made a negligible amount of these judgments (*Mean* < .01). Remember responses were significantly more likely than familiar responses, $F(1, 40) = 54.57$, $p = .001$, $\eta_p^2 = .58$ and as with the other analyses for the face task, there was no evidence of a statistically reliable pattern over lag intervals, as no effect of lag was observed ($F < 1$). A reliable subjective experience x group interaction was found, $F(1, 40) = 6.59$, $p = .01$, $\eta_p^2 = .14$, providing supporting evidence to the IRK analysis that patients' recognition of faces was accompanied by significantly lower levels of subjective remembering than controls. No other interactions from this analysis reached significance (*F*s < 1).

A repeated measures ANOVA assessing laterality found a significant effect of subgroup, $F(1, 38) = 3.63$, $p = .02$, $\eta_p^2 = .22$. Bonferroni post-hoc comparisons found no significant differences between groups (*p*s > .09), suggesting all subgroups made comparable levels of guess responses. The large effect of subjective experience remained, $F(1, 38) = 25.50$, $p = .001$, $\eta_p^2 = .40$, but the interaction with group was no longer significant, $F(3, 38) = 2.11$, $p = .12$, $\eta_p^2 = .14$. The fact that LTLE had the lowest Remember score for one of the IRK measures for study items, and no difference found here, most likely reflects the increased difficulty with recollecting faces that were encoded before the delay in the experiment.

Table 4.8 Mean (SD) proportion of subjective Remember and Familiar judgments assigned to repeated inclusion lag items at each interval in Experiment 4.2.

	Remember				*Familiar*			
	Lag 2	Lag 4	Lag 8	Lag 16	Lag 2	Lag 4	Lag 8	Lag 16
Control	.87 (.24)	.84 (.25)	.82 (.25)	.86 (.20)	.13 (.24)	.16 (.25)	.17 (.25)	.14 (.20)
TLE	.66 (.32)	.60 (.31)	.67 (.31)	.70 (.26)	.32 (.28)	.36 (.28)	.31 (.31)	.28 (.25)
LTLE (*N*=12)	.68 (.35)	.62 (.30)	.64 (.31)	.68 (.29)	.30 (.31)	.36 (.29)	.33 (.32)	.31 (.29)
RTLE (*N*=7)	.60 (.28)	.68 (.30)	.68 (.39)	.72 (.28)	.37 (.24)	.27 (.27)	.29 (.38)	.25 (.22)
BTLE (*N*=4)	.71 (.34)	.39 (.34)	.71 (.21)	.71 (.16)	.29 (.34)	.52 (.23)	.29 (.20)	.21 (.16)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

4.7.5 Experiment 4.2. Summary

The results from the face task are much more varied than the word version of the experiment, and overall, provide an interesting insight into how recollection and familiarity processes may be utilised in different ways depending on the difficulty of a task and the materials being tested on. For the behavioural measures, neither hypothesis relating to performance on inclusion and exclusion repeated items were supported: Controls performed significantly better on inclusion items and no difference was found for exclusion FPs. Moreover, the left, not right, temporal group performed the worst on inclusion items, but objective PDP estimates revealed equivalence between all groups. The results of the lag component to the task are thus difficult to reconcile. The significant reduction in Remember responses along with lower performance to inclusion items in the patient group suggests that in this variation of the task, recollection was required to a greater extent simply to distinguish new faces from any previously seen item. Whereas Jennings and Jacoby's (1997) original formulation of how different patterns of processing are necessary to complete each condition may hold true for the verbal material, it would appear that in a task where there is a great degree of similarity or overlap in contextual features of items, successful inclusion performance relies more heavily on effortful, controlled retrieval. It is still unclear why the left temporal group performed the worst on these items, but did not show a corresponding impairment in Remember responses. Further, it is unclear why a recollection impairment would manifest in inclusion items, but performance would be equivalent between patients and controls on repeated exclusion items, which can only be rejected if one recollects the source of prior occurrence. However, these errors were numerically higher overall in the TLE group, and the standard deviations were quite large, so perhaps with a larger sample size and less heterogeneous neuropsychological profile in the patient group, significant differences would be found on this measure. This variation in performance is also likely to be the reason that no difference was found in objective PDP estimates. Moreover, the overall difficulty of the task may account for the fact that the expected increase in FPs and familiarity judgments/estimations for longer lag intervals were not found.

Some concrete evidence for reduced recollection in the TLE group was borne out of the subjective experience process estimations for study items, however. Again, rather unexpectedly, the LTLE group displayed the lowest score on one of these measures. One suggestion for this is that the LTLE subgroup in this sample have poorer overall memory capacity in general than the smaller group of right temporal patients. In support of this, the LTLE group's neuropsychological profile (as described in Chapter 2) did suggest these patients had more pervasive memory impairments, and even displayed significant impairments in one non-verbal measure (figure recall). Although the RTLE group showed the worst performance on the face version of the WRMT, the lack of lateralised impairment seen in the current experiment may be due to the fact the task requires the recruitment of additional brain structures not damaged by TLE. Nevertheless, different findings may have emerged If the number of these patients was increased, and careful matching was ensured between pre- and post-operative subjects.

For study items, there was also some evidence to suggest that patients had decreases in familiarity also. Although the hippocampus is primarily the site of pathology in MTL epilepsy, atrophy has been evidenced in surrounding rhinal and parahippocampal cortices in this patient group (e.g. Bernasconi, 2003) and resection of these extra-hippocampal areas has been associated with selective impairments in familiarity based processing (Bowles *et al*., 2007). Given that this task comprises recognition of multiple complex, unfamiliar facial stimuli, it is entirely possible that even subtle damage to these areas has caused this reduction in subjective familiarity. As mentioned earlier, there was no reduction found in PDP estimates of familiarity – however, the IRK estimates are based on responses to the items that were studied, and then recognised after a delay with increasing amounts of interfering information, whereas PDP estimates are based on performance of inclusion and exclusion items within the test phase. Therefore, if there were only a very subtle impairment in familiarity, one might predict that the IRK measure would highlight this as the subjective experience is based on an increasingly degraded memory trace.

Although the results here are rather mixed and did not support all predictions, they still contribute to the overall aim of this chapter in its pursuit of comparing subjective and objective measures of recollection. For study items at least, the lower performance in the patient group is characterised by a consistent recollection deficit, as well as evidence of a reduction in familiarity. This difference in phenomenology was also apparent for repeated inclusion items; therefore, whenever patients were asked about their subjective experience, they consistently reported lower levels of remembering. Although this result did not necessarily correspond to the recollective behavioural measure and PDP estimates, it suggests that even in the face of subtle memory impairment, patients are aware of, and consciously experience this alteration in underlying cognitive processing.

4.8 Discussion

The present study set out with two broad aims. The first objective was to deploy an inclusion/exclusion paradigm that had not been previously conducted in TLE, to provide further evidence that the PDP is a viable means of detecting potentially subtle forms of memory impairment in this group. By incorporating the R/K procedure into this paradigm, a comparison of objective process estimates and subjective experience was possible. Second, based on the finding in the previous chapter that the subgroup of LTLE patients in the sample displayed evidence of a material specific impairment, I wanted to expand my range of testing materials and complete another task that measured recollection with visual stimuli. This, it was hoped, would shed further light on any laterality differences between the groups. The findings related to these are outlined below, with some final concluding remarks relating to the more clinical aspects of the present study.

The results of Experiment 4.1 are supportive of the four previous TLE papers that have used inclusion and exclusion tasks to highlight recollection deficits in this patient group (Cohn *et al*., 2009; Del Vecchio *et al*., 2004; Hudson *et al*., 2009; Martin *et al*., 2012). Similar to these verbal tasks, the repetition lag procedure devised by Jennings and Jacoby (1997) was used here and displayed that TLE patients are more likely to use familiarity processing as a basis for responding. As well as confirming that this clinical sample had difficulty in drawing on recollection to complete the lag component of the task, it was displayed that their subjective experience for both study and test items were reflective of this. There was also evidence suggesting the LTLE group had worse performance on the behavioural measure of recollection, and correspondingly reduced subjective remembering. This finding is in line with the material specific impairments found by Hudson et al. (2009) in their PDP task, and as discussed earlier, provides some support for Moscovitch and McAndrews' (2002) study that used the R/K paradigm in this patient group.

Whereas the previous chapter was concerned with the assessment of the contextual detail available to participants during subjective remembering, the present study had more of a focus on participants' awareness of the two competing processes that operate during this complex task. Experiment 4.1 suggests that the R/K paradigm is a useful way of accurately measuring participant's conscious access to their cognitive operations; the correspondence between experiential states and strategic regulation in both groups implies that TLE patients are metacognitively aware of their reliance on familiarity during recognition of this verbal material. This can therefore be taken as indirect evidence to support previous work outlined in Section 1.11.3 that has displayed intact metacognitive processing in TLE.

Although the present results are useful theoretically, there are several important clinical considerations also. The opposition procedure adopted here was originally used to display age related differences in the contribution of these two processes; later, Jennings, Webster, Klaykamp, & Dagenbach (2005) drew on these findings and hypothesised that it may be possible to specifically target recollection in a training paradigm that encourages participants to use this process. By gradually increasing the lag intervals in this task, they showed that older adults were increasingly able to draw on recollection to reject repeated items. Moreover, these benefits in recollection *transferred* to other memory tasks. As covered in Section 1.5.1, verbal memory decline is the hallmark of dominant LTLE, and post-operative function is often reduced further following temporal lobectomy in this group (Alpherts *et al*., 2006; Baxendale, Thompson, Harkness, & Duncan, 2006). Some attempts at cognitive rehabilitation following surgery have provided promising results in terms of a reduction in the manifestation of verbal memory decline (Helmstaedter *et al*., 2008) but the field of memory rehabilitation is still lacking in good empirical research. Therefore, there is potential value in attempting to target recollective processes, which are known to be reduced in TLE. The finding that subjective experience judgments follow the same pattern as the objective measures in this task suggests that the R/K paradigm may have good use in any clinical application of this procedure also.

In terms of the diagnostic uses of this type of task, it has been shown by Tse et al. (2010) that exclusion errors provided greater predictive power than psychometric tests in distinguishing early stage Alzheimer's disease from healthy aging. Further, as Yonelinas and Jacoby (2012) state in their PDP review, "Further experiments done to examine the utility for diagnosis of specifying qualitative differences in the bases for responding would be useful" (p. 674). Although the aim here was not to develop a task that was intended for diagnosis of memory impairment, the results certainly address these authors' point as they go to show that there are measurable qualitative differences in the experiential state associated with these bases for responding. This appears more obvious for word stimuli, however. The relationship between standardised neuropsychological test performance and the various measures of recollection collected within the tasks in this thesis are discussed in Chapter 7.

The reasons for not finding such consistent effects in Experiment 4.2 were touched upon above, but there are further explanations for the lack of laterality effect in RTLE, and the poor performance in LTLE. Although the neuroscience literature has been able to quite consistently display that the right temporal lobe is preferentially responsible for face processing (e.g. Kelley *et al.*, 1998; Coleshill *et al*.,2004), the neuropsychological literature has been more mixed, with a number of studies failing to find significant differences between left and right TLE groups on face memory tasks (Carvajal, Rubio, Martín, Serrano, & García-Sola, 2009; Glogau, Ellgring, Elger, & Helmstaedter, 2004; Testa, Schefft, Privatera, & Yeh, 2004). Like the present study, Glogau et al. (2004) found similarly unexpected results, with their LTLE group performing worse than RTLE on one of their measures. These authors included a measure of facial expression perception, and concluded that a deficit at the perception level most likely hindered the left temporal groups' initial encoding and storage. Although there was not a uniform impairment found in the current left temporal group, the above account at least offers one possible explanation for the results. An alternative position is that the *occasional* poorer performance in the left temporal group is a result of functional reorganisation of the contralateral epileptic hemisphere; studies have shown that verbal memory can be preferentially 'saved' over more typical right hemispheric functions (Ogden, 1989; Strauss, Satz, & Wada, 1990).

Other factors that may influence face memory performance are the presence of right hemispheric language dominance in the LTLE patients (Helmstaedter *et al*., 1994) and the presence or absence of hippocampal sclerosis in both right and left temporal groups (Bengner *et al*., 2006). Testing these explanations is much beyond the scope of this thesis, and it seems best to accept that on this occasion, with this task, predictions were not met. Because of the complexity of facial stimuli and the cited inconsistencies within the literature, the design employed in the present study may not be the most useful in assessing this form of memory in TLE. Nevertheless, there was some evidence of reduced recollection in the patient group, which still lies central to the overriding objective of this thesis.

In conclusion, the present study has provided evidence of both theoretical and neuropsychological value. The R/K paradigm was found to be sensitive in highlighting impairments in objective recollection found using a repetition-lag opposition procedure in TLE. Patients' experiential state therefore paralleled the underlying cognitive processing carried out during the task, for word stimuli at least. The results of Experiment 4.2 did not support hypotheses relating to laterality, but raised similar questions to other studies in the literature regarding the strict separation of left and right temporal lobe functions. Still, good evidence was found suggesting general recognition impairments were accompanied by the expected corresponding states of awareness. This theme is explored further in the following chapter.

5 Associative memory and subjective confidence

5.1 Introduction

In the previous two chapters, the relative contribution of subjectively experienced and objectively measured recollection and familiarity to single item recognition has been examined in TLE. The aim of the current chapter was to extend this in two ways. First, although the contextual source memory task presented in Chapter 2 touched on the importance of the medial temporal lobes' importance for the binding and integrating of information, this kind of measurement is constrained by participants' willingness to use the additional contextual information during encoding. In other words, in a person with memory impairment, the task load may affect the extent to which they strategically encode source information, such as the colour or location of an item. Another more commonly employed method of assessing relational forms of memory is through the use of associative recognition paradigms, as described in Section 1.9.2.1.

Whereas the previous chapters incorporated the R/K procedure to make a metacognitive evaluation based on subjective experience, this procedure does not directly assess the perceived veracity, or confidence associated with a recognition response. As noted in the main Introduction, the difference between dual-process accounts of recognition memory and single trace theories is that the latter assume recognition arises from a single memory process, with remembering and knowing (or familiarity) arising due to differing levels of memory strength along a continuum (e.g. Donaldson, 1996). It is not the aim of this chapter to attempt to resolve any broader theoretical issues regarding the validity of either account; as discussed, I specifically take a dual-process approach in this thesis. However, confidence in recognition memory can also be examined outside of the complexities of this long-standing debate and contextualised within a metacognitive framework. Therefore, given the expected impairments in the TLE sample presented in this thesis, the primary aim of the current experiment was to assess *monitoring*, or awareness of memory through subjective confidence judgments. This was achieved by using the associative recognition developed by Cohn et al. (2007, 2008, 2009). By integrating a more typical metacognitive measure such as confidence ratings within a task able to delineate recollection and familiarity processes, I hoped to provide a novel theoretical contribution to the TLE literature. A secondary aim was to replicate the results provided by Cohn et al. (2009) in their study with TLE patients. Below I present a summary of the relevant research before moving onto specific hypotheses and the experiment

As covered in Section 1.8.5.1, a number of recent dual-process models use a comparison of evidence from single item and associative memory studies in their conceptualisation of the role of the MTL in the integration of different sources of information. Along these lines, Cohn and Moscovitch (2007) and Cohn et al. (2008) compared single item recognition with different types of associative memory in an effort to delineate the extent to which performance relied on processes occurring during binding at encoding or strategic retrieval. Associative identification, which is the typical measure assessed in similar studies, reflects a participant's discrimination ability in rejecting rearranged study words in a pair and endorsing intact studied pairs; familiarity with the two previously studied items will not offer enough information to differentiate intact from rearranged pairs. To do this, mental time travel is needed, which permits retrieval of the association between items. In this sense, the use of recollection to overcome familiar items to retrieve specifics from encoding parallels the processes needed in resolving targets from repeating foils in the Experiment presented in Chapter 3. Conversely, associative reinstatement is measured in a separate *pair recognition test* that simply requires an 'old' response to any combination of old studied items (therefore, familiarity is sufficient to correctly accept any pair). The reinstatement measure is expressed as the *increase* in performance associated with recognition of intact pairs, as compared to rearranged pairs. It therefore provides a measure of binding ability. Item memory is also calculated from this task using hits and base rate FPs. As discussed in the Method section below, recollection and familiarity estimates can be computed by using recognition scores from both tasks in a variant of the PDP.

Cohn et al's first paper displayed that associative identification and associative reinstatement are dissociable from item memory and also from one another, and suggested that whereas associative identification relies heavily on recollection based strategic recall-to-reject processes, associative reinstatement is characterised more by associative familiarity (Cohn & Moscovitch, 2007). Their second paper demonstrated that older adults were impaired on associative identification and recall-to-reject measures, but not on associative reinstatement. Thus, associative memory impairments in this population were described as arising from retrieval processes where recollection was necessary, and not due to problems in initial associative binding (Cohn *et al*., 2008). Pertinent to the current experiment however, is the third paper using this task with a group of post-operative temporal lobectomy patients (Cohn *et al*., 2009). In this paper, the authors found pervasive impairments in all associative measures, and found item familiarity to be deficient in their dominant TLE group, providing evidence of a material specific impairment in this verbal material. The main conclusion drawn from these findings was that the impairment in associative reinstatement provides evidence that the MTL is bilaterally involved in the relational binding of information, whereas recognition that does not involve relational binding involves unilateral MTL areas. Moreover, associative identification, which is dependent on strategic retrieval operations, relies not just on the MTL, but a network also involving the prefrontal cortex. These data were obtained with a group of patients who had undergone almost complete resection of the MTL, thus adding to this literature which has already examined healthy adults, amnesic individuals and older adults. One of the aims of the present experiment was therefore to examine these relational and item memory measures in a more presumably representative sample of TLE patients. As discussed below, this was achieved by using an almost identical task to that of Cohn et al. (2009).

The main motivation for the present experiment was to provide a novel contribution to the TLE literature by assessing metacognitive monitoring of recognition memory in this patient group. As covered in Section 1.11.3, the handful of recent studies that have assessed metacognition in a laboratory setting in TLE have found no evidence for impairments in experimental tasks (Andres *et al*., 2010; Howard *et al*., 2010). Moreover, these studies found intact monitoring and control in patients despite clear evidence of impaired verbal episodic recall and recognition memory. Hence, although patients had poor memory, they were aware of this, and appropriately updated memory predictions. However, the two studies by Andres et al. (2010) and Howard et al. (2010) used only JOL and FOK ratings for short single item word lists. Subjective confidence has not been assessed as a metacognitive measure in TLE. Although previous evidence thus far suggests that TLE patients have marked memory impairments but intact metacognitive accuracy, it would be useful to assess confidence in the context of a more demanding relational memory paradigm that requires monitoring the output of a number of cognitive processes.

More precisely, the main interest here was to compare recognition confidence between item types that relied more, or less, on recollection and familiarity. For example, correct recognition of intact pairs in pair and associative identification tasks is reliant on the contribution of recollection *and* familiarity, whilst in the associative identification task, correct responses to rearranged items require the more strategic recall-to-reject recollective like process, whereas familiarity alone is sufficient for correct recognition of these in the pair task. I was interested to explore this from a metacognitive perspective; perhaps errors are made on this pair type because the increased familiarity for two previously studied items leads to a corresponding increase in subjective confidence, which the participant then acts on and subsequently makes an incorrect response. If this were true, we might expect people with TLE to have higher confidence judgments than controls for errors to rearranged pairs in an associative identification task. Although this pair type seemed critical to test a metacognitive account, a more general interest was in patients' *sensitivity* to task demands and how *accurate* their confidence was; i.e. whether their confidence would show a normal pattern whereby incorrect responses are assigned lower confidence than correct responses.

5.2 Method

5.2.1 Participants

Patients 7 and 27 did not complete the experiment. All other patients described in Chapter 2 participated but data for patient 12 was removed due to a system failure during testing. Additionally, data was also removed for one control participant as close inspection of his data revealed a lack of understanding of task instructions – this was evident as he consistently made false alarms to rearranged pairs in the associative identification task but his base rate level of false alarms to new items was comparable to the group average. Thus, data below are presented for 23 TLE patients and 18 healthy controls.

5.2.2 Materials

The experiment was based on the procedure used by Cohn et al. (2009). Two lists of 96 word pairs were created; one using 7 letter nouns, the other 6 letter nouns. These were then divided into 16 lists of 12 semantically unrelated word pairs, with the 7 letter words always forming the cue of the pair. Word frequency was obtained by using SUBTlex (Brysbaert & New, 2009) and imageability values were obtained from the MRC psycholinguistic database (Coltheart, 1981*b*). Cue frequency did not differ significantly between lists $F(15,165) = .04$, $p = 1.00$; nor did target frequency, $F(15,165) = .08$, $p = .994$. Frequency values ranged from 0.22 – 240.94 words per million, with a mean value of 26.26 for cue words ($SD = 44.34$) and 27.06 ($SD = 35.14$) for targets. Cue imageability was also matched well across lists, $F(15,165) = 1.48$, $p =$

.19, as was target imageability, *F*(15,165) = 1.34, *p* = .25. Imageability values ranged from 258-639, with a mean value of 489.32 (*SD* = 91.18) for cue words and 510.96 (*SD* = 90.33) for targets. A paired samples t-test found this difference to be significant, *t*(191) = 2.27, *p* = .03, hence targets were more imageable than cues.

The lists were rotated to create 8 versions of the experiment which were counterbalanced across participants, as were the two different test types (pair and associative recognition task, explained below). Participants studied 120 word pairs (10 lists), as well as three buffer pairs at the beginning and end of presentation. At test they viewed four different types of word pairs: 24 were *intact* pairs, consisting of the old studied pairs; 24 were *rearranged* pairs, consisting of studied pairs rearranged to form new pairs with cues always being a 7 letter word and targets 6 letters; 24 were *half-old* pairs, consisting of the cue from 12 old studied pairs being joined with 12 new targets and 12 old studied targets being paired with 12 new cues; the final 24 pairs were *new pairs*, consisting of completely new cue-target pairings. Therefore, participants viewed 96 critical test pairs, which were presented in a randomised order. E-prime software was used for stimuli presentation and data collection. Table 5.1 provides examples of study items and the different pairings described above.

Table 5.1 Example of stimuli presentation/construction in the associative recognition tasks.

	Cue	Target
Study pair 1	Holiday	Flower
Study pair 2	Fortune	Record
Test		
Intact	Holiday	Flower
Rearranged	Fortune	Flower
Half-old	Holiday	Saucer
New	Mineral	Letter

5.2.3 Procedure

During the study phase, participants were instructed that they were about to be presented with a large number of word pairs, and will be given 5 seconds to study each one, before having to generate a sentence using the two words. They were instructed that there were two rules they should try and follow when creating each sentence. Firstly, they must always use the two words in the order that they appeared; second, they should try their best to use the word in the form it appeared in. The experimenter explained that for example, if one of the words was 'bank', they should avoid using words such as 'banked' or 'banking'. However, participants were told that if they could only think of a sentence using an alternative ending then they should still provide this as an answer as the aim of the sentence generation was to aid encoding. In this respect, the study procedure was slightly different to that used by Cohn et al. (2009), who required the maintenance of the singular form of each word at all times. Each participant completed two practice sentences and the experimenter clarified understanding of the procedure. Participants then viewed the word pairs at a rate of one every 5 seconds, with a fixation cross appearing subsequently. Participants were free to generate a sentence whilst words were onscreen if they wished. Whilst the fixation was onscreen, the experimenter keyed a response to indicate whether the participant successfully generated a sentence. If a reasonable delay had elapsed indicating difficulty with the sentence, or if the participant stated they could not make a sentence, a key was pressed to move onto the next pair. One-way ANOVA revealed that the mean proportion of pairs successfully formed into sentences did not differ between patients (M = .79, SD = 0.17) and controls (M = .80, SD = 0.15); F (1, 40) = 0.09, p = .76. The average length of the study phase trended toward significance between patients (M = 25.13 minutes, SD = 7.80) and controls (M = 21.00 minutes, SD = 5.51); F (1, 40) = 3.62, p = .06. In Cohn et al.'s (2009) original article, there were clear significant differences in encoding time between patients and controls; therefore, whilst it is acknowledged that on average there was more of a delay between patients initial encoding and test, this was generally better matched in the present study.

The test phase followed immediately after encoding and participants were instructed that they were about to be tested for the word pairs in two different ways. Thus, each participant was given the pair and associative recognition tests in counterbalanced order. Examples of both tests were explained using the practice items from the study phase. In the pair recognition task, they were told that they were to respond 'yes' to pairs of words that contained any two study items (old and rearranged pairs), regardless of whether they were paired together originally. Alternatively, they were told to respond 'no' whenever a pair was comprised of at least one new word (new and half-old pairs). In the associative identification test, participants were told to only respond 'yes' when the two words on screen formed the original studied pairing (old pairs) and respond 'no' to any other pair (half-old, rearranged and new pairs)[11]. Yes/No responses were recorded using the 'v' and 'm' keys, with the participant choosing the most comfortable way of depressing these. The keys were counterbalanced across participants, however. The novel addition to this paradigm was to ask participants how confident they were in their given answer. Therefore, during the instructions, participants were told that following their Yes/No decision, a screen would appear asking them "How confident are you that your answer is correct?" Confidence responses were on a five point scale of 0, 20, 40, 60, 80 and 100%. Keys d-k were used for these responses, with d always being 0% and k always 100%.

5.3 Results

The results for the recognition measures derived from each task are presented first, followed by an assessment of the confidence judgments assigned to each item type. As discussed earlier, the main focus was to assess overall group differences between the TLE and control groups; therefore, analyses of the laterality subgroups are presented at the end of each section. Alpha was set at $p < .05$ two-tailed unless otherwise stated.

5.3.1 Objective memory performance

The proportion of "old" responses to the four pair types (new, half-old, rearranged and intact) for the pair and associative identification tasks are presented in Table 5.2. In the pair task, "old" responses to rearranged pairs represent hits; in the associative identification task they represent FPs. These scores were used to calculate *d*' values, correcting FPs of 0 to 0.02 and hit rates of 1 to 0.98. Item memory was calculated using hits to rearranged pairs and FPs to new pairs in the pair recognition task; associative reinstatement was calculated for the pair task by

[11] As discussed in Section 1.7.3.1, PDP estimations are confounded when participants fail to respond as instructed under different test conditions. There were some occasions where participants did not initially understand the instructions and in these cases, the experimenter repeatedly went through them until satisfied they understood. Additionally, the experimenter asked participants to justify why they had made recognition decisions for the first few items of each test to be fully sure this was the case. A qualitative look over all the data revealed that, as mentioned in Section 5.1.1, only one control clearly appeared to have misunderstood.

subtracting the item memory *d*'-score from the *d*'-score derived from the proportion of old responses to intact and new pairs; associative identification was calculated using hits to intact pairs and FPs to rearranged pairs in the associative identification task. Estimates of recollection and familiarity were computed following Cohn et al. (2009), using a variant of the PDP (Jacoby, 1991; Yonelinas *et al*., 1995).

Table 5.2 Mean (SD) Proportion of 'Old' responses to each Item type in pair and associative identification tasks.

	Pair recognition task				Associative recognition task			
Group	New	Half-Old	Rearranged	Intact	New	Half-Old	Rearranged	Intact
Control	.07(.09)	.23(.15)	.60(.20)	.82(.18)	.01(.02)	.06(.10)	.14(.12)	.76(.19)
TLE	.15(.17)	.39(.19)	.59(.19)	.75(.21)	.10(.20)	.16(.21)	.30(.22)	.72(.20)
LTLE	.19(.23)	.43(.19)	.57(.19)	.73(.25)	.17(.29)	.18(.22)	.37(.19)	.71(.20)
RTLE	.17(.12)	.45(.19)	.67(.18)	.81(.16)	.08(.08)	.22(.26)	.36(.25)	.77(.21)
BTLE	.08(.09)	.23(.06)	.53(.18)	.68(.22)	.03(.04)	.06(.05)	.13(.12)	.63(.21)

Note: TLE = temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy. *N* = 10 for LTLE, 8 for RTLE, 5 for BTLE; control *N* = 18.

As Figure 5.1 shows, the TLE group as a whole scored lower than controls on all of the above measures. This difference was however, not reliable for item memory, $t(39) = 1.58$, $p = .12$, $d = 0.50$ but differed significantly for associative identification, $t(39) = 3.13$, $p = .003$, $d = 1.00$ and associative reinstatement, $t(39) = 2.09$, $p = .04$, $d = 0.67$. The control group was compared to LTLE, RTLE and BTLE with one-way ANOVAs. A main effect was not found for the item memory or associative reinstatement measures, $F(3, 41) = 0.87$, $p = .46$, $\eta^2 = .06$; $F(3, 41) = 1.78$, $p = .17$, $\eta^2 = .12$, respectively. Associative identification differed significantly across the groups, $F(3, 41) = 2.90$, $p = .05$, $\eta^2 = .19$; Bonferroni post-hoc (corrected to $p < .012$ for multiple comparisons) failed to display a significant difference between the LTLE group and controls' scores (*M difference* = 1.01, $p = .06$).

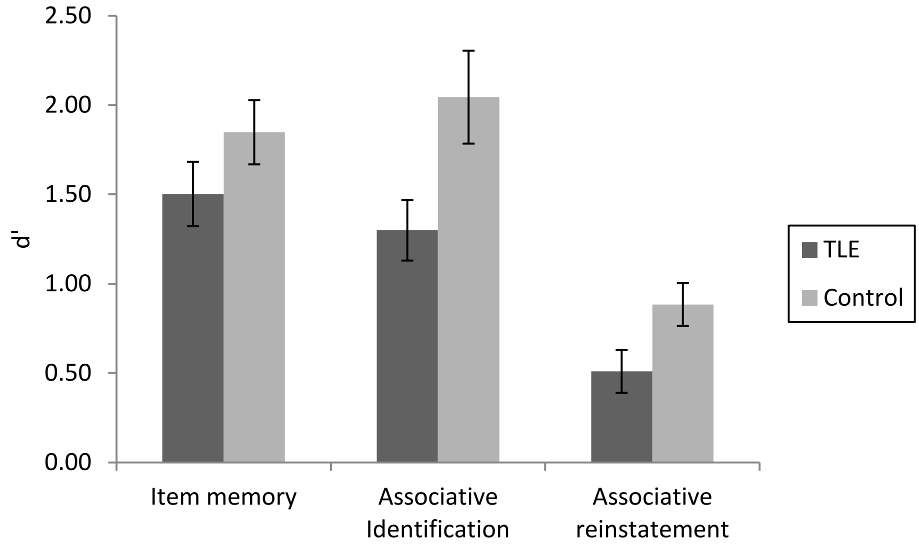

Figure 5.1 Mean item memory, associative identification and associative reinstatement in patient and control group with standard error.

The recollection estimate, displayed in Panel A of Figure 5.2, revealed a trend toward significance between the TLE group and controls, $t(39) = 1.82$, $p = .08$, $d = 0.58$. There was no difference found when comparing controls and the three TLE subgroups, $F(3, 40) = 1.58$, $p = .21$, $\eta^2 = .11$. Item familiarity, as expressed as *d'* (Panel B; Figure 5.2) was entirely comparable between TLE and controls, $t(39) = 0.55$, $p = .59$, $d = 0.18$.

To examine relational binding further, hit rates to intact pairs (recall-to-accept) and FPs to rearranged pairs (recall-to-reject) were analysed on the associative identification task, as in Table 5.2. The TLE group as a whole were found to have significantly higher FPs to rearranged pairs compared to controls, $t(36.11) = 3.34$, $p = .002$, $d = 1.11$ but did not differ in hit rates to intact pairs, $t(39) =0.84$, $p = .83$, $d = 0.27$. Therefore, patients appear to be able to successfully utilise recall-to-accept retrieval strategies, and have an impaired ability to recall-to-reject. Moreover, a laterality analysis revealed a group difference, $F(3, 41) = 4.45$, $p = .009$, $\eta^2 = .26$, with Bonferroni post-hoc comparisons displaying no difference between the three patient groups (*p*s > .16), but the means suggested the greatest difference lay between the LTLE and control group (*M difference* = 0.21, $p = .04$).

Therefore, at the group level, TLE patients did not display difficulty in single item recognition, but on the measures assessing relational binding operations there was evidence of impairments. These results are generally in line with Cohn et al. (2009), who found impairments in relational binding in their TLE group. They also found clearer evidence of recollection impairments, but notably, the sample included post-operative patients who would have had more widespread hippocampal pathology. Unlike them, however, the current sample was not impaired in item memory, or familiarity (where *dominant* TLE patients were impaired relative to controls). This again is likely due to differences in patient samples. Nevertheless, the convergent results provide further evidence for the role of the MTL in relational binding.

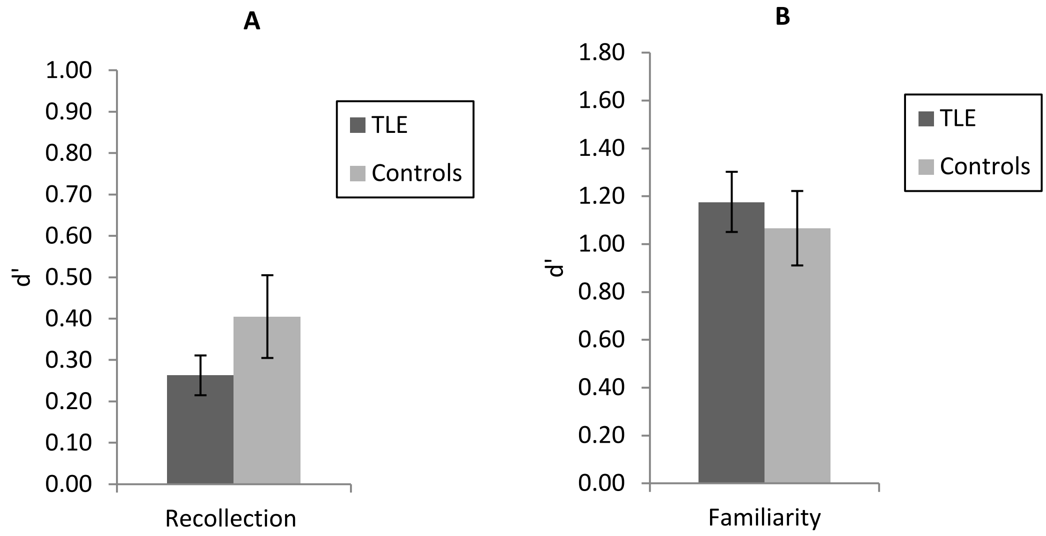

Figure 5.2 Mean recollection (Panel A) and familiarity (Panel B) estimates.

5.3.2 Confidence

The novel contribution of the present experiment was to measure subjective confidence associated with the different response types across the pair and associative recognition tasks. Table 5.3 is segregated into the mean confidence with which people believed their answers were correct for each pair type overall (metacognitive *accuracy*) and for correct answers (CRs and hits) and incorrect answers (FPs and misses) (metacognitive *sensitivity*). In the pair task, ‘rearranged correct’ corresponds to pairs that were correctly responded as “old”, whereas in the associative identification task this refers to pairs that were correctly rejected. Similarly, ‘incorrect’ in the pair task refers to pairs that were not recognised, and in the associative identification task refers to pairs that were incorrectly endorsed as being intact.

Table 5.3 Mean (SD) percentage confidence assigned to answers for each pair and response type overall (Sensitivity) and by correct/incorrect (Accuracy).

	Metacognitive Sensitivity				*Metacognitive Accuracy*							
Group	New Overall	Half-Old Overall	Rearranged Overall	Intact Overall	New CR	New FP	Half-Old CR	Half-Old FP	Rearranged Correct	Rearranged Incorrect	Intact Hits	Intact Misses
Pair task												
Control												
M	83.01	77.04	80.79	88.66	84.00	63.63	77.09	75.39	82.03	74.53	91.59	72.12
SD	13.31	15.03	13.97	9.47	13.07	23.09	15.05	17.43	14.60	17.36	8.84	20.73
TLE												
M	71.12	69.78	70.94	80.04	71.21	62.09	68.99	68.86	74.37	61.05	82.41	61.40
SD	18.24	14.14	14.51	13.81	19.02	24.26	14.87	16.10	16.28	17.02	14.97	21.67
AI task												
Control												
M	90.69	89.49	84.44	89.12	90.91	70.00	89.49	80.76	85.66	75.16	92.49	73.47
SD	10.71	11.57	12.38	9.02	10.75	25.82	11.27	23.94	11.82	22.06	7.59	16.82
TLE												
M	74.27	73.58	72.81	79.93	74.30	60.13	74.24	60.42	72.67	69.03	82.59	65.60
SD	19.01	18.37	16.76	14.67	19.67	24.82	18.72	18.76	17.44	19.69	15.07	21.75

Note: CR = correct rejection, FP = false positive, AI = associative identification, TLE = temporal lobe epilepsy. Shaded columns represent confidence assigned to items critical for calculation of objective relational memory measures.

5.3.2.1 Sensitivity – does confidence shift according to materials and task?

The first point of interest was to assess overall confidence to see if this measure was sensitive to the difficulty of the different pair types across the two tasks. Thus, a 2 (group) x 4 (pair type) x 2 (task) repeated measures ANOVA was conducted with group as a between-subjects factor and task and pair type as within-subjects factors. Confidence was reliably higher overall in the control group, $F(1, 39) = 6.25$, $p = .02$, $\eta_p^2 = .14$, and there was a main effect of pair type, $F(3, 117) = 13.82$, $p = .001$, $\eta_p^2 = .26$ with post-hoc comparisons confirming this was in the expected direction such that intact items were assigned significantly higher confident responses (*ps* < .02) than the other pair types, which did not differ from each other (*p*s > .36). There was no interaction between group and pair type, $F(3, 117) = 0.81$, $p = .49$, $\eta_p^2 = .02$. There was no main effect of task, $F(1, 39) = 1.28$, $p = .26$, $\eta_p^2 = .03$. Given that the instructions were identical for the two tasks for three of the pair types, this is not surprising. However, pair type did significantly interact with task, $F(3, 117) = 6.11$, $p = .001$, $\eta_p^2 = .14$. The means suggest this is predominantly a result of confidence being much higher for half-old pairs in the associative identification task and to a lesser extent new pairs , where as confidence for rearranged and intact pairs appears more comparable between the two tasks. Given that the associative identification task only requires an 'old' response when the initial bound relationship is retrieved between two words, it is unsurprising that confidence is higher for half-old pairs. There was no interaction between group and task, $F(1, 39) = 0.001$, $p = .99$, $\eta_p^2 = .001$, or between group, pair type and task, $F(3, 117) = 1.33$, $p = .27$, $\eta_p^2 = .03$. The same analysis was rerun looking at laterality and following a significant group effect, post-hocs showed no difference between the TLE subgroups (*p*s >.08), but a highly significant difference between LTLE and controls ($p = .003$). There was no interaction between subgroup and other variables (*F*s < 1.06) suggesting a uniform decrease in confidence in the LTLE patients.

In sum, the ANOVA shows that the TLE group are significantly less confident overall, which is best explained by low confidence in the subgroup of LTLE patients. The fact that there are no significant interactions with group suggests that patients respond no differently in their judgements for the different tasks and materials than controls. In short, their judgements are sensitive to the difficulty of the task they have been presented and moreover, the group effect suggests they are sensitive to their own memory difficulties.

5.3.2.2 Metacognitive accuracy – is confidence different for incorrect and correct answers?

Metacognitive accuracy within the current experiment is viewed as a participant's ability to adjust their confidence levels according to response types (i.e. correct and incorrect answers). Metacognitive accuracy was first assessed with a 2 (group) x 2 (task) x 4 (pair type) x 2 (response type) repeated measures ANOVA. However, due to a number of participants not making any FPs on certain pair types, this left a data set with only one control participant and 14 TLE patients. Therefore, the analyses were conducted separately on the pair types critical for calculating the recognition scores above; the rearranged and intact pairings (shaded box in Table 5.3). Hence, there were 21 TLE patients and 11 low performing controls[12] in a 2 (group) x 2 (task) x 2 (pair type) x 2 (response type) repeated measures ANOVA, with group as a between subjects factor. With this sub-sample, no significant effect of group was found, $F(1, 30) = 2.01$, $p = .17$, $\eta_p^2 = .06$. This may simply be due to the fact that lower confidence is assigned to FPs. Indeed, t-tests displayed there to be no significant difference in confidence to correct pairs across tasks between the better, and worse, performing controls (*p*s > .11). As expected, there was a highly significant main effect of response type, $F(1, 29) = 37.39$, $p = .001$, $\eta_p^2 = .55$, such that correct rearranged and intact pairs were assigned higher confidence than incorrect pairs. This suggests that even the worse performing participants on both tasks are metacognitively competent – they are able to accurately assign higher confidence to correct answers and significantly shift their confidence downward to incorrect answers. There was no effect of task, $F(1, 30) = 1.87$, $p = .18$, $\eta_p^2 = .06$,indicating that the different instructions did not influence the way confidence was assigned to these critical pair types. There was also no main effect of pair type in this analysis, $F(1, 30) = 3.26$, $p = .08$, $\eta_p^2 = .10$, compared to above where overall confidence was higher for intact pairs as compared to rearranged pairs.

Critically, no significant interaction was found between group and any of the variables (*F*s < 2.18, *p*s < .15), suggesting that TLE patients and this group of controls' pattern of confidence responses were highly comparable across tasks, materials and for both correct and incorrect

[12]Because this subgroup comprised participants making FPs to both pair types, performance on the critical memory measures was checked. In contrast to the whole sample analysis, no significant group differences were found between patients and control subgroups, therefore they were the worst performing control participants. As the LTLE patients appeared to perform worse overall, I also compared these 10 patients with the 11 controls. A significant difference was found in associative identification (t=2.24, p=.04) but no other measures – the LTLE group performed worse than the lowest performing controls. Additionally, t-tests were conducted between these 11 low performing controls and the other 7 higher performing controls on the memory measures and significant differences were found in the proportion of rearranged FPs in the AI task, associative identification and recollection, but not in proportion of intact hits in the AI task, associative reinstatement, item memory or familiarity. There were no significant differences found in confidence levels between these control subgroups for correct items on the critical pairings.

answers. The only significant interaction found was between pair type and response type, $F(1, 30) = 14.84$, $p = .001$, $\eta_p^2 = .33$. This result is interesting because even though there was no main effect of pair type, the interaction suggests that the decrease in confidence between correct and incorrect items for the rearranged pairs (marginal means: correct = 77.19; incorrect = 67.81) was less than that for intact pairs (marginal means; correct = 86.31; incorrect = 67.16), with incorrect items being assigned almost equivalent confidence levels. This is in spite of the fact that incorrect responses in the pair task represent misses and in the associative recognition task represent FPs. The interaction is in line with performance: confidence is higher for correct answers in intact pairs than rearranged pairs[13].

The experiment set out with the aim of examining whether a metacognitive failure might be behind the false positive errors in the associative identification task which characterise the poor performance in the TLE group (Cohn *et al*., 2009). This study has replicated the same associative deficit in TLE patients, and has found that they are overall less confident than controls (although have a similar level of confidence to poorly performing controls). Nonetheless, the TLE group assign confidence in line with different types of task and materials in the same way as controls and have significantly higher confidence for correct answers than incorrect answers. The acid test of the main hypothesis comes in looking at the errors on the rearranged pairs on the associative identification task. Errors on this task characterise the TLE associative deficit, where the participants need to recall-to-reject. A metacognitive account of this error would be that the participants are over confident for these particular items, given that they are endorsed as old when they are not (in keeping with highly familiar items being mis-recognised as an old item from a particular context). To examine this I looked specifically at the confidence level for these errors. The mean confidence level for control FPs in this task (75.16%, $SD = 22.06$) and for TLE patients (69.03%, $SD = 19.69$) did not differ significantly, $t(35) = 0.89$, $p = .38$, $d = 0.30$ and no difference was found in an analysis of laterality subgroups either, $F(3, 36) = 0.29$, $p = .84$. In sum, there is no evidence for metacognitive failure in this TLE group, even on a task which pinpoints their memory difficulties and even on the particular errors which characterise their deficit.

[13] Confidence was also assessed for correct and incorrect rearranged and intact items from the associative recognition task (as these are the measures used to calculate associative identification) - no difference was found between LTLE and the control subgroup. Hence, performance was impaired but confidence was still assigned in a comparable way.

5.4 Discussion

There were two main aims of the present experiment. First, the novel contribution was to assess associative memory and recollection impairments in TLE from a metacognitive perspective; it was found that despite impaired associative and relational memory abilities, confidence is assigned in a highly comparable manner between patients and controls for recognition responses that require differing use of recollection and familiarity. The second aim was to replicate previous findings by Cohn et al. (2009); using an identical task, associative identification and reinstatement were impaired in a more representative sample of TLE patients not comprised solely of individuals with extensive medial temporal resections.

Results from the present study and those from similar research discussed in Section 1.10.3 undoubtedly suggest that the processes of recollection and familiarity are used during associative recognition. However, by following this line of enquiry, it is all too easy to forget that participants are not simply passive learners of information, with these underlying cognitive mechanisms acting without one's own volition. Instead, when completing the present experiment, or any other recognition task, a participant is using a variety of metacognitive processes and strategies. Although the studies discussed in 1.9.3 have suggested that TLE patients are able to accurately use memory monitoring in experimental tasks, and subsequently control further study, to date no studies have assessed confidence in recognition decisions. Subjective confidence is a potent metacognitive variable in learning, and I wished to explore whether differences in memory ability would be accompanied by any changes in confidence to answers in TLE. Furthermore, although memory performance, subjective states of awareness and confidence have been shown *not* to be isomorphic with one another (Rajaram, Hamilton, & Bolton, 2002; Wells, Olson, & Charman, 2002), the fact that subjective confidence associated with recognition has been linked to target familiarity (Yonelinas, 1994) and the vividness of recollected details (Robinson, Johnson, & Robertson, 2000) suggested this was a useful line of enquiry for the literature given the known impairments in these processes in TLE. Essentially, the present findings suggested that the TLE group were metacognitively intact. The measure of metacognitive sensitivity displayed that patients were overall less confident in their recognition responses, and this was more so for the LTLE group, hence paralleling the recognition memory scores. Furthermore, the comparison of confidence for correct and incorrect answers yielded a consistent pattern suggesting that despite their memory impairments, TLE patients accurately assign lower confidence to incorrect items, and increase confidence accordingly for intact items. Therefore, the critical error driving their low performance (i.e. making FPs after failing to recall-to-reject) is not a result of making an erroneous highly confident recognition response following subjective familiarity of two old items. Instead, as discussed above and as Cohn et al. (2009) suggest, these errors are driven by an impairment in the ability to use recollective based strategic retrieval to recall the initial sentence that was encoded. The results are therefore supportive that this clinical group are able to accurately monitor the contents of their memory.

The current data are compatible with the two most recent empirical studies assessing metacognition in TLE. Howard et al. (2010) and Andres et al. (2010) demonstrated intact metacognitive accuracy in this group through equivalent gamma correlations in JOL and FOK predictions, and intact monitoring and control through comparable adjustment in judgments and study time according to item difficulty. My results build on these findings well, as patients were displayed to be metacognitively sensitive to different task instructions and difficulty of items within a paradigm that is arguably much more taxing than single item recall and recognition. Whereas the results provide evidence in support of the argument that fronto-temporal *memory retrieval* is impaired in this group, the accurate monitoring displayed suggests that any frontally mediated executive component to metacognition is left intact.

An influential model of how people make predictions about their memory was proposed by Koriat (1997) that bares relevance here. He suggests that metacognitive judgments are made on the assessment of intrinsic cues (e.g. assessment of item difficulty), extrinsic cues (e.g. assessment of encoding conditions) and mnemonic cues (e.g. subjective experience associated with ease-of-processing). In the present task, it would seem that patients are reliant on the same kind of cues to make metacognitive assessments about accuracy as controls in spite of memory difficulties; they are accurate in judging which items are more difficult (an intrinsic cue), which items were encoded more successfully as sentences (an extrinsic cue) and make confidence judgments based on their current subjective experience of the qualitative information available in a comparable way to controls (a mnemonic cue).

Certain inconsistencies still remain within the TLE metacognitive literature, however. For example, Prevey et al. (1988) found some evidence for overestimation in memory ability in TLE, and Andres et al. (2010) found a tendency for patients to actually have more accurate post-study global JOLs than controls. Additionally, other questionnaire based studies have typically revealed underestimations in memory ability in TLE (Banõs *et al*., 2004; Elixhauser *et al*., 1999; Gallassi *et al*., 1988; Giovagnoli *et al*., 1997; O'Shea *et al*., 1996; Vermeulen *et al*., 1993). Therefore, it would seem that methodological differences in the literature provide contrasting results. As Andres et al. (2010) discuss, the real problem in this area appears not to be that patients have difficulty in the 'online' monitoring and control of their performance on laboratory episodic memory tasks. Rather, as discussed in Section 1.6, the real issue is the discrepancy found between patients self-perceived level of day-to-day memory functioning and their performance on standardised neuropsychological tests, which are used for diagnostic purposes. It is more likely that these kinds of discrepancies are what have led to the suggestion that metacognitive failures may drive memory impairments in this clinical group. These clinical issues are covered in the following two chapters, where I present the data from a self-report everyday metamemory questionnaire in this patient sample and examine the results in the context of a more 'real world' memory task. I then go on to comprehensively investigate the factors that may influence self-perceived memory function, by looking to see if there is any relationship between this, and the impairments in recollective ability displayed across the tasks already presented in this thesis.

These results thus provide an important theoretical contribution to the TLE literature. However, there are some limitations. For example, it has been concluded that the metacognitive accuracy of patients is comparable to controls due to the observation of a trajectory where low confidence is associated with incorrect answers and subsequently increases for item types that achieved greater recognition performance. There is an extant literature on the confidence accuracy (CA) relationship, and a more typical measure is to assess the correlation between differing levels of confidence and accuracy using the non-parametric gamma statistic (see Mengelkamp & Bannert, 2010, for a discussion). This type of analysis is able to provide a within, as well as between-subjects CA relationship measure, which would be useful in further exploring metacognitive monitoring in TLE. This was in fact attempted, but there were an insufficient number of data points for the six confidence levels for certain item types (for example, intact pairs were characterised by extremely high levels of confidence in both groups). A future study may wish to examine this in a more simplified paradigm. Additionally, although the measure of sensitivity suggested participants were accurate in adjusting confidence to the difficulty of each item type within and between tasks, another useful extension of this would be to investigate exactly *how* patients and controls use subjective confidence. For example, Hines, Touron, and Hertzog (2009) displayed subjective confidence judgments to be an important heuristic for guiding subsequent study time allocation – a measure of metacognitive control. Another interesting avenue to explore would be to see whether feedback regarding the relationship between people's confidence and accuracy would influence subsequent recognition decisions. Specifically, if participants are informed that low confidence associated with answers in this paradigm are indicative of an incorrect response, would this subsequently aid their sensitivity and lead to reassessments of their memory? Although the present results have effectively dispatched the idea that memory errors are a result of a metacognitive failure in TLE, it is evident that metacognitive influences to recognition memory are still a useful line of enquiry. Indeed, a recent paper by Lloyd (2007) advocated consideration of the metacognitive 'distinctiveness heuristic', as well as recollection and familiarity, when assessing people's recall-to-reject strategies.

Overall, the results of the recognition memory measures provided replication of those by Cohn et al. (2009). However, there were several points of divergence, which are likely due to differences in the samples used. First, the above authors displayed uniform impairments in associative identification, associative reinstatement, recollection estimates and item memory in dominant and non-dominant post-operative TLE patients compared to controls. Moreover, they found intact item-familiarity estimates in their non-dominant group, but impairments in the dominant group. The present study, on the other hand, found intact familiarity and item memory, impaired associative identification and reinstatement and some evidence for an impairment in process-dissociation derived recollection estimates. Additionally, it was displayed that the low performance of the LTLE participants was driving group differences between patients and controls on the associative identification measure, as well as in recall-to-reject recollective abilities in the associative recognition task. Because language dominance was not assessed in the current sample, and I included patients with bilateral epileptic foci, a comprehensive analysis of laterality was not the focus of the present investigation. However, given that the task primarily requires the use of verbally mediated encoding and retrieval processes, the finding of a preferential impairment in patients with left sided lesions provides at least some support for the material specificity principle (Jones-Gotman, 1997; Milner, 1974), which was also inferred to a certain extent by Cohn et al. (2009).

The fact that this preferential impairment in the LTLE group only manifested in the associative identification and recall-to-reject ability can be accounted for by current conceptualisations of the neurocognitive mechanisms underlying associative reinstatement and associative identification. Specifically, associative reinstatement is viewed as a process that involves relational binding in medial temporal areas during encoding, whereas associative identification is thought to rely on recollection dependent strategic retrieval operations involving the MTL and prefrontal cortex (Castel & Craik, 2003; Cohn *et al.,* 2008; Cohn *et al*., 2009). This evidence comes from studies suggesting associative reinstatement is reduced when strong links are prevented from being made during encoding (Castel & Craik, 2003; Cohn & Moscovitch, 2007); it is less affected, and hence dissociable from associative identification under conditions that interfere with retrieval processes (Cohn & Moscovitch, 2007); and it is unaffected by normal aging, where associative memory deficits have been shown to be the result of impaired strategic retrieval (Cohn *et al*., 2008). Thus, the lack of statistical difference in laterality subgroups, but *overall* impairment in associative reinstatement in the present study confirms Cohn et al.'s (2009) suggestion that this kind of binding during encoding requires bilateral involvement of the MTL. Conversely, the finding of a marked impairment in LTLE for the processes involving strategic retrieval of information (associative identification and recall-to-reject) suggest that these processes, which involve a more widespread network of MTL and prefrontal areas, may be supported in a more unilateral fashion. Further, it is believed that the reason why the same consistent pervasive deficits in the measures as Cohn et al. (2009) were not found is due to the fact their sample of patients had all undergone extensive resections of both hippocampal and perirhinal medial temporal areas. The present sample did include three left and three right resected patients, but the majority had varying diagnoses of localisation related TLE, not necessarily confined to mesial temporal sclerosis. This accounts for the fact that a clear cut impairment in recollection was not found, or item memory, which as Cohn et al. (2008) suggest, is more dependent on recollection in a paired task such as this as compared to single item paradigms. Nevertheless, the finding that associative reinstatement was impaired in the sample as a whole suggests that even subtle MTL damage is sufficient to cause impairments in associative binding at encoding.

It is also important again to highlight the differences that were found in performance within the control group. After returning to the analyses to assess false alarm rates in greater depth, a clear division was discovered between higher and lower performing controls. Although the results indicated that most of the group differences between patients and controls were eliminated when only comparing the low performing controls with patients, the associative identification measure was still found to be impaired, and again this was driven by performance of the LTLE subgroup. Taken together then, the recognition results suggest that despite variability in performance in the general population in associative memory ability, relational binding and strategic retrieval are overall more affected following MTL damage, and this is likely to have a material specific basis. A good follow up study to the current experiment then would be to assess differences in visual and verbal encoding/retrieval in well circumscribed left and right sided patients. Indeed, the assessment of within (word-word) and between (e.g. word-face) item associative recognition has already received attention in the amnesic literature (Mayes *et al*., 2004; Vargha-Khadem *et al*., 1997) and has contributed primarily to our understanding of familiarity in associative memory.

In summary, the experiment in this chapter has provided a replication of Cohn et al.'s (2009) study and shown that impairments in the ability to bind information at encoding and strategically retrieve associations are detectable in a more representative group of TLE patients. These impairments are most striking for paired word recognition involving effortful retrieval strategies that rely on recollection, and likely have a material specific basis. Despite this, novel evidence is provided that this patient group use subjective confidence in a comparable way to controls, and hence further supporting the notion that metamemory is intact in TLE.

6 Self-perceived memory function, awareness and the role of episodic memory in dating public news events

6.1 Introduction

The previous empirical chapters have examined recollection and familiarity in the context of anterograde recognition memory. However, in recent years, empirical investigations into the cognitive sequalae of temporal lobe epilepsy (TLE) have drawn attention to a number of other memory impairments arising from degraded consolidation processes, including accelerated long-term forgetting and autobiographical memory (AM) impairments (Butler & Zeman, 2008). Of these, the study of AM has been the most prominent and as mentioned in the main Introduction, a number of recent innovative studies have sought to delineate the impairments found in specific episodic and semantic components of this memory system (Herfurth, Kasper, Schwarz, Stefan, & Pauli, 2010; Manning, Chassagnon, Hirsch, Kehrli, & Maitrot, 2005; Noulhiane *et al*., 2007; Viskontas, McAndrews, & Moscovitch, 2000; Voltzenlogel *et al*., 2006). To reiterate, episodic AMs are associated with contextual retrieval of a time-limited event in one's past, and produce a mental reliving of the personal experience, often bringing about the same sensory-perceptual-cognitive-affective details as that at the time of encoding; semantic memory can either be *personal*, representing information about one's life experienced as knowledge in the absence of contextual details or *public*, representing the knowledge we acquire about the world and events around us in which we are not actively involved (Conway, 2001; Conway & Pleydell-Pearce, 2000; Tulving, 1985; Tulving, Schacter, McLachlan, & Moscovitch, 1988). Although personal episodic and semantic memory are critical to sustain a sense of self in time, as Brown (1990) states, "Though most news events are rapidly forgotten, the few important facts that remain shape our stored public events memory, which affects an important part of our awareness of the surrounding world and allows us to share cultural community interests" (p.45). Thus, memory for publicly shared knowledge regarding the events occurring around us is also a critical part of our experience.

Previous studies assessing public semantic memory in TLE have utilised a wide variety of tasks, finding impairments in recognition and naming of famous faces (Barr, Goldberg, Wasserstein, & Novelly, 1990; Lah *et al.,* 2004; Lah, Lee *et al*., 2008; Seidenberg *et al*., 2002; Viskontas, McAndrews, & Moscovitch, 2002), recognition of past television programmes (Barr *et al*., 1990), fluency tasks (Lah et al., 2004, 2006) and most commonly, interviews about public news events comprising recall and recognition components (Barr *et al*., 1990; Bergin, Thompson, Baxendale, Fish, & Shorvon, 2000; Haag *et al*., 2010; Lah et al., 2004, 2006; Leeman, Macklin, Schomer, & O'Connor, 2009).

The more questionnaire-oriented tasks above provide objective assessments of participants' knowledge of public news events over different time periods, but one method that appears not to have been examined in TLE is the ability to correctly *date* public news events. This potentially arises from theoretical orientation, whereby researchers subsume memory for public news events as distinctly separate from episodic autobiographical memories. However, the 'mental time travel' that is the hallmark of episodic memory necessarily involves an assessment of temporal-spatial relations (Tulving, 2002). Comparing younger and older adults, Fradera and Ward (2006) sought to tease apart the potential sources of information used to place memories in time. Their results suggested that dating accuracy was not related to knowledge of the event *per se*, but relied more on the ability to contextualise the event within a personally experienced autobiographical period. Their finding that contextual information surrounding the event aided dating accuracy is consistent with a *location based* theory, which suggests time estimation is dependent upon the information people store about their environment and own internal state during the event (e.g. Friedman, 1993). Because there is a wealth of literature suggesting people with TLE have both deficits in episodic and semantic memory, the first aim of the present study was to explore whether such impairments would critically affect patients' ability to accurately estimate the date of recent news events occurring within the past ten years.

As Fradera and Ward (2006) argued, the ability to correctly date previous news events is partially dependent on retrieval of contextual *periods* of life, but presumably people's memories for news events are still encoded with contextual elements regarding their source of acquisition, such as where they were when they learnt about the event. Although there is a large literature on 'flashbulb memories' of particularly striking and important events, those that are less salient still evoke some degree of recollective detail, and this has also not yet been explored in TLE.

A useful way to examine this, as has been done in the previous chapters, is to use the R/K paradigm (Tulving, 1985). Previous studies applying the R/K paradigm to AMs in TLE have found reduced levels of subjective remembering for events across the lifespan (Noulhiane *et al*., 2007) and an impaired ability to subjectively remember memories from self-defining periods of life (Illman, Rathbone, Kemp, & Moulin, 2011). Although the current experiment aimed only to assess public, and not personal events, a key motivation was to incorporate a number of subjective measures that are thought to reflect recollective processing. To this end, participants were asked if they could recall the specific context in which they learned of salient public events happening, and were asked for ratings of vividness during retrieval. Therefore, participants were assessed on the extent to which subjectively experienced qualitative information during retrieval impacted on their ability to correctly date past public events.

The present study also extended upon those in Chapters 2-5 and attempted to address the clinical issue outlined in Section 1.6 – that is, the commonly observed discrepancy between subjective report of memory problems and objective measurement. So far, the empirical work on this topic has operationalised subjectivity with self-report during memory tasks. Therefore, it is possible that a questionnaire that encompasses a wide variety of beliefs and feelings about memory ability may address the complaints made by TLE patients.

There have also been no attempts to assess the link between subjective reports of everyday memory function and retrograde memory in TLE. To examine whether perception of day-to-day memory function is related to subjective and objective measures of AM, the Multifactorial Memory Questionnaire (MMQ; Troyer & Rich, 2002), a previously validated and reliable metamemory measure, was administered as well as the public events test.

As discussed in the main Introduction, TLE patients have been found to be unimpaired on standard laboratory tasks of metacognition. The results thus far in this thesis have shown patients' subjective experiences to appropriately reflect their underlying memory impairment; this was through the correspondence of subjective states of awareness and objective memory measures and the appropriate assignment of confidence judgments to accuracy. The results of the experiment in Chapter 5 refuted the idea that the associative memory deficit in TLE is a result of an impairment in metamemory. However, a metacognitive account of AM impairment has not been examined in TLE. Therefore, a metacognitive monitoring based question was included in the public events task. Participants were asked to state whether they believed they knew they year of the event (Yes/No response) *before* giving the option to provide a year. This allowed an examination of both accuracy and subjective indexes of memory according to participants' metacognitive evaluations.

6.2 Methods

6.2.1 Participants

Because the public events test and MMQ are self-administered tasks, it afforded the collection of data from a large sample on the Internet, as well as collecting data from the participants described in Chapter 2.

The online version of the questionnaire was advertised primarily through a UK based epilepsy charity's website and bimonthly publication (EA). The TLE sample consisted of 82 responders; 67 completing the online version of the task and 15 of the patients presented in Chapter 2, who completed an identical paper copy. The initial healthy adult control (HAC) sample included 139 participants (10 of which were control participants presented in Chapter 2). Four of these were excluded due to incompletion of any of the public events task. The two groups were systematically matched case by case, on age and years of education; the mean years of education value was substituted for four control participants who failed to complete this question. Hence, the final sample presented in subsequent analyses consists of 82 participants in each group. Summary demographic data for both groups, and epilepsy related variables for the TLE group are presented in Table 6.1.

6.2.2 Sample characteristics

To check for differences between groups one-way ANOVAs and chi-square tests were conducted. Alpha was set at $p<.05$ for all analyses unless otherwise stated. A one-way ANOVA displayed the groups to be well matched on age, $F(1,163)= .004$, $p = .95$, and years of education, $F(1,163)= .04$, $p = .85$. No specific predictions were made regarding these variables.

A marginally significant difference in gender distribution was found between groups: χ^2 (1) = 3.02, $p = .08$, such that there were more males in the HAC group than the TLE group. Overall, however, the groups were primarily comprised of female participants[14].

All participants were asked before beginning the public events task what their average weekly exposure was to news programmes on television, and how often they read newspapers or

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[14] Previous literature has suggested that there are differences between males and females in various measures of autobiographical memory. Therefore, supplementary ANCOVA analyses looking at gender differences can be found in APPENDIX G. In short, when used as a covariate, gender did not remove any of the important main effects or interactions between group and the variables of interest presented below.

viewed online news material. These were asked separately, and participants were given arbitrary options of '0-2 times per week', '2-4 times per week', '4-6 times per week', '6-8 times per week' and '8 or more times per week'. One control participant failed to complete these questions, hence the remaining proportion of participants responding to each option are presented in Table 6.1. To ensure that any subsequent memory effects were not confounded simply by either groups' exposure to world news events, a chi-square analysis was conducted on these data. A significant value was obtained for exposure to television news, χ^2 (5) = 13.58, *p* = .02. As Table 6.1 shows, this difference lies in the fact that the TLE group actually report higher levels of habitually watching television news programmes. Because previous research unequivocally suggests that this group is impaired on measures of public semantic memory, this is not discussed further because any increase found in memory for the control group cannot simply be attributed to increased exposure to media. Moreover, for exposure to newspapers and online content, no significant difference was found between the groups, χ^2 (5) = 2.30, *p* = .81.

6.2.3 Epilepsy related variables

Participants were asked if they knew the aetiology of their illness from recent MRI scans or neurophysiological (EEG) investigations. They were asked to record this in a text box, and were next asked to select from a drop-down box, if known, the hemispheric localisation of their TLE. They were given the options of left, right, both sides (bilateral) and 'don't know'. In some cases, participants selected an option from the drop down box that was inconsistent with the text description they provided beforehand. For example, one participant wrote 'left hippocampal sclerosis', but selected 'right' for lateralisation. In this case, 'left' was used to group the participant as information in an open text box was more reliable than one requiring a mouse click, where mistakes are more easily made. Similarly, if someone selected 'right' but had written that there was 'no cause found', the participants was grouped as 'no cause found'. Therefore, the numbers presented in Table 6.1 represent best efforts to accurately estimate the number of patients in each laterality group whilst taking all information into account.

TLE participants were also asked about their surgical status, and were given the options of 'already had surgery', being considered for surgery', 'considered unsuitable for surgery' and 'surgery has not been mentioned'. They were then given the option to provide information about their surgery, and indicated how long ago the procedure was carried out. Because the focus of the investigation was not to specifically assess lateralised impairments in TLE, or compare pre- and post-surgical groups, for ease the left and right resected patients were added into each general hemispheric group. One-way ANOVAs were computed to explore any differences in the demographic and clinical variables between these subgroups. There was no significant difference in age between the left, right, bilateral and 'unknown' groups, $F(3, 81) = 1.16$, $p = .33$. Nor was there a difference in years of education, $F(3, 81) = 0.17$, $p = .92$, meaning all subgroups were well matched with each other, and the HAC group. We also found age of onset; $F(3, 80) = 1.63$, $p = .19$ and illness duration; $F(3, 80) = 0.83$, $p = .48$ to be matched between the four subgroups. Therefore, in the following analyses it is assumed that these epilepsy related variables have little impact on any differences between scores in these hemispheric groups. As above, the main focus was on comparison of the HAC group and TLE sample as a whole; therefore, analysis of lateralised groups is presented at the end of each section purely for exploratory purposes.

Participants were also asked if they currently suffered from any neurological or psychological disorders other than TLE, for example, anxiety and depression. If they answered Yes to this question, they were asked to provide brief details. The data in Table 6.1 reflect the number of participants that both answered Yes to this question and provided enough information to extrapolate whether they were currently experiencing anxiety or depressive disorders, or other psychological or neurological problems. 'Other' in the TLE group includes participants with bi-polar, interictal psychosis, panic attacks, multiple sclerosis, migraine and a previous transient ischemic attack. In the HAC group this includes one person with migraine. Additionally, participants were asked to note the name of any other medications they were taking that they believed may affect their current cognitive function.

Citalopram was by far the most common medication used to treat self-reported anxiety and depression, and in the 'Other' responses for the TLE group, one participant reported taking venlafaxine, one was taking quetiapine alongside citalopram, one taking risperidone and another amyltriptyline for severe headaches. This information was not requested from the HAC group. These scores are consistent with previous research suggesting higher levels of psychiatric disorders in TLE than in the healthy population (Marsh & Rao, 2002). Once again, because this was not the focus of this study, and because a validated measure of current symptom levels was not obtained, these variables are not considered in further analyses.

Table 6.1 Demographic data, self-reported news exposure and clinical data for TLE and controls.

	TLE (*N*=82)	HAC (*N*=82)
Age		
Mean	46.95	46.82
SD	13.24	13.90
Male/Female %	22/78	34/68
Education		
Mean number years	14.32	14.40
SD	2.96	2.86
Average weekly news exposure		
Television (%)		
0-2 x p/week	17.40	26.80
2-4 x p/week	8.80	24.40
4-6 x p/week	23.80	18.30
6-8 x p/week	25.00	13.40
8 or more	25.00	15.90
Newspaper and online (%)		
0-2 x p/week	35.00	36.60
2-4 x p/week	17.50	20.70
4-6 x p/week	15.00	17.10
6-8 x p/week	13.80	11.00
8 or more	18.80	13.40
Age diagnosed		
Mean	24.37	n.a.
SD	16.81	
Illness duration		
Mean	25.06	n.a.
SD	16.77	
Lobe of origin		
Left	23	n.a.
Right	17	
Bilateral	8	
No cause found	34	
Surgical status		
Post surgical	14 (7left, 7 right)	n.a.
Pre surgical	5	
Surgery unsuitable	11	
Not mentioned	50	
Unanswered	4	
AED therapy		
Monotherapy	38	n.a.
Polytherapy	37	
Unanswered	7	
Psychological/Neurological status		
Anxiety	14	5
Depression	18	5
Other	6	1
Other medications		
Anti-depressants/anxiolytics	15	n.a
Other	2	

***Note:* TLE = temporal lobe epilepsy, HAC = healthy adult control.**

6.3 Materials and Procedure

The first page of the online study contained detailed information and clearly stated that completion of the questionnaires would be taken to indicate informed consent. Following completion of background demographic information and clinical data for the TLE group, participants first completed an unrelated questionnaire that is not reported here.

6.3.1 The Multifactorial Memory Questionnaire (MMQ)

To assess subjective perception of daily memory functioning, the Multifactorial Memory Questionnaire (MMQ; Troyer & Rich, 2002) was deployed. The original MMQ is a 57 item self-report questionnaire consisting of three subscales; Contentment (18 items), Ability (20 items) and Strategy (19 items). MMQ-Contentment items assess positive and negative emotions associated with memory and subjective ratings of current memory ability (e.g. I am generally pleased with my memory ability). Level of agreement with various statements is indicated on a 5 point scale (strongly agree, agree, undecided, disagree and strongly disagree) based on reflection of the past two weeks. One item was omitted from the original subscale - “When I forget something, I fear that I may have a serious memory problem, like Alzheimer’s disease”. It was felt this item was more specific to the older adult population in which the MMQ was validated on, and would not be useful in an age diverse sample of people with TLE. Scores for responses range from 0-4, with higher scores indicating greater contentment. MMQ-Ability items assess everyday memory situations such as remembering to pass on a message, and are phrased as memory failures (i.e. How often do you forget to pass on a message?). The frequency with which these errors have occurred over the past two weeks are recorded by participants on a 5 point scale (all the time, often, sometimes, rarely, never). These are then also scored from 0-4 with higher scores indicating better subjective memory ability. Finally, MMQ-Strategy items measure the extent to which participants have used memory aids in daily life over the past couple of weeks (e.g. How often do you write down in a notebook things that you want to remember?). This is also scored from 0-4, with higher scores indicating *less* frequent use of such strategies.

A small proportion of items were missed by participants, and following Troyer and Rich (2002), the scores for these scales were prorated based on the completed items.

6.3.2 Public events task

The public events task was designed as having two public news events for each year 2001-2010 (20 events in total) covering stories from around the world on topics such as natural/other disasters, political events, crimes/terrorism, entertainment, sporting events and other prominent news stories (see APPENDIX F for a list of events used). Each event was written in a sentence that provided sufficient detail to be identified but omitting the year; for example, 'Queen Elizabeth II of England marks 50 years as monarch with the Golden Jubilee'. Items were presented in a fixed random order for all participants and they were told that they would be asked to make various ratings regarding their memory of them. They were then provided with a list of instructions about the memory ratings required for each public event. They were first asked, '*Do you recall the event happening?*' giving a dichotomous Yes/No option and described as 'We simply want you to think back and see if you can recall the event happening'. The next question was *'Specific context*' and participants were told:

> *'You should answer YES if you can think back to the specific time and place when you learned of the event happening. For instance, you might recall being at a friend's house being told by them one evening. In other words, you have a memory of learning of the event which lasts less than a few hours. Alternatively, you should answer NO if you cannot recall such a memory.'*

This question was specifically designed such that each memory/event could be defined as having recollection accompanied with it. Following these subjective assessments of memory, participants were asked if they believed they knew the year the event had occurred (Yes/No) – this was the metacognitive measure designed to allow an assessment of objective accuracy of dating contingent upon participants *monitoring* of their memory. They were then asked to select a year from a dropdown box for all events, even if they did not think they knew the year. Next, for each event, participants were asked to rate the personal significance of the event (*1 = No personal significance – 7 = Highly personally significant*), and were told ' For instance, if you were involved in the event or knew someone who was, the event is likely to be more personally significant.' Finally, participants were asked to rate the vividness of their mental images whilst thinking of their experience of the event (*1= No mental images – 7= Highly vivid mental images*). Participants then moved onto the actual questionnaire, during which the above ratings were presented in the same order for each item.

6.4 Results

Based on the previous literature suggesting lowered levels of perceived day-to-day memory functioning in TLE, the first part of the analyses focused on the MMQ in order to assess whether these same memory complaints would be evident in the current sample. The analysis then continues to assess the results of the public events task. Consistent with the rest of the work in this thesis, the analyses focus on subjective memory measures, objective memory scores and ends with a comparison of subjective/objective measures.

6.4.1 MMQ

The MMQ was included to provide an assessment of participants' subjective perception of day-to-day memory functioning. The mean scores for each subscale in the TLE, HAC and lateralisation subgroups are presented in Table 6.2. A repeated measures ANOVA (with *group* as the between subjects factor) showed a highly significant main effect of group, $F(1, 162) = 121.90$, $p = .001$, $\eta_p^2 = .43$, such that the HAC group had higher scores overall. There was also a significant main effect of subscale, $F(1, 162) = 50.70$, $p = .001$, $\eta_p^2 = .24$[15] and a significant interaction between subscale and group, $F(1, 162) = 23.79$, $p = .001$, $\eta_p^2 = .13$. Follow-up one-way ANOVA revealed the TLE group to have significantly lower scores on each subscale ($Fs > 53.68$). The critical finding is that people with TLE have a significantly lowered subjective perception of their memory and utilise memory aid strategies less than healthy controls.

To explore any differences between hemispheric subgroups, one-way ANOVAs were conducted on the three subscale scores excluding the control data due to the large differences found between the combined TLE group and HACs. No main effects were found for any subscale ($ps > .89$), suggesting that left, right, bilateral and people with TLE who did not know their hemispheric localisation did not differ in any of the metamemory domains from the MMQ. Additionally, no significant association (Pearson's *r*) was found between illness duration or onset and each subscale, and one-way ANOVAs found no significant difference between TLE participants on AED monotherapy, polytherapy or unspecified regimes ($ps > .16$).

[15] Because the values from each subscale represent arbitrary values unique to that scale, no further comparison was made between them. Instead, it is the interaction term that is of interest.

In summary, the results from the MMQ are supportive of previous research suggesting perceived lower levels of subjective memory functioning in TLE. This was found to be unrelated to any of the epilepsy related variables recorded. This is in contrast to other research (e.g. Hendriks *et al*., 2002) where an association was found between perceived function and illness duration. This may, however, be due to differences in methodology as these authors only measured perceived forgetting, where as the MMQ comprises multiple domains of metamemory.

Table 6.2 Scores obtained on the Multifactorial Memory Questionnaire subscales.

Measure	Contentment (Max = 68) *M (SD): Range*	Ability (Max = 80) *M (SD): Range*	Strategy (Max = 76) *M (SD): Range*
TLE (*N* = 82)	22.11 (11.84): 3 - 52	34.62 (11.02): 11 - 61	31.39 (12.82): 4 - 70
HAC (*N* = 82)	45.05 (11.07): 7 - 62	48.47 (10.82): 15 - 72	44.53 (9.98): 24 - 74
LTLE (*N* = 23)	20.61 (11.15): 3 - 48	34.71 (10.49): 17 - 61	30.75 (13.44): 4 - 68
RTLE (*N* = 17)	23.00 (15.05): 3 - 52	33.88 (11.94): 17 - 57	32.39 (15.44): 13 - 70
BTLE (*N* = 8)	21.15 (7.18): 12 - 32	36.19 (10.36): 19 – 51	28.65 (10.38): 14 - 42

Note: TLE = temporal lobe epilepsy; HAC = healthy adult control; LTLE = left temporal lobe epilepsy; RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

6.4.2 Public news events task

The questioning format of this task yielded several subjective and objective measures of memory; means and standard deviations for these are presented in Table 6.3.

6.4.2.1 Subjective measures

The ‘Proportion of events subjectively recalled’ refers simply to whether participants said they could recall the event happening or not (Yes/No response). One-way ANOVA found a significant difference between the two groups on this measure, $F(1, 163) = 31.05$, $p = .001$, $\eta^2 = .16$, such that the HAC group reported higher levels of subjective recall than the TLE group. The ‘Proportion of events with encoding context recalled’ refers to events where the participant could essentially *recollect* the specific time and place when they acquired the memory of the event happening. There was also a significant difference found between the groups for this, $F(1, 163) = 4.16$, $p = .04$, $\eta^2 = .03$, again with the HAC group reporting a higher instance of retrieving the encoding context.

Vividness and personal significance ratings were both scored out of seven, with higher scores representing more vivid imagery of the event and greater personal significance, respectively. A significant difference was found between vividness scores, $F(1, 163) = 9.34$, $p = .003$, $\eta^2 = .05$, suggesting on average across all events, people *without* TLE more vividly recalled memories. No significant difference was found between personal significance however ($F < 1$). This finding is helpful because it shows that the differences in memory cannot simply be attributed to varying levels of personal significance. Further, it shows that there is no systematic bias in under confidence or overly conservative use of the rating scales.

The 'Proportion of years responded Yes' was a metacognitive measure as this is the participant's subjective assessment of the veracity of their memory for which date (year) certain events occurred. There was a significant difference between the groups, $F(1, 163) = 10.24$, $p = .002$, $\eta^2 = .06$, such that controls indicated they could correctly label the year of each event more than people with TLE.

Differences between hemispheric subgroups were then explored using one-way ANOVAs and Bonferroni post-hocs. For proportion of events subjectively recalled, a main effect of group was found, $F(4, 163) = 8.35$, $p = .001$, $\eta^2 = .17$, with the right, bilateral and 'don't know' groups performing significantly worse than controls (ps $< .03$) but not the LTLE group ($p = .12$). There was no evidence of a difference between TLE subgroups. For the proportion of events where the encoding context was recalled, no main effect was found, $F(4, 163) = 1.44$, $p = .22$, $\eta^2 = .001$. A main effect of vividness was found, $F(4, 163) = 2.65$, $p = .04$, $\eta^2 = .06$, with post-hoc analyses suggesting that the difference lay between the 'don't know' group and controls' scores. This result is unsurprising given the larger number of participants in this TLE subgroup group, and is uninteresting from a theoretical viewpoint.

Overall, the results of these subjective measures suggest that controls *feel* like they recall more events than the TLE group, which is associated with a higher number of events in which they believed they could select the correct year. They also report remembering the encoding context to a greater extent, and overall, show higher levels of vividness. Attention must be paid to the relatively small effect sizes, however. Moreover, these differences arise in the context of relatively equal ratings of personal significance across all events.

There is also a consistency between the low memory self-efficacy and assessment of functioning seen on the MMQ in TLE, and the reduction in subjective measures on the public events task. To assess any potential relationship between these measures, Pearson correlations were computed between scores on the MMQ subscales and each subjective measure for the TLE and HAC groups separately[16]. The only subjective measure to correlate with any of these was the proportion of events subjectively recalled; small positive correlations were found in the TLE group between this measure and MMQ-Ability (r = .26, p = .02) and MMQ-Contentment (r = .27, p = .02), suggesting that higher perceived levels of current memory functioning and contentment with memory were associated (albeit to a small degree) with the number of events subjectively recalled. No significant correlations were found in the HAC group.

6.4.2.2 Objective measures

The objective measure in the task related to participants' ability to correctly select the year that corresponded with the public event happening. There were a number of participants in each group who failed to select any dates for events, but still answered the subjective measures. Thus, when analysing the overall proportion of years correctly dated (correct number of years/20), there were 74 participants in the TLE group and 79 HACs. There was a trend such that the number of years attempted by the HAC group (*Mean* =12.54, *SD* = 6.80) was higher than the TLE group (*Mean* = 10.50, *SD* = 7.78); t(159.17) = 1.79, p = .08. However, A one-way ANOVA showed no significant difference between the groups in the proportion of events correctly dated, F(1, 152) = 2.16, p = .14, η^2 = .01.

A further assessment was of participants' relative accuracy when dating was incorrect. This provides a measure of how close participants were in their estimation of the year events happened. Table 6.3 displays the means for the unsigned absolute difference, which reflects the average distance, in years, participants were from correctly dating the event. The mean difference on the other hand, takes into account both positive and negative values. For example, if a participant selected the year 2002 for an event which actually occurred in 2005, their score would be -3. The mean difference score presented in Table 6.3 reflects the average of these scores across all participants and events. The resulting positive score for both groups reflects an overall tendency to date years as more recently than they actually occurred, which

[16]A full correlational analysis of demographic and experimental variables can be found in APPENDIX H. It was decided not to include this in the Results section because a) the more important assessment was of differences between the two groups' scores and b) a comprehensive correlational analysis of various measures is presented in Chapter 7. Notably, several interesting correlations emerged between the subjective and objective measures, all essentially suggesting that greater awareness, better objective memory ability and increases in subjective measures are positively related to a certain degree.

has previously been coined *forward* telescoping in the literature (Janssen, Chessa, & Murre, 2006; Rubin & Baddeley, 1989). One-way ANOVAs were conducted on these data and revealed no significant differences between the TLE and HAC group and between all TLE subgroups on these measures (*F*s < 2.08).

Table 6.3 Mean (SD) for subjective and objective memory measures in the public events questionnaire.

Measure	TLE	HAC
Subjective		
Prop events subjectively recalled *M* (*SD*)	.67 (.18)	.79 (.10)
Prop events with encoding context recalled *M* (*SD*)	.31 (.23)	.38 (.23)
Vividness rating *M* (*SD*)	3.03 (1.11)	3.56 (1.10)
Personal significance *M* (*SD*)	1.99 (0.94)	2.03 (0.84)
Prop of years responded 'Yes' *M* (*SD*)	.20 (.17)	.30 (.21)
Objective		
Accuracy for all years attempted *M* (*SD*)	.38 (.28)	.44 (.23)
Unsigned absolute difference (in years) *M* (*SD*)	1.70 (1.16)	1.46 (1.06)
Mean difference (in years) *M* (*SD*)	0.57 (1.24)	0.68 (1.19)
Subjective-Objective		
Accuracy when said 'Yes' to year *M* (*SD*)	.55 (.33)	.60(.28)
Accuracy when said 'No' to year *M* (*SD*)	.08 (.12)	.10 (.13)
Prop encoding context recalled and correct year *M* (*SD*)	.33 (.28)	.45 (.28)
Prop encoding context not recalled but correct year *M* (*SD*)	.09 (.12)	.14 (.13)
Mean vividness for correct items *M* (*SD*)	4.47 (1.69)	4.74 (1.36)
Mean vividness for incorrect/unanswered items *M* (*SD*)	2.83 (1.04)	3.26 (1.00)

Note: Prop = proportion; TLE = temporal lobe epilepsy; HAC = Healthy adult controls.

After conducting the same analyses to compare the left, right, bilateral and 'don't know' TLE subgroups and controls, no significant main effects were found (*F*s < 1.93), suggesting that these objective measures of performance were not affected by lateralisation of epileptic focus. There were also no significant correlations between any of the objective measures and the MMQ subscales in either group.

In summary, people with TLE were as accurate as controls at correctly dating the public events, and show the same level of dispersion when providing the incorrect date.

6.4.2.3 Subjective-Objective comparisons

As mentioned above, before selecting the year, participants were given the option to say 'Yes' or 'No' to whether they could correctly recall it. If participants are metacognitively intact, we would expect that there would be significant differences in dating ability between those items that participants reported as knowing the year for versus those that they stated they did not. The scores for these measures are shown in Table 6.3. The score for "Accuracy when said 'Yes' to year" was calculated by dividing the number of correctly dated years that had been assigned a Yes response to the question by the *total* number of items assigned a Yes response. For the 'Accuracy when said 'No' to year' measure, the number of years correctly dated following a No responses was divided by the *total* number of years assigned a No response. Notably, a number of participants in each group failed to select an option for the metacognitive question in certain instances, or in some cases selected the No option for every event, meaning a score could not be computed for accuracy after responding Yes. Hence, the analysis was run with 69 people in the TLE group and 78 controls. These data were submitted to a repeated measures ANOVA with group as a between subjects factor. No significant effect of group was found, $F(1, 146) = 1.27$, $p = .26$, $\eta^2 =.01$. However, a highly significant main effect of accuracy type based on Yes/No prediction was found, $F(1 ,146) = 375.71$, $p = .001$, $\eta^2 = .72$, such that participants as a whole were more accurate in their dating of events when they previously stated they did know the year. No interaction was found between group and the two accuracy types, $F(1, 146) = 0.40$, $p = .53$, $\eta^2 =.003$. Therefore, the groups did not differ in the accuracy with which they reported events.

The final analysis focused on an assessment of the degree to which the subjective measures of recollective quality of participants' memory would vary according to the accuracy with which they could date the public events. The ability to retrieve contextual information regarding the source of acquisition of a memory, and to experience vivid mental images during recall, are hallmarks of the mental time travel associated with episodic autobiographical memory retrieval (Tulving, 2002). In the present task participants were not asked to rate the vividness of their memory of the encoding context, but to rate the extent to which they could generally form vivid mental images of the event in their past. Correlational analyses evidenced no association between vividness and the proportion of events where the encoding context was recalled, suggesting they were carried out as instructed.

As in Table 6.3, a probability value was calculated for when participants correctly dated the year of the event as well as responding that they could recall the encoding context (number of events assigned a Yes response to encoding question and also correct year/total number of events assigned Yes to encoding question), and their accuracy when they could not recall the encoding context (number of events assigned a No response to encoding question but selected the correct year/total number of events assigned No to encoding question). A 2 (accuracy for recalled context vs unrecalled context) x 2 (TLE vs HAC) repeated measures ANOVA was conducted, with group as the between subjects factor. Taking into account missing data, the sample sizes were N=72 for TLE and N=81 for controls. This revealed a significant main effect of group, $F(1, 150) = 10.07$, $p = .002$, $\eta_p^2 = .06$, with the HAC group obtaining greater accuracy overall under these parameters. There was also a significant effect of accuracy type, $F(1, 150) = 158.35$, $p = .001$, $\eta_p^2 = .51$, suggesting that participants were more accurate in dating events when they were able to retrieve the encoding context. The interaction also approached significance, $F(1, 150) = 3.64$, $p = .06$, $\eta_p^2 = .02$ and as the means display, this appears to be due to the controls' increase in accuracy over the TLE group being larger for events where they were able to retrieve the encoding context compared to when they could not. The same analyses assessing the TLE subgroups found no effect or interaction. Thus, it appears that both groups benefit in dating accuracy when they are able to recollect contextual information about their original encoding of the event memory, but there is a trend such that this is more so for healthy adults.

Similarly, a value was calculated for the mean vividness rating for correctly dated items, and incorrectly dated items or those that were not assigned a date (assuming participants did not know the year for these). Another 2 (vividness for correct items vs. vividness for other items) x 2 (TLE vs. HAC) ANOVA was conducted with group as a between subjects factor. This analysis included $N = 68$ for TLE and $N = 78$ for controls. In the above analysis comparing the two groups overall, a significant difference was found in vividness ratings across all events. Under this 2 x 2 analysis, only a marginal effect of group was found, $F(1, 144) = 3.43$, $p = .07$, $\eta_p^2 = .02$.

However, a significant main effect of vividness item type was revealed, $F(1, 144) = 223.89$, $p = .001$, $\eta_p^2 = .61$, suggesting that vividness was higher for correctly dated events. There was no interaction between vividness item type and group ($F < 1$).

Correlational analyses were conducted between the MMQ subscales and the subjective-objective measures described above. No significant correlations emerged in the HAC group. In the TLE group, significant positive associations were found between all MMQ subscales and the proportion of events correctly dated where the context was *not* recalled (Ability scale: $r = .27$, $p = .02$; Contentment scale: $r = .23$, $p = .04$; Strategy scale: $r = .35$, $p = .001$). No other correlations were found. This result is hard to reconcile as it is difficult to explain why subjective perception of memory would only correlate with this one measure of conditionalised accuracy.

Overall, this analysis reveals that increases in subjective experiences associated with episodic memory are somewhat diagnostic of the ability to correctly date previous public events; this was particularly evident for recollection of the unique encoding context, where healthy adults were more likely to retrieve this episode, which in turn elevated performance on these items.

6.5 Discussion

The present study diverged slightly from the rest of the work in this thesis by assessing memory in TLE with more *naturalistic* measures. The aims were similar, however, as the study explored the link between subjective and objective measures of memory, with the recollection aspect coming from assessment of AM in a novel public events task.

The results of the MMQ suggested that people with TLE are significantly less content, and have lower perceptions of their current memory ability than healthy adults, and also appear to utilise memory aid strategies to a lesser extent. These findings build on the well established evidence that a large proportion of patients with TLE subjectively report everyday memory difficulties (Corcoran & Thompson, 1992; Hall *et al*., 2009; Hendriks *et al*., 2002; Salas-Puig *et al*., 2009; Thompson & Corcoran, 1992). In line with this perceived impairment in subjective functioning, the TLE group were found to be impaired in the subjective measures of the task assessing memory for salient international public news events from the past decade; people with TLE reported lower levels of recalling the events, had a significantly lower instance of remembering the encoding context of such events, and lower levels of mental imagery. These results are in line with the recollection impairments in TLE already evidenced in this thesis. The relationship between retrograde and anterograde recollection is explored in the following chapter.

Despite these impairments, there was no difference in dating accuracy between groups, even for incorrect answers. Moreover, just like healthy adults, people with TLE showed evidence of intact metacognitive evaluations of their knowledge for dates. It was also revealed that an increase in measures of subjective experience (recalling the encoding context and more vivid mental imagery) was associated with better dating accuracy in both groups; for recall of the encoding context, this was found more so for controls.

To my knowledge, there has been no other study that has specifically looked at current perceptions of day-to-day memory alongside measures of retrograde memory in TLE. The present examination of the relationship between the MMQ and measures from the public events task only revealed an association between the Ability and Contentment scales and the number of events subjectively recalled in the TLE group. Although this correlation was weak, this result keeps in line with the rest of the results suggesting intact metacognitive awareness in this group; the more the TLE group were happy with their memory, and judged their memory ability to be better, the more events they subjectively recalled. This was not found in the HAC group however, suggesting there may be subtle differences in the interaction between antero-retrograde memory evaluation and subjective experience between TLE and those without epilepsy. The relationship between subjective perception of everyday memory and anterograde recognition is explored further in the following chapter as this is likely to aid understanding of the common discrepancy between perceived and objectively measured memory function in this group.

Previous group studies utilising public events tasks in TLE have typically aimed to assess the impact of epilepsy-related variables or the effect of excisions on this type of memory (Barr *et al.*, 1990; Bergin *et al.*, 2000; Lah *et al.*, 2004; 2006) and more recently, Haag et al. (2010) sought to examine the influence of long-term consolidation processes by assessing temporal gradients. Although some of these studies concurrently assessed episodic components of *personal* AM, they did not provide any measure of the influence this memory system had on the encoding and retrieval of *public* semantic knowledge. This is in spite of the acknowledgment that although there is functional and neuroanatomical independence of the episodic and semantic systems, they still work in a synergistic fashion to provide a complete memorial experience (e.g. Greve, van Rossum, & Donaldson, 2007). In the present study, participants were asked if they could specifically recall where, when and in what circumstances they learned of the event; therefore assessing the extent to which they could *recollect* it. This kind of task is usually associated with the ‘flashbulb’ memory literature, which focuses on particularly striking and memorable news events; this study was mostly interested in less salient public events that must also go through a process of contextually-bound encoding. The ‘context’ question was thus comparable to a *Remember* response in the R/K paradigm, which reflects a subjective state of awareness during retrieval imbued with contextual information about a prior event (Tulving, 2002). A recent study by Petrican et al. (2010) did in fact utilise the R/K paradigm on a public events task with two groups of older adults and two patients; one of which had medial temporal damage, the other with anterior and lateral temporal damage and sparing of medial temporal areas. They found evidence that like personal AMs, the subjective experience associated with public events follows a similar decay trajectory over time and varies according to the degree of medial temporal damage. For young-older participants (58-69 years), recollection peaked for recent time periods and sharply declined thereafter, whilst familiarity followed a linear decay path; for old-older participants (74-85 years), recollection was more impaired for recent, compared to remote time periods, due to impairments in encoding associated with age-related structural changes in the MTL. Additionally, their patient with circumscribed MTL damage displayed a global impairment in recollection with preserved familiarity, whilst the patient with lateral/anterior damage displayed good overall performance on the basis of very well preserved recollective processing.

Therefore, their results provided evidence that the retrieval of memories for culturally shared events is characterised by both episodic (subjective remembering) and semantic (subjective knowledge) processes. In the present study, although the relative decay of these memory processes over long time periods was not assessed, the findings mirror those of Petrican et al.’s (2010) old-older adult group, suggesting that people with damage to the MTL have a significantly reduced ability to consciously retrieve the contextual information associated with recent public events. This was also characterised by significantly lower levels of vivid mental imagery compared to healthy adults. Moreover, this was found in the absence of a difference in perceived personal significance of events in the two groups, suggesting the effect is not due to an asymmetry in the emotional content of participants’ memory. Taken together, the findings from the present study and those of Petrican et al. (2010) demonstrate that assessing subjective and objective indices of public semantic memory is a fruitful endeavour.

The finding that people with TLE subjectively recalled fewer events is consistent with previous studies that have found impairments in recognition or recall of public events in TLE. However, no evidence was found to suggest people with TLE were more inaccurate at dating events compared to controls, nor were they more likely to over or under-estimate the years elapsed when they incorrectly labelled the date. Taken with the findings of impaired subjective episodic measures, one may be persuaded by an argument that the ability to correctly retrieve temporal information required for dating events is more reliant on the semantic memory system, which is presumably better preserved in the TLE group. However, both groups were significantly more likely to date events correctly when they were able to retrieve the encoding context of the event and experience the memory vividly.

The better dating performance associated with the subjective measures is indicative of a reconstructive process involving more personally relevant episodic autobiographical information, consistent with *location based* theories of event dating (e.g. Friedman, 1993). These findings support Fradera and Ward (2006), who showed that events were more likely to be dated accurately when participants could assign a more specific personal context period to them and Brown (1990), who found *personal* autobiographical material was commonly verbally reported in temporal estimation tasks. In previous studies, the kinds of temporal information people report to determine dates are also supportive of *distance-based* theories (e.g. Brown, Rips, & Shevell, 1985). Distance based theories suggest that the strength or accessibility of qualitative characteristics of a memory trace influences dating accuracy, with the more information subjectively known, the more recent the event will seem. Although the vividness measure in the present study could be assumed to reflect a form of qualitative accessibility of a memory, it was not my aim to directly test this account. It is most likely, as Janssen et al. (2006) describe in their model, that different types of temporal information are employed under different conditions to date events. Future research with TLE, or other memory impaired populations could inform this literature by measuring the level of knowledge participants have for events, and assess chronological ordering over long periods of time. To further examine the contribution of episodic memory, it would also be interesting to evaluate exactly how people provided the date information; for example, assess any differences in the extent to which people with TLE and healthy adults attempted to locate the public event within the context of a more personally experienced time point or life period. Studies such as this would no doubt add to ongoing neuroscientific debate about the consolidation of episodic and semantic memory in AM.

One of the merits of studying public events knowledge in TLE and other neuropsychological populations is that results are objective, as recall and recognition rates correspond to pre-selected verifiable historical event information. Such tasks thus overcome the subjective nature of other personal AM tools that rely on introspective reports and can only be validated by a family member or close friend or relative. However, past studies have not assessed patients' evaluation and monitoring of their objective memory performance during such tasks.

The use of dating ability in the present task afforded the opportunity to incorporate such a measure as I was able to ask participants if they *thought* they knew the correct year before they selected one. By using the MMQ, I was able to see if negative perception of day-to-day memory functioning would be associated with disturbances in the monitoring of memory for other types of information. This was found not be the case. Only a handful of studies have assessed metacognitive ability in TLE, of which the most recent have incorporated standard anterograde metamemory tasks and found no impairments (Andrés *et al.,*2010; Howard *et al*.,2010). Admittedly, the metacognitive assessment here was a comparatively rudimentary measure to assess awareness of participants' knowledge; nevertheless, the results are supportive of a lack of any impairment in TLE. Drawing on all of the results discussed above, it is possible that although people with TLE may have a greater reliance on semantic rather than episodic information to chronologically order events, this may provide a sufficient heuristic on which to judge the veracity of their memory (i.e. the year the event occurred), and is hence qualitatively indistinguishable in terms of metacognitive performance.

Whilst the present study provides a useful contribution to the epilepsy and memory literature, there are also several limitations. For example, whilst the use of an online questionnaire was effective in collecting a relatively large data set, there are obvious problems associated with this kind of cross-sectional methodology. For example, whereas accurate diagnostic information was able to be obtained from the smaller sample tested throughout the rest of this thesis, there is a reliance on participants' own accurate reporting of epilepsy-related variables. Administering the task in person with patients in a clinical environment would thus be beneficial, and would ensure full completion of the task.

Given that previous evidence is inconsistent regarding the effect of epilepsy related variables on public events memory, what may be useful is a comparison of the subjective, objective and metacognitive measures used presently in different localisation related epilepsies. For example, although frontal lobe epilepsy has been associated with similar neuropsychological impairments to TLE (Exner *et al*., 2002), it may be interesting to see if this group displayed a different profile of performance on tasks such as the one here, as the prefrontal cortex is known to be critical for metacognitive processing (Maril, Simons, Mitchell, Schwartz, & Schacter, 2003; Souchay, Isingrini, & Espagnet, 2000) and play an important role in the controlled retrieval of autobiographical information (Cabeza & St. Jacques, 2007).

From a clinical perspective, although the results of the present study are useful for understanding AM impairment in TLE, group level analyses such as these are unlikely to supplement routine neuropsychological assessments unless a standardised instrument with normative values is created that can be easily administered to an individual in a clinical setting. Moreover, an inherent problem in assessing public events knowledge is that any instrument would need to have memory items updated on a regular basis, which poses a potentially large obstacle.

In summary, the present study provides confirmatory evidence to the well-documented observation that people with TLE have a negative perception of their day-to-day memory ability; this seems quite unrelated to retrograde memory performance, however. I have also provided novel evidence to suggest that although people with TLE may be impaired in subjective mnestic experiences associated with the retrieval of public event information, they showed no identifiable deficit in the ability to correctly date events. This intact objective performance was also mirrored by intact *awareness* of the veracity of temporal information and thus supports other findings in this thesis. The results provide evidence that at least under certain conditions, contextual and associative information from the episodic memory system may be used to support the retrieval of public semantic memory. In TLE, it appears that the integrity of the semantic memory system is relatively better preserved, and is sufficient to produce accurate temporal estimations of dates, at least over a recent ten year period.

Having now assessed a variety of different memory functions from a dual-process perspective, the following chapter presents a correlational analysis of these measures in an attempt to draw together all of the findings.

7 Exploring the comparability of different forms and uses of recollection: a correlational analysis

7.1 Overview

Four key findings have emerged from the work presented in this thesis. 1) the TLE sample show identifiable impairments in standardised neuropsychological tests associated with medial temporal lobe functioning; 2) consistent evidence suggests their ability to subjectively remember both newly learned and previously encoded autobiographical information is significantly reduced; 3) objectively measured performance that requires the use of recollection is impaired and 4) despite these impairments, patients still show evidence of intact metacognitive awareness, shown primarily through the above convergence of findings from subjective and objective recollection, and an appropriate assignment of confidence in accuracy. The aim of the current chapter was to synthesise some of these findings in order to address some broader theoretical and clinical questions.

As discussed in Section 1.8, recollection is conceptualised differently between dual-process theories. To recapitulate, in Jacoby's (1991) PDP framework, recollection is defined relatively strictly as a controlled process, or basis for responding, that allows one to accurately determine the source of information (i.e. which list did this come from? Or, which item was this studied with?). It is therefore measured, or estimated objectively, through task performance. On the other hand, the first-person approach as advocated by Tulving (1985) and Gardiner (2001) sees recollection as a state of consciousness that arises from the retrieval of a variety of contextual and associative information. Despite these differences, previous evidence (e.g. Yonelinas, 2001*a*) and that provided here, suggests that there is convergence between methods used to assess them. Therefore the subjective state of remembering is at least to a certain extent a reflection of the underlying process used in more objective based tasks. However, an interesting addition to this theoretical issue is to explore the *relationship* between different measures of recollection across tasks. The overriding question here is, does recollective ability, or the propensity to subjectively experience recollection in one task relate to other tasks? The first part of this chapter thus presents an exploratory correlational analysis of some key summary measures from each experimental chapter.

Examining the relationship between different familiarity measures may also provide a useful addition to the dual-process literature. However, because the focus of this thesis was primarily to better understand the nature of recollective processes and subjective experience in TLE, it was decided not to include such analyses in the present chapter. Importantly, it is acknowledged that the existence of correlations between recollection *and* familiarity measures has, in the past, been argued to provide evidence refuting the critical independence assumption adopted within dual-process theories (Curran & Hintzman, 1995;1997; *see* Jacoby, Begg & Toth, 1997 and Jacoby & Shrout, 1997, for a rebuttal to these claims). Although this kind of analysis is evidently important for the interpretation of dual-process data more broadly, it was beyond the scope of the present work to add to this debate. Hence, only recollection measures were included.

A further question – of clinical relevance - is to what extent is neuropsychological test performance related to different indices of recollection? As discussed in Section 1.11.2, this kind of question has received empirical attention in the older adult literature to test the hypothesis that aging is associated with decrements in recollection due to both MTL and frontal lobe dysfunction (e.g. Bugaiska *et al*., 2007; Clarys, Bugaiska, Tapia, & Baudouin, 2009; Davidson & Glisky, 2002; Prull *et al*., 2006).

A common observation in the TLE literature is that patients subjectively complain of poor memory, but their standardised test scores do not corroborate this. One possible explanation which has had little attention is that standardised neuropsychological assessments may lack *specificity* and do not cover a broad enough range of memory functions to highlight what may be subtle impairments. The sample presented here subjectively complained of poor memory but were also impaired compared to controls on a number of neuropsychological tests associated with MTL function. However, it is still of interest to explore whether there is a relationship between such scores, and measures of recollection. The second part of this chapter thus presents a correlational analysis between various neuropsychological test scores and the summary recollection measures taken from the experimental tasks in this thesis. Because these tests are classically used to assess integrity of MTL function, we would expect at least some correlations to emerge between measures due to the fact that recollective binding is dependent on this brain area. Because the neuropsychological assessment included several measures associated with executive function, this also allowed the opportunity to add to the findings gleaned from the older adult literature regarding the role of recollection in frontal functioning.

Finally, the potential influence of anxiety and depression on experimental measures is examined. Whilst the control and TLE groups were well matched on HAD scale scores, mood disorders are more common in TLE than the general population (Marsh & Rao, 2002) and it was deemed important to assess the possibility that recollective ability may be mediated by these variables.

In summary, the main focus in the present chapter was on assessing the relationship between recollection and the above measures in the memory-impaired epileptic sample with the aim of contributing to the TLE and dual-process literatures. As such, just the epileptic group are presented. The sample sizes included in each analysis varied depending on the measures included – although the exact *N* is only reported for individually reported correlations, the range of participants is noted for the larger analyses. Separating the sample into LTLE, RTLE and BTLE groups would have resulted in too small numbers for this correlational approach, and so the analysis disregarded laterality subsamples. Full correlation matrices are presented for analyses that yielded a number of significant Pearson coefficients at the $p < .05$ level; for others, only individual significant correlations are reported.

7.2 Correlational analysis of experimental recognition measures

Due to the large number of measures derived from each experimental task, a certain degree of selectivity was necessary, so each analysis was limited to a few key variables. Firstly, the overall aim was to assess the relationship between measures of recollection; therefore, standard recognition memory performance measures (e.g. *A′* or item memory scores) were not included. Further, although the presentation of all the varieties of subjective IRK estimates allowed for a comprehensive approach within each experiment, they were not included here. Instead, only the standard Remember IRK calculation was used, as there is a precedent in the dual-process literature to report this. The objective measure of recollection used for the contextual source memory task (Chapter 3) was the overall probability of correctly recalling contextual features of successfully recognised items (i.e. the average proportional accuracy for location, order and colour). Measures from the word and face repetition-lag PDP tasks (Chapter 4) include the collapsed mean objective process estimations of recollection for repeated lag-items. For the associative recognition task (Chapter 5), objective measures included associative reinstatement and associative identification *d*′ estimates and PDP derived recollection estimates. Correlations between all of these measures are presented in Table 7.1 but for clarity these are discussed in three different sections; 1) correlations between subjective recollection measures, 2) correlations between objective recollection measures, 3) correlations between subjective and objective measures, The *N* ranged between 20-24 patients for all correlations.

7.2.1 Correlations between subjective recollection measures

The three subjective measures of recollection in Table 7.1 include Remember judgments in the source memory experiment (1), word repetition-lag Remember judgments (4) and the face repetition-lag Remember judgments (6) assigned to correctly recognised study items. Word and face repetition-lag Remember judgments significantly correlated with one another, but neither did with Remember judgments in the source memory task. The correlation between these two subjective measures may be due to commonalities in task demands. Despite the differences in type of information being processed, it may be that subjective recollection operates in a similar way under these task parameters, meaning patients who have a better ability to subjectively remember items in one task are also able to in the other.

7.2.2 Correlations between objective recollection measures

The objective measures were the proportion of correctly recalled contextual features in the source memory paradigm (2); the PDP estimates of recollection for repeated item performance in the word (3) and face (5) repetition-lag tasks; associative reinstatement (7); associative identification (8) and the associative recognition PDP estimate of recollection (9). A number of significant positive correlations emerged between these measures.

The proportion of contextual features recalled on the source memory task and face and word PDP recollection estimates all correlated significantly with associative identification; the word and face PDP task recollection estimates correlated with each other; and the proportion of contextual features in the source memory task correlated with the face PDP recollection estimate.[17]

The correlation between the word and face PDP recollection estimates is perhaps the one that would be most expected due to the fact that recollection is strategically applied in the same way in these tasks despite differences in the material being processed. That is, recollection can be used with familiarity to accept repeated inclusion items, but it alone is necessary to *overcome* familiarity and reject repeated items in the exclusion test.

Whereas the repetition-lag estimate provides a strict measure of the extent to which one can use recollection to discriminate between items from different lists, associative identification and the retrieval of contextual features in the source memory task are similar in that they provide a measure of recollective *binding* ability. For the source memory task, this is a measure of the binding of various perceptual and temporal information, and associative identification is a measure of the extent to which recollection is successfully used to restore bound representations of two words that were initially encoded. Despite differences in the way each measure conceptualises recollection, the fact that moderate significant correlations exist between them suggests that it is a common underlying process. Notably, however, the measures did not all correlate with each other, suggesting there are other contributing factors.

7.2.3 Correlations between subjective and objective measures of recollection

One of the critical aims of this thesis was to explore the extent to which objective recollective processes are related to the subjective experience of remembering. Evidence in support of this has already been displayed by the fact that patients are impaired on both types of measure. Positive correlations between subjective and objective measures provide complementary evidence, as they suggest that better recollective ability in performing a task has a *relationship* with the probability of engaging in subjective remembering. Some support for this is borne out of the data in Table 7.1 (analysis of which includes a total of 36 comparisons between

[17]There were also significant correlations between the objective measures in the associative recognition task; the recollection estimate correlated positively with associative identification and negatively with rearranged item FPs. Associative identification was also negatively correlated with this FP rate. Because these measures use similar item performance within their calculations, these correlations are unsurprising – I therefore discuss them no further. Moreover, the reader will notice that the confidence ratings from the associative recognition experiment are not included in Table 7.1; analyses showed there to be no significant correlation between some key confidence measures associated with the items that are more or less dependent on recollective processes and the measures from other tasks. Instead, as above, correlations only existed between these confidence ratings and the other measures *within* the task (i.e. associative identification and recollection estimates), which is again unsurprising and is also covered in Chapter 5 where the overall level of confidence is discussed in relation to the magnitude of the measures they are related to in both groups.

measures). The proportion of subjective Remember responses in the source memory task correlated with the total amount of contextual features retrieved, the word repetition-lag PDP recollection estimate and also with associative identification; the word repetition-lag PDP subjective Remember proportion correlated with both word and face PDP objective estimates and associative reinstatement.

The correlations that have been observed so far between the two repetition-lag tasks are perhaps the most interesting. As Kelley and Jacoby (1998) discuss, recollection and familiarity estimates derived from the PDP are *context dependent*. So, different material types will provide a different context in which to support automatic and controlled uses of memory. Because of this, they suggest, the estimates will be isolating different things between tasks and not necessarily comparable. However, the significant correlations found between subjective and objective measures of recollection between the word and face tasks is suggestive that the cognitive and subjective basis of recollection is similar between the two, despite the fact that participants are using this process to discriminate between two qualitatively different types of information.

Taken as a whole; the very existence of the above correlations provides evidence in a memory impaired population that subjective and objective measures of recollection are correlated within and between tasks. This suggests that even in spite of impairments caused by damage to critical MTL brain areas, the conscious experience of remembering has a relationship with an identifiable cognitive process.

However, when making such a large scale comparison of different measures, the risk of making a Type I error is increased; in the context of the results above, this means that not correcting for such error may result in *falsely* accepting that there are true relationships between the measures. A typical method to overcome this is the Bonferroni correction, where a modified significant criterion is used (α/k, where k is the number of different comparisons or statistical tests). Using the appropriate Bonferroni correction, α would be set at .001 (.05/36). For some of the other analyses presented in this chapter (such as recollection measures with neuropsychological tests), this value would decrease even more as an even larger number of comparisons are made. In short, very few of the correlations stand up to this strict criterion.

Table 7.1 Correlation matrix for key measures of recollection across experimental tasks in the TLE group.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Source Memory R	-								
2. Source Memory Total Context Prop	.46	-							
3. Word PDP Combined Lag R	.53	.36	-						
4. Word PDP Hit Subjective R	.12	.34	.45	-					
5. Face PDP Combined Lag R	.34	.51	.42	.45	-				
6. Face PDP Hit Subjective R	.14	.18	.27	.45	.25	-			
7. AR Associative Reinstatement *d′*	.20	.42	.29	.48	.20	.23	-		
8. AR Associative Identification *d′*	.45	.20	.66	.43	.55	.24	.19	-	
9. AR R estimate	.15	-.08	.34	.17	.31	.05	-.25	.68	-

Note: R = recollection, Prop = proportion, Word PDP = word version of the repetition-lag process-dissociation procedure, Face PDP = face version of the repetition-lag process-dissociation procedure, AR = associative recognition task, AI = associative identification. Pearson correlation coefficient values underlined are significant at the $p < .05$ level; values underlined in solid line are significant at the $p < .01$ level.

Whilst the potential problems of inflated Type I error rates are fully acknowledged, the Bonferroni correction was not applied here. As Perneger (1998) describes, the Bonferroni method leads to a substantial reduction in the statistical power of rejecting the null hypothesis. That is, as Type I error is reduced, Type II error increases. One way of reducing the probability of making a Type I error is not to include irrelevant variables in analyses; as was described earlier, some *key* measures of recollection were chosen, and a number of variables were not included for the very reason that they were likely to create added noise to the analysis. As Pernenger (1998) states, simply describing what tests of significance have been performed and why, is generally the best way of dealing with multiple comparisons. Correlations were examined between subjective and objective recollection because there is good theoretical reason (derived both behaviourally and neuroanatomically) to believe a relationship would exist between them.

Further, there is no agreed upon consensus as to when Bonferroni corrections should be used[18] (Nakagawa, 2004; Perneger, 1998). As these authors discuss, the correction method has been removed from the context of its original framework, where it was advocated as a means to aid decision making in repetitive situations (Neyman & Pearson, 1928). In contrast, the purpose of the present investigation was to explore the co variation between similar memory processes. Although *strict* Bonferroni corrections were not applied here, I return to this issue later on with reference to other comparisons.

7.3 Correlations between recognition measures and naturalistic measures

The sections above focused exclusively on the measures of recollection derived from the anterograde recognition memory tasks presented in Chapters 3-5. It was seen in Chapter 6 that there was little relationship between any of the three subscales from the MMQ (Contentment, Ability and Strategy) and the objective and subjective autobiographical measures from the public events task. However, the relationship between subjective perception of memory, autobiographical measures, and anterograde measure of recollection has not been previously examined in TLE.

[18] As the reader will have noted, Bonferroni corrections have been used in other statistical analyses dealing with laterality effects throughout this thesis, where the number of comparisons is smaller. This was primarily because of the smaller numbers in each group and much variability within scores; hence, the likelihood of making Type I error was high. In any case, the direction and meaning of the results has always been discussed even if the correction led to non-significant findings.

7.3.1 Subjective perception of memory and anterograde recognition

The interesting theoretical and clinical question outlined in the Introduction is to what extent patients' subjective perception of their memory is related to measures of recollection derived from recognition performance. It has already been shown in this thesis that patients' subjective reports of memory can be valid assessments of the underlying cognitive process engaged during recognition. Therefore, I next investigated the extent to which scores on the MMQ would relate to recognition based recollection measures (see APPENDIX I) This included the nine subjective and objective measures included in Table 7.1 and the three individual subscales of the MMQ (resulting in 27 comparisons). In summary, only one significant correlation emerged – this was between the Ability subscale and the proportion of subjective Remember responses assigned to study items in the face repetition-lag PDP task (r = -.46, p = .04, N = 20). The evidence presented here therefore suggests that patients' perception of their day-to-day memory ability, contentment or affect related to their memory dysfunction, or use of compensatory strategies is not related to recollection measures derived from empirical tasks.

When taking into account the content of the questions in the MMQ, this lack of relationship is unsurprising. The memory Ability subscale perhaps theoretically shares the most in common with performance on a recognition task, as it asks questions related to errors in memory. However, although some of these could be compared to failures in recollection (e.g. How often do you retell a story or joke to the same person because you forgot that you had already told them?, or How often do you have trouble remembering details from a newspaper/magazine article you read earlier that day?) many of the questions represent abilities that are dependent on other memory processes. For example, "How often do you forget a birthday or anniversary that you used to know well?" This question arguably addresses a failure in *semantic* memory. Others deal with prospective memory, for example, "How often do you forget to buy something you intended to buy?" Clearly these questions are designed to capture instances of memory failure in everyday situations and the MMQ is thus a useful measure of general perception of memory. The measurement of recollection in experimental recognition memory tasks is rather more specific, and although the evidence above suggests that a common subjective and objective recollective process may operate between such tasks, general everyday memory questions are perhaps not the best way of measuring this. It may be that a more specific questionnaire of everyday memory ability that targets instances of recollective failure may show more correspondence to these measures.

As mentioned in Chapter 1, previous research that has assessed the relationship between TLE patients' subjective reports of memory and neuropsychological test performance has often found little correspondence between the two (see Hall *et al*., 2009, for a review). A variety of subjective report measures have been used in such studies, but the MMQ has not been previously deployed.

The analysis of the MMQ and public events task in Chapter 6 included 15 of the patients recruited for my main research project as well as others recruited via the internet solely for the purposes of that study. The other patient participants in the current project were all asked to complete the MMQ and public events questionnaire, but those who had not completed these before a predetermined date were excluded from the analysis in Chapter 6. A further six questionnaires were returned after this date (by patients 5, 8, 12, 15, 20 and 25), three of which only contained a completed MMQ (patients 8, 20 and 25). Thus, a correlational analysis of the MMQ subscales and the raw scores[19] from the 12 neuropsychological tests outlined in Chapter 2 was carried out with N = 19 and 20, varying due to missing neuropsychological data in certain cases (APPENDIX I).

This analysis showed there to be no significant relationship between the Ability, Contentment and Strategy subscales and neuropsychological measures, except for one significant correlation between the Strategy subscale and FAS verbal fluency score (r = -.67, p = .001, N = 20). The interpretation of this would be that people who reportedly use fewer memory aid strategies have poorer verbal fluency. This verbal fluency test measures the number of words spontaneously produced beginning with the letters F, A and S over a three minute period. Better performance on this task is thus aided by the initiation of some form of strategy. In the case of the letter 'F', for example, going through words beginning F*a*, F*e*, F*i* and so on, would be an example of a strategy likely to benefit performance more than simply generating random words beginning with the letter. This initiation of strategies is reliant on intact executive function; the items in the Strategy subscale of the MMQ include tasks that similarly involve this kind of mental planning and organisation (e.g. "How often do you create a story to link together information you want to remember?" Or, "How often do you mentally elaborate on something you want to remember?"). The correlation therefore suggests that those who do not engage in daily strategic activities to enhance memory perform worse on a task that involves a similar strategic component.

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[19] Raw scores were used in this analysis and those presented in Section 7.4 because the MMQ and various recollection estimates are not standardised for age like the normative values in these neuropsychological tests. Therefore, using raw scores helps control for the added variability between the measures.

The pattern of results across the current TLE sample differs from the literature mentioned above (i.e. Hall *et al*., 2009) because it was found that patients had both significantly lowered perceptions of their memory functioning *and* were impaired on standard neuropsychological measures. Therefore, their subjective complaints can be seen to be validated objectively in clinical terms. However, the lack of correlation between these two provides further support for the discussion above that self-report measures, due to their focus on specific everyday difficulties, may be measuring fundamentally different memory constructs to those captured in standardised tests.

7.3.2 Comparison of anterograde recollection with autobiographical measures

A correlational analysis was conducted between the same nine recollective measures from the anterograde experimental tasks as above and a similar set of public events variables that were used in the correlational analysis in Chapter 6 (APPENDIX I). The subjective measures included the proportion of events subjectively recalled, the proportion of items where the specific context of learning of the event was recalled, the mean vividness rating across all events, and the mean vividness only for events that were subjectively recalled. The objective measures included the total number of events correctly dated, the proportion of years attempted that were correctly dated. Thus, there were 54 comparisons made. Only four significant correlations emerged. The proportion of events subjectively recalled correlated positively with the objective and subjective recollection estimates from the word repetition-lag PDP task (r = .64, p = .01; r = .78, p = .001, N = 16 for both) and the associative identification estimate (r = .52, p = .05, N = 15). The large Pearson values for the correlation with the word repetition-lag PDP task are particularly compelling, given the small sample size here. Interestingly, the way the ‘recall’ question was phrased to participants in the public events task did not specifically orient them toward recollection – it was in fact the ‘context’ question that did this as it probed the participant to retrieve a unique episode in which they acquired information regarding the public event. Although simply ‘recalling’ an event may to a certain extent be reliant on semantic knowledge, the results here provide evidence to suggest that a better ability to subjectively and objectively recollect in some anterograde recognition measures is related to a greater ability to recall non-personal autobiographical events. Despite this relationship, it is unclear why the vividness associated with the recall of these events did not correlate with the anterograde recollection measures.

Furthermore, the total number of events correctly dated correlated with the total proportion of contextual features recalled in the source memory task ($r = .55$, $p = .02$, $N = 17$). This result also makes sense theoretically; better performance in the source memory task is suggestive of successful binding of multiple contextual features. Likewise, remembering the year that something happened is likely to require the retrieval of information bound to the event at encoding.

This is the first time a comparison of subjective and objective recollective measures between retrograde and anterograde tasks has been conducted within the same TLE sample in this way, and although little clear-cut evidence emerged, it would be of theoretical interest to explore this further. Using AM tasks that assess personal episodic memories may be more likely to reveal relationships with anterograde recollection due to their shared neurobiological substrates. However, the non-significant correlations are interesting in light of the fact that deficits were found in both measures in the TLE group. This suggests that the tasks are measuring different things. Unfortunately, the interpretation of such null findings is faced with the same problems as the significant correlations; the sample sizes were small, meaning reduced power to detect any meaningful relationships.

Overall, the results provided here suggest there may be some relationship at the group level, but precise lesion documentation would be highly instructive in this kind of analysis to specifically assess the extent to which selective MTL damage affects antero-retrograde recollection.

7.4 Correlational analysis of neuropsychological performance and experimental measures

7.4.1 Correlation with anterograde recollection

As discussed in the Introduction, the relationship between neuropsychological tests and measures of recollection has been examined previously, predominantly in the aging literature. To my knowledge, this has not been conducted in TLE however, and certainly not with such a large comparison of empirical tasks.

Table 7.2 presents a correlational analysis of the key recollection measures used in the sections above, as well as the raw scores from each neuropsychological test (*N* ranged between 20-24 participants). The correlations between each neuropsychological test are not reported as it was not the aim to assess the relationship between these (but see Discussion). The analysis included 108 comparisons.

There are several main points, or questions, to examine within this data: 1) Do measures of recollection *generally* correlate with neuropsychological test performance? 2) Is there a difference in the extent to which objective and subjective measures correlate with the neuropsychological tests? 3) Are the neuropsychological tests associated with executive, or frontal functioning correlated with recollection to the same extent as those reliant on MTL functioning? 4) Are there observable differences in the number of correlations between recollective measures and neuropsychological tests fractionated further along theoretical lines? Rather than state the individual correlations between measures, I will give a summary of the findings and how they relate to each question.

Do measures of recollection correlate with neuropsychological tests? It is clear from Table 7.2 that a number of recollective measures correlate significantly with neuropsychological test performance. The recollection measures that share the most correlations with these neuropsychological tests are the subjective and objective recollection estimates from the word repetition-lag PDP task (2 and 5) and the associative identification estimate (8). In contrast, the total proportion of contextual features recalled in the source memory task (4), the subjective recollection estimate of the face repetition-lag PDP task (3), associative reinstatement (7) and the objective recollection estimate from the associative recognition task (9) have the fewest correlations between neuropsychological test scores. An obvious question then, is what are the differences between the recollection measures that do and do not correlate well with neuropsychological tests? Addressing the following issues sheds light on this.

Is there a difference in the extent to which objective and subjective measures correlate with the neuropsychological tests? There appear to be no clear differences in the extent to which subjective or objective recollective measures correlate with the neuropsychological tests; the only notable observation here is that the face PDP subjective recollection measure (6) did not correlate with many of the neuropsychological measures, where as the other two verbal based subjective recollection measures did. However, it did correlate with another non-verbal test (BMIPB figure immediate; 10). Notably, the majority of the neuropsychological tests were verbal in nature, meaning a direct verbal/non-verbal comparison is difficult. Differences in material type are discussed further below.

Are the neuropsychological tests associated with executive, or frontal functioning correlated with recollection to the same extent as those reliant on MTL functioning? There is some evidence to suggest that recollective measures correlated with neuropsychological tests that are more reliant on executive function. This was most evident for the category fluency score (19), which correlated with three recollection measures, both subjective and objective. Fluency and digit span may not be the most representative measures of executive function. However, an influential model proposed by Miyake et al. (2000) suggests that executive function is characterised by three interrelated, yet separately operating processes of shifting, updating and monitoring and inhibition. To gain a more comprehensive measure of executive function, a more complex task that requires the use of all of these, such as the Wisconsin Card Sorting Test (WCST; Berg, 1948) may be more suitable. Indeed, in the older adult literature, subjective Remember judgments have been found to correlate with measures derived from this task (Clarys *et al*., 2009). Of course, older adults and TLE patients are fundamentally different in terms of neuropathology, and other studies have found no such relationship between frontal-measures and a variety of objective and subjective measures of recollection in aging *(*Prull *et al*., 2006). Future work with TLE samples would be useful to assess the contribution of frontal-lobe functioning to recollection.

From Table 7.2, there is, however, compelling evidence that recollection measures are related to neuropsychological tests of MTL functioning. These correlations were found for subjective Remember judgments drawn from different paradigms, objective recollection estimates drawn from single item inclusion/exclusion performance, and a recollective measure of relational binding in associative recognition.

Returning to the problem with multiple comparisons, a breakdown of these associations reveals that the number of significant correlations found exceeds the number that would be predicted to occur by chance. As a whole, there were 108 relationships analysed (9 recollection measures x 12 neuropsychological measures) and 36 significant correlations were found. With α set at .05, approximately 6 correlations would be expected to occur by chance. When using a Bonferroni correction that takes into account such a high number of comparisons, there are no resulting significant correlations (with α adjusted to a highly strict .0005 level). Although some of the correlations may occur due to noise in the data, a number of these had Pearson values ≥.60, which is considered to be a moderate-large effect size (2 and 13; 5 and 10; 5 and 11; 6 and 12; 8 and 14; 8 and 15). It seems unlikely that interpreting this data as meaning there is a relationship between recollection and neuropsychological measures is simply a systematic Type I error. Moreover, the aim was not to provide conclusive evidence that the recollection indices and neuropsychological tests are measuring the exact same construct. Rather, it was a theory driven exploratory analysis looking at the *potential* relationships between them.

The results provide support for the study cited above by Prull et al. (2006), who found objective recollection estimates from inclusion/exclusion performance and proportions of subjective Remember judgments were highly correlated with a composite neuropsychological measure of MTL function. Additionally, the experiments presented here, although using a similar paradigmatic approach to those authors, had varying test instructions and task demands. These results are also drawn from a within-participants comparison similar to Prull et al. (2006), removing some of the problems associated with comparing correlations between measures from different groups of participants and tasks.

Are there observable differences in the number of correlations between recollective measures and neuropsychological tests fractionated further along theoretical lines? Two distinctions can be made here – between verbal and non-verbal tasks, and between immediate and delayed tasks. The two non-verbal neuropsychological tests used were the BMIPB figure and WRMT faces; the former appears to correlate with a number of recollection measures (especially the immediate score), where as the WRMT face component shares little relationship with these measures. Given that the WRMT involves a 2-AFC format, where participants must simply choose which face they recognise from the study phase, this task is solvable by familiarity alone. The BMIPB figure however, is arguably more reliant on recollection as a complex, unmeaningful, integrated set of geometric shapes must be recalled from memory. Although familiarity may be helpful if participants use a 'generate-recognise' strategy (where they begin drawing part of the figure and use familiarity to add extra features to this), it is most likely that a recollective process is more heavily involved. In terms of laterality findings for the non-verbal face repetition-lag PDP task, the objective recollection estimate correlated with both verbal and non-verbal neuropsychological measures, and the subjective estimate only correlated with the immediate BMIPB figure score. Therefore, there appears not to be any special relationship; of course, it must be taken into account that this analysis collapsed across patients with both left, right and bilateral foci, so it may not be the best suited to drawing conclusion regarding laterality.

The second distinction between the neuropsychological tests is between immediate and delayed performance. Delayed verbal memory performance in particular has been related to hippocampal integrity (Kalviainen *et al*., 1997), and as described in the main Introduction, recent dual-process neurobiological models of memory ascribe special importance to the rhinal cortices in the processing of incoming information (e.g. Montaldi & Mayes, 2010). In short, the results here provide little evidence that delayed neuropsychological tests scores correlate more with measures of recollection; in fact, the opposite pattern can be observed.

In summary, the results suggest that a better ability to subjectively remember both visual and verbal material, and a better ability to use recollective processes to solve complex recognition memory tasks is positively related to performance on a range of neuropsychological memory tests. Despite the small number of tests of executive function, the evidence suggests more of a relationship between recollection and MTL functioning. As a final cautionary note, although it has been argued that a Bonferroni correction applied to the analyses may artificially increase Type II error, one must still interpret the results tentatively as it is difficult to draw firm conclusions with this small sample size and large number of comparisons.

Table 7.2 Correlation matrix between anterograde recollection measures and neuropsychological tests for the TLE group.

		MTL measures								*Executive measures*			
		10. BMIPB Fig Imm	11. BMIPB Fig Del	12. BMIPB List A1-5	13. BMIPB List 6	14. BMIPB Story Imm	15. BMIPB Story Del	16. WRMT Words	17. WRMT Faces	18. FAS verbal fluency	19. Category fluency	20. Digits forward	21. Digits back-ward
Subjective	1.Source Memory R	.48	.38	.44	.24	.31	.23	.44	.15	.30	.33	.44	.47
	2.Word PDP Subjective Hit R	.56	.58	.53	.68	.40	.38	.45	.47	.33	.55	.24	.19
	3.Face PDP Subjective Hit R	.43	.36	.16	.21	.09	.10	.22	.36	.15	.59	.44	.19
Objective	4.Source Memory Context Prop	.22	.16	.28	.31	.08	.13	.56	.18	.29	.18	.20	.00
	5.Word PDP Combined Lag R	.60	.62	.53	.55	.50	.48	.51	.31	.13	.46	.09	.30
	6.Face PDP Combined Lag R	.44	.41	.63	.52	.38	.41	.52	.13	.38	.40	.34	.37
	7.AR Associative Reinstatement d'	.17	.16	.29	.40	.27	.37	.33	.40	.30	.19	-.01	.11
	8.AR Associative Identification d'	.52	.49	.53	.42	.70	.65	.45	.10	.50	.35	.22	.33
	9.AR R estimate	.29	.35	.42	.19	.42	.45	.37	-.28	.25	.17	.07	.16

Note: R = recollection, Prop = proportion, Word PDP = word version of the repetition-lag process-dissociation procedure, Face PDP = face version of the repetition-lag process-dissociation procedure, AR = associative recognition task, AI = associative identification, MTL = medial temporal lobe, BMIPB = BIRT Memory and Information Processing Battery (Coughlan *et al*., 2007), WRMT = Warrington Recognition Memory Test (Warrington, 1984). Pearson correlation coefficient values underlined are significant at the *p* < .05 level; values underlined in solid line are significant at the *p* < .01 level.

7.4.2 Correlation with public events measures

The analyses presented in Section 7.3.2 suggested that the proportion of events subjectively recalled from the public events task in Chapter 6 was most related to measures of recollection. The analysis above in Section 7.4.1 suggested recollective measures were correlated with a number of neuropsychological tests. The next enquiry was to see if neuropsychological test scores correlated with the public events test scores. This analysis is presented in Table 7.3 and is based on similar participant numbers (between 16 and 17 patients) as that in Section 7.3.2. A total of 72 comparisons were made. The results converge with the findings outlined above; the proportion of events subjectively recalled (1) correlated with a number of MTL neuropsychological tests (7, 8, 10, 11 and 16). This provides even further evidence that this measure reflects a form of autobiographical *recollective* process mediated by MTL functioning. In terms of the two objective scores of dating accuracy (3 and 4), almost no relationship was found between these and neuropsychological measures. This was except for a positive relationship between the total number of events dated correctly (3) and verbal fluency (15). The fact this measure displayed consistent positive (but mostly non-significant) correlations with neuropsychological measures and proportion of years attempted that were correct shared consistent, non-significant correlations perhaps highlights the limitations of making comparisons between such qualitatively different forms of memory in a correlational analysis.

Whereas the vividness measures from the public events task did not correlate with recollection, the mean vividness score across all events (5) did in fact correlate with immediate (11) and delayed (12) story recall, the WRMT faces (14) and verbal fluency (15). One theoretical explanation of this could be that the these two MTL neuropsychological tests may share a common visual component to them; face recognition is a typical visual measure, but successful story recall has been associated with a better ability to imagine events (e.g. Sadoski, Goetz, Olivarez, Lee, & Roberts, 1990). This common visual component may partially explain the relationship with perceived vividness in the public events task.

Similar to Section 7.3.2 however, the mean vividness associated only with subjectively recalled events (6) did not show the above pattern; in fact, this measure significantly negatively correlated with both digit span measures (17 and 18). Because the overall mean vividness measures takes into account many more responses, perhaps this measure is after all more sensitive in detecting a wider continuum of the contribution of recollection to recall of public events. Future work using different measures of recall for different types of memory is likely to clarify this issue.

Table 7.3 Correlation matrix between key public events task measures and neuropsychological tests in the TLE group.

	7. BMIPB Fig Imm	8. BMIPB Fig Del	9. BMIPB List A1-A5	10. BMIPB List 6	11. BMIPB Story Imm	12. BMIPB Story Del	13. WRMT Words	14. WRMT Faces	15. FAS verbal fluency	16. Category fluency	17. Digits forward	18. Digits backward
1.Prop events subjectively recalled	.55	.51	.34	.59	.51	.44	.38	.40	.47	.63	.30	.25
2.Prop events context recalled	.26	.17	.06	.22	.19	.16	.20	.03	.23	.25	.03	-.15
3.Number of events correctly dated	.16	.12	.17	.34	.28	.22	.27	-.08	.52	.24	.16	.11
4.Prop years attempted that were correct	-.38	-.39	-.44	-.36	-.32	-.26	-.09	-.11	-.09	-.02	-.10	-.29
5.Mean vividness all events	.44	.36	.24	.46	.61	.57	.37	.52	.64	.24	-.20	-.29
6.Mean vividness events subjectively recalled	.07	.02	.02	.06	.34	.37	.28	.15	.41	-.19	-.50	-.53

Note: Prop = proportion, BMIPB = BIRT Memory and Information Processing Battery (Coughlan *et al*., 2007), WRMT = Warrington Recognition Memory Test (Warrington, 1984). Pearson correlation coefficient values underlined are significant at the *p* < .05 level; values underlined in solid line are significant at the *p* < .01 level.

7.5 The role of anxiety and depression levels

As mentioned in the main Introduction, anxiety and depression are common in TLE, and high symptom levels of these have been found to inflate patients' subjective worries about memory. The relationship between depression, anxiety and objective memory performance is quite variable, however. For example, Burt, Zembar, and Niederehe (1995) found clear associations between memory impairment and depressive symptoms in a clinically depressed sample, but this varied among different types of memory and throughout different subsets of depressed individuals. In TLE, depressive symptoms have been associated with impaired auditory memory, but again, the relationship is highly variable, being influenced by factors such as laterality of focus and degree of hippocampal integrity (Dulay, Schefft, Fargo, Privitera, & Yeh, 2004). Similarly, the deleterious effects of anxiety on memory have been suggested to be quite specific, for example, by reducing attentional capacity and hence reducing short-term or working memory load (Eysenck & Calvo, 1992). It is therefore possible that elevated levels of anxiety or depression could contribute to impairments in recollection, as well as other forms of memory.

A correlational analysis was performed for the TLE group between HAD scale (Zigmond & Snaith, 1983) anxiety and depression scores and all subjective and objective experimental antero-retrograde measures described in the above analyses (Appendix I; a total of 36 comparisons were made). Anxiety and depression scores had a strong significant positive correlation with each other ($r = .64$, $p = .001$, $N = 23$), which is in line with a wealth of research suggesting a high degree of comorbidity between these symptoms (see Pollack, 2005, for a review). However, anxiety scores did not correlate with any of the anterograde or retrograde recollection measures outlined above. This finding is highly encouraging, as it suggests that despite the elevated (yet non-significant) levels of anxiety in the TLE group, this was not likely to be the reason for their recollection impairments.

Depression only had one significant negative correlation with the proportion of events where the specific encoding context was recalled in the public events task ($r = -.50$, $p = .04$, $N = 17$). This is consistent with existing literature that has shown depression is related to over-general autobiographical memories that lack specificity of content (e.g. Brewin, Reynolds, & Tata, 1999). In general, these findings suggest concomitant mood disturbance was not related to recollective memory ability, especially for anterograde recognition tasks.

Finally, the correlational analysis between the MMQ subscales and anxiety and depression revealed only one significant correlation: The MMQ Strategy subscale had a significant negative correlation with HADs anxiety ($r = -.48$, $p = .03$, $N = 20$). Because lower scores on the Strategy subscale indicate a *greater* use of memory aid strategies, this correlation suggests people who are more anxious engage in more of these activities. This makes intuitive sense; if a person is worried about their memory, they are probably more likely do to things that will help them remember information. Of course, a causal relationship cannot be concluded from this analysis – it could be argued that engaging in these memory aid activities actually results in further anxiety about memory.

7.6 Discussion

Having established impairments in subjective and objective recollection in TLE in the rest of this thesis, the current chapter had a clear aim of exploring a range of broader theoretical and clinical aims. The key findings were that a clear positive relationship exists between recollection measures derived from different experimental paradigms; these, and other neuropsychological memory scores are largely dissociable from subjective perceptions of memory (as measured through questionnaire self-report); recollective ability, both subjective and objective, is related to neuropsychological tests of MTL functioning; and finally, non-clinical anxiety and depression levels have a negligible relationship with measures of recollection.

The observed relationships between different measures of recollection between and within tasks provides support for the contention that despite the different conceptualisations of recollection embodied in various dual-process led experimental paradigms, each of them are measuring a common cognitive process (Yonelinas, 2001).

However, this analysis was not meant to provide a definitive theoretical account of the covariation between different recollection measures. Rather, it was an exploratory analysis meant to add to the findings already presented that subjective and objective recollection, although impaired in TLE, may be calibrated and hence related to some extent. The data on which these correlations are based could of course be broken down and analysed in various ways to further explore these relationships. There are also many other measures that were not included in the analyses which may also covary with one another, such as measures of familiarity, recognition sensitivity and bias. As mentioned in the Introduction, further assessment of the relationship between recollection and familiarity measures is likely to add to continuing debate regarding the independence assumption of dual-process theories, and would no doubt inform our understanding of the way in which these two processes are used in concert to aid memory performance. Unfortunately, such an analysis requires a detailed consideration of further statistical concepts that it was felt would detract away from the main focus of the current chapter.

There are also alternative methods for assessing the dependencies between the above variables, which could be utilised in further investigations. For example, using path analysis or structural equation modelling, comparisons could be made between the data obtained from patients and controls. Notably, recent attempts have been made to assess the relationship between recollection and familiarity, such as using hierarchical nonlinear regression techniques (Pratte & Rouder, 2012). Clearly, this is still a ripe area of research that will continue to receive empirical attention.

From a clinical perspective, appreciating the exact processes, and hence brain areas involved in certain neuropsychological tests, is crucial. This is because neuropsychological assessment has become fundamental in surgical decision making in TLE. Considerations here include the measurement of relative impairments in verbal and non-verbal memory for the purposes of lateralisation, and measuring the *extent* of impairments to determine likely post-operative memory decline. Saling (2009) provides a critique of the currently adopted neuropsychological approach to epilepsy. Citing inconsistencies in the verbal/non-verbal distinction in the literature, he discusses how the simple application of factorially derived measures of left or right sided function from a battery of subtests is no longer applicable. This approach, he argues, does not take into account task-specificity and the possibility that individual types of tests are reliant on more separable cognitive systems that operate in discrete MTL sub regions. The main distinction he makes regards LTLE and the role of the hippocampus in arbitrary forms of learning (such as unrelated word-pairs), and the role of anterior temporal structures in learning of information that is reliant on pre-existing semantic representations (e.g. prose recall and list learning). An important criticism he makes is that correlations found between neuropsychological measures are typically concluded to mean that these are fundamentally measuring the same constructs, therefore, a patient's score on either are thought to reflect the same thing. He goes on to say that, "This approach to validity assigns no particular importance to the nature of the task (such as its cognitive architecture), or to the possibility that task-specific factors might be subserved by different causal mechanisms" (p. 571).

Thus, the conclusions drawn from this chapter about the common underlying nature of recollection between tasks must be interpreted with caution. Although the evidence does suggest that a common recollective process, most likely hippocampally based, operates between the tasks, each paradigm does indeed differ in its requirements and the analysis presented is unable to shed light on the influence of pre-established semantic loading of items, for example. Because of the heterogeneity of the sample, conclusions about laterality are also difficult to establish. Nevertheless, future studies would be useful in bridging the gap between the dual-process and neuropsychological assessment literatures in TLE whilst taking into account Saling's (2009) concerns. These kind of theoretical and clinical themes are developed further in the following chapter.

8 General Discussion

8.1 Overview

This thesis set to out to further our understanding about memory impairments and awareness in TLE. This was achieved by developing a number of empirical tasks that were all theoretically driven by dual-process theories of memory; hence, the objective was to examine the extent to which TLE is characterised by reduced *recollection*.

Whilst each experiment addressed this central aim, they were also designed in such a way as to shed light on some further theoretical and clinical issues. Incorporating a range of subjective and objective memory measures afforded the opportunity to examine the different ways various dual-process theories conceptualise recollection. Because recollection is assumed to rely on the MTL, patients with TLE provide an excellent sample with which to test these assumptions. As well as contributing to the dual-process literature, this comparison of subjective and objective measures of memory meant a fundamental clinical question could be concurrently addressed. That is, what are patients' qualitative experiences of their memory impairment like?

Table 8.1 presents a summary of the key findings from each chapter, and is subdivided into the headings of objective/recognition memory performance; subjective experience/awareness; objective recollection and familiarity and; subjective-objective comparisons. This reflects how subjective-objective comparisons of memory tied each experiment together. Table 8.2 further consolidates the main findings into a simpler format, summarising whether general recognition memory impairments were found in the TLE group and whether subjective/objective recollection and familiarity were reduced or impaired on each task. In the rest of this chapter I extend this summary of findings and provide a general discussion with reference to relevant existing literature. The more theoretical and clinical considerations are covered following this summary in the context of the findings from Chapter 7. Some limitations of the present research and future directions are then outlined at the end of the chapter.

Table 8.1 Detailed summary of main experimental findings.

	Main findings			
Chapter	*Recognition/objective memory performance*	*Subjective experience/awareness*	*Objective recollection and familiarity*	*Subjective-Objective comparison*
2.Neuropsychological Assessment	Impairments in all but one of the neuropsychological tests assessing MTL functioning.	Patients complained of various memory difficulties in daily life.	n/a	Neuropsych assessment provides objective validation of subjective complaints.
3. Source memory	Impairment in recognition memory with LTLE having worst discrimination performance.	Significant reductions in R responses in TLE with familiarity intact; LTLE had lowest level of subjective remembering.	Source memory performance for retrieval of location, order and colour of items comparable to controls.	In controls, better source memory and external associative information for R responses. In TLE, contextual retrieval did not differentiate between R/F responses.
4.1 Word repetition-lag PDP	Old-new discrimination worse in TLE; unimpaired for inclusion items; LTLE made the most exclusion items FPs.	Same as Ch. 3 for studied items, with no clear laterality differences. For repeated inclusion items, fewer R responses made in TLE overall and as lags increased. BTLE sig. < controls, LTLE also low.	Collapsed over lag interval, TLE R estimate sig < controls, with F intact. F increased as a function of lag interval in both groups.	High degree of convergence between impaired objective R measures and reduced subjective R across old-new items and repeated-lag items.
4.2 Face repetition-lag PDP	TLE/controls were = on FPs to new items; controls sig > TLE for hits to old items. Impaired on inclusion items with LTLE sig < controls. No difference in exclusion FPs.	R sig < in TLE for study items, with some evidence for LTLE having the lowest; corrected F score sig < in TLE also. For repeated inclusion items, TLE sig < R responses than controls.	No difference in R or F estimates between TLE and controls.	Consistency in lower subjective R in TLE when probed, but comparable to controls in objective R suggesting different demands between study/ repeated items.
5. Associative recognition	Item memory and hits to intact pairs equivalent in TLE/controls. AI, AR sig < in TLE; rearranged FPs sig > in TLE.	TLE and controls adjust confidence accordingly to difficulty of task and correct/incorrect items.	No sig. impairment in TLE for recollection estimate; familiarity intact.	TLE show awareness as confidence reflects poor objective memory ability.
6. Naturalistic measures: MMQ and public events	No diff. found in overall public event dating accuracy. Groups were also comparable in under/overestimation of date when incorrect.	Sig. < levels of perceived memory function in TLE (MMQ). TLE sig. < controls on all subjective measures related to recall of public events, except personal sig. Both groups judge awareness of knowledge appropriately.	n/a	No relationship between MMQ and public events measures. Retrieval of encoding context led to ↑ in dating accuracy, but more so in controls. Dating accuracy also related to ↑ vividness comparably between groups.
7. Correlation analysis (TLE only)	Neuropsych test performance related to subjective/objective recollection.	Sig. correlations found between subjective measures of recollection between tasks.	Sig. correlations between R measures.	Sig. correlations between a range of subjective and objective measures of R.

Note: PDP = process-dissociation procedure, MMQ = Multifactorial memory questionnaire (Troyer & Rich, 2002), TLE = temporal lobe epilepsy, MTL = medial temporal lobe, LTLE = left temporal lobe epilepsy, FP = false positive, AI = associative identification, AR = associative reinstatement, R = remember, F = familiar.

Table 8.2 Basic summary of main experimental findings.

			Subjective		Objective	
Chapter	Paradigm	Recog. deficit	R reduced?	F reduced?	R impaired?	F impaired?
2	Neuropsych. tests	✓	-	-	-	-
3	Source memory	✓	✓	x	✓	-
4 (Words)	PDP	✓	✓	x	✓	x
4 (Faces)	PDP	✓	✓	✓	x	x
5	Associative recog.	✓	-	-	x	x
6	Public events	x	✓	-	-	-

Note: PDP = process-dissociation procedure, recog = recognition, R = recollection, F = familiarity.

8.2 Summary of findings

8.2.1 Chapter 2

Chapter 2 presented the results of the detailed neuropsychological assessment conducted with both patients and controls. This assessment included standardised measures of immediate and delayed visual/verbal recall and recognition memory, as well as some measure of executive function.

The TLE sample was found to be impaired compared to the control group on every memory measure except multi-trial list learning. The impairments found are thus consistent with the extensive literature documenting the effects of TLE on standardised tests of anterograde memory (see Baker & Goldstein, 2004; Goldstein, 1991; McAndrews & Cohn, 2012, for reviews). The sample was comprised of patients with complex, chronic TLE, relatively recently diagnosed TLE, and those who had had resective surgery; although individual patients' scores were not presented, all of these types of patients have previously been found to show memory impairment in standardised measures (Aikiä, Salmenperä, Partanen, & Kälviäinen, 2001; Richardson *et al.*, 2004; Smith *et al.*, 2011; Vaz, 2004). Although there was variability in the extent of impairments, establishing clear deficits at the group level provided the platform with which to further examine the basis of memory problems in this group. Moreover, performance was comparable to controls on digit span and fluency measures; this provided evidence to suggest that any further memory impairment discovered was not due to frontal-lobe dysfunction.

There was some evidence of lateralised differences in memory. Somewhat surprisingly, left and bilateral TLE patients had the worst performance compared to controls on delayed recall of the BMIPB figure; based on lesion site, one can account for the greater impairment in bilateral patients as presumably verbal and non-verbal memory areas would be affected. The poor performance in LTLE was most likely due to worse overall memory capacity. Less surprising was the finding that LTLE showed the worst performance in story recall.

Previous research has found the WRMT to have poor pre-operative lateralising value, but greater left/right TLE discriminability following temporal lobectomy (Hermann, Connell, Barr, & Wyler, 1995). In the current sample, this test revealed a preferential verbal impairment in LTLE, as well as worse performance for face recognition in RTLE. Based on the Hermann et al. study, this is likely due to the inclusion of pre- and post-operative patients.

In terms of their experience of memory decline, all patients reported some degree of subjective memory complaint; the results of the neuropsychological assessment thus provided some validation of these. There was no direct quantification of perceived memory failure at this stage, however.

8.2.2 Chapter 3

Chapter 3 assessed source memory in TLE; the novel aim was to compare the types of contextual information available to patients and controls during different subjective states of awareness during recognition using the R/K paradigm (Tulving, 1985).

Recognition of target words was impaired in patients, with LTLE having the worst performance. Overall retrieval of contextual details of items was not however different to controls. This finding is contrary to the previous TLE studies that have shown this patient group to be impaired in their retrieval of spatial context information (Kopelman *et al.*, 1997), source memory for who performed an action (Schwerdt & Dopkins, 2001) and memory for the context in which trivia answers were provided (Thaiss & Petrides, 2003). The paradigms used are very different, however, and the main analysis looked at performance during different subjective experiences, as discussed below.

TLE patients showed a reduction in the number of subjective Remember responses, whilst familiarity was intact. Consistent with recognition performance, LTLE patients made the fewest Remember responses. These results support the findings of Moscovitch and McAndrews

(2002), who showed material specific impairments in remembering in a similar recognition task. A selective reduction in subjective remembering for verbal material in LTLE is far from a consistent finding in the literature, however. Although impaired in comparison to controls, Bowles et al. (2010) found no difference in proportion of Remember judgments between left and right sided patients who had both had amygdalo-hippocampectomies. Moreover, Blaxton and Theodore (1997) found patients with a left epileptic focus provided significantly fewer Remember responses regardless of material type (words or abstract designs). Because non-verbal memory was not assessed in this task, the results cannot directly speak to other studies that have found different patterns of impairment in subjective remembering between left and right TLE patients (Bengner & Malina, 2008; Blaxton & Theodore, 1997). Nevertheless, the results are supportive of this literature in that they provide further evidence that recognition memory is subserved primarily through assessments of familiarity in TLE.

Objective recollection, as mentioned above, was measured in terms of the amount of contextual features that were retrieved with target words. When comparing Remember and Familiar judgments in TLE, it was found that these two subjective states of awareness could not be reliably distinguished on the basis of such contextual retrieval. However, in controls, Remember responses were associated with increased source memory performance. The findings in the control group therefore replicate a number of studies that have found subjective remembering to be associated with better retrieval of individual and multiple bound source features (Dudukovic & Knowlton, 2006; Meiser & Bröder, 2002; Meiser *et al*., 2008; Perfect *et al*., 1996; Starns & Hicks, 2005).

The main question to emerge from these findings is, on what basis are Remember responses made in TLE? A recent study on older adults by Boywitt, Kuhlmann, and Meiser (2012) had similar findings in that source memory did not differentiate between Remember and Familiar responses, despite unimpaired overall objective performance. As with their suggestions, it could be that TLE patients base their Remember responses on contextual information not queried during the experiment; patients here reported a comparable level of external associations to controls, though. From one signal detection perspective (Wixted & Mickes, 2010), a Remember response is made if enough source information is retrieved to pass a *threshold*. Therefore, it may be that control participants base their Remember response on the to-be-retrieved contextual information, but the other external associative information accompanying recognition in patients is sufficient to make a Remember response. The fact that Familiar responses were associated with the retrieval of some degree of contextual information is also consistent with a memory strength interpretation, whereby Familiar responses simply represent weaker memories. Crucially, however, as Yonelinas (2002) states, the dissociations found between recollection and familiarity in MTL damaged groups and healthy adults provide the best evidence against such accounts. The issue of single trace interpretations of the data in this thesis is discussed further in Section 8.5 below.

8.2.3 Chapter 4

Chapter 4 looked at recollection and familiarity from the perspective of Jacoby's (1991) PDP, which conceptualises the two processes as automatic and controlled bases for responding. This was achieved using the repetition-lag task (Jennings & Jacoby, 1997) with two novel methodological alterations. First, the R/K paradigm was incorporated into the task, in order to compare subjective recollective experience with the cognitive basis of recollection. Second, identical verbal and non-verbal (unfamiliar facial stimuli) tasks were employed in order to examine laterality differences and to more generally assess any potential change in the extent recollection and familiarity are utilised between different material types.

In the word version of the task, recognition memory impairments were found, with LTLE patients performing the worst on items where successful performance was dependent on successful recollection (repeated lag items in the exclusion task). There only appears to be one other study in the published literature that has compared left and right TLE patients in an inclusion or exclusion task of this sort. Fell et al. (2011) used a continuous verbal recognition paradigm analogous to the inclusion test presented here, with the exception that there were no study phase items. Measuring hits and FPs with lag intervals ranging up to 30 items, they found performance did not differ between left/right presurgical patients. Differences in procedure make it difficult to compare these discordant findings, however.

The pattern of results for subjective experience responses to study items mirrored those reported in Chapter 3, where a significant reduction was found in Remember judgments, whilst familiarity was intact in TLE. No laterality differences emerged on these items, however. For repeated inclusion items, patients made significantly fewer Remember judgments than controls, and these decreased as a function of lag. Critically, the objective process estimations converged with this finding; patients were impaired in their objective use of recollection overall and familiarity was shown to increase linearly as a function of lag comparably in both groups.

This finding contributed to the overall aim of this thesis in elucidating memory impairment in TLE from a dual-process perspective. Importantly, the convergence in subjective and objective recollection is in line with previous literature that has found high correspondence between the two measures (Jacoby, Yonelinas, & Jennings, 1997; Jacoby, 1998; Prull *et al*., 2006; Yonelinas, 2001, 2002; Yonelinas *et al*., 2002). This is the first time, however, that this correspondence has been shown in a repetition-lag task, and moreover the first illustration of this in TLE. The results suggest that patients' subjective reports are valid interpretations of their underlying memory processes.

The finding of an impairment in objective recollection estimates and intact familiarity is supportive of two previous TLE studies that have used the PDP in the context of word-stem completion paradigms (Del Vecchio *et al*., 2004; Hudson *et al*., 2009). Moreover, a body of work in aging populations and Alzheimer's disease has found similar patterns of results using the repetition-lag procedure (Boller, Jennings, Dieudonné, Verny, & Ergis, 2012; Jennings & Jacoby, 1997; Jennings & Jacoby, 2003; Tse *et al*., 2010). These consistent dissociations suggest this task is particularly effective in measuring MTL dependent memory dysfunction. Indeed, exclusion item performance has been found to have diagnostic power over standardised neuropsychological tests in highlighting memory impairment in Alzheimer's disease (Tse *et al*., 2010). It may therefore be highly useful in the field of epileptology. I return to this point in Section 8.4.

The findings from the face version of the task were somewhat different. In patients, performance on study items was impaired and associated with lower levels of subjective Remember responses, with one of the familiarity estimates also being significantly below that of controls. Recent studies in amnesics by Bird, Shallice and Cipolotti (2007) and Bird and Burgess (2008) suggest that recognition of unfamiliar faces is driven primarily through familiarity and other processes operating outside the hippocampus; because the sample here included patients with a diverse range of aetiologies and epileptic profiles, it is possible that general MTL damage led to reductions in both recollection and familiarity.

LTLE patients had the lowest performance on repeated inclusion items and also had the lowest subjective recollection estimates. These results do not support the three previous group studies that have assessed subjective experience for non-verbal memory recognition memory in TLE (Bengner & Malina, 2008; Blaxton & Theodore, 1997; Moscovitch & McAndrews, 2002). The repetition-lag task is however, more complex than the simple single item-recognition paradigms utilised in those studies; successful performance on each test requires increased attention due to constant interference created by new and repeating items. It was suggested that the results of the LTLE patient group may be due to an overall greater impairment in general memory capacity. Unfortunately, there are no other published studies in the TLE literature that have used this task and made similar comparisons between left and right TLE patients; Martin et al. (2012) used an exclusion procedure involving categorised visual scenes, but they do not report laterality results.

Despite evidence of reduced subjective remembering in patients for repeated inclusion items, the objective process estimations derived from overall task performance revealed no impairment in objective recollection and familiarity. Essentially, no difference was found between groups when taking into account exclusion FPs, which is surprising given that recollection is theoretically required to successfully reject these items. Although there was correspondence between some of the recollection measures, it was suggested that the difficulty of the task may have obscured any underlying impairment in the TLE group in their objective use of recollection.

The divergence in findings between the word and face versions of the task is a good example of how controlled and automatic uses of memory, as conceptualised by the PDP, are context dependent (Kelley & Jacoby, 1998). Although participants have to apply the same basic set of principles to complete each task, changing the material type may have provided a different context in which recollection and familiarity operate. As the performance measures showed, the facial stimuli were more difficult, and this may have altered participants' goals or intentions, which also constitute part of the 'context' (Jacoby & Kelley, 1998). The SMF outlined by Johnson and colleagues also ascribes importance to how memory operates differently when participants' motivations change (Johnson & Raye, 2000; Johnson, 2006; Johnson, Hashtroudi, & Lindsay, 1993; Mitchell & Johnson, 2009). In sum, it is important to consider these additional factors when interpreting results between different tasks.

8.2.4 Chapter 5

Whilst Chapters 3 and 4 looked at patients' experience of their memory impairment through application of the R/K paradigm, Chapter 5 aimed to contribute to this area further by employing a more standard metacognitive measure – subjective confidence. This was achieved by borrowing the associative recognition paradigm originally developed by Cohn and Moscovitch (2007). Using this paradigm, Cohn et al. (2009) had previously provided evidence of impairments in a number of measures that index relational binding ability in a group of post-surgical TLE patients. In Chapter 5, participants were asked to make confidence judgments for all recognition decisions; therefore the aim was to evaluate metacognitive sensitivity and accuracy over item types that were more or less reliant on recollection and familiarity. Due to the variation in patients, the results regarding recollection and associative memory were also suggested to be more representative than Cohn et al.'s (2009) study.

TLE patients were found to be impaired in associative memory measures dependent on binding and strategic retrieval (associative identification estimate and rejection of rearranged items in the associative identification task). Whereas these measures are thought to engage both MTL and frontal regions, patients were also impaired in associative reinstatement, which is thought to be a purer index of MTL relational binding ability (Cohn *et al*. 2009). This was also in light of the fact that patients did not differ from controls in the number of sentences successfully created during encoding.

Item memory and hits to intact pairs (which are solvable by recollection *and* familiarity) were equivalent between patients and controls, however. This supports studies that have shown disproportionate decreases in associative over item memory deficits in other groups with MTL dysfunction, such as older adults (Castel & Craik, 2003; Cohn *et al*., 2008) and amnesics (Giovanello *et al*., 2003; Kan *et al*., 2007*b*). The amnesic studies in particular have suggested that associative deficits are a result of hippocampal pathology; however, some authors have criticised this literature on the basis that memory encoding is not adequately matched between patients and controls (Stark, Bayley, & Squire, 2002). Matching procedures were not used in the experiment in Chapter 5, therefore a note of caution must be taken in interpreting the findings.

There were several points of divergence between the results obtained here and those of Cohn et al. (2009). These authors found impairments in left and right patients on PDP derived recollection estimates, whereas familiarity impairments were found in the dominant TLE group. I found no impairment in either recollection or familiarity estimates. Cohn et al.'s (2009) data therefore provide evidence for material-specific verbal impairments in familiarity in LTLE, which was also recently shown by Martin et al. (2011). That there was no lateralised deficit in recollection in Cohn et al.'s (2009) study was explained in terms of the fact that recollection is probably more reliant on bound verbal and visual associations (i.e. making images when encoding sentences). Therefore, there is likely to be more of a bilateral involvement for recollection, whereas familiarity relies predominantly on verbal information. Both of the above studies included patients with anterior temporal lobe resections. Therefore, the lack of laterality findings in Chapter 5 most likely represent differences in lesion extent and location.

Initially, the lack of impairment seen in PDP derived recollection estimates seems to contradict the results of the other relational measures. However, these estimates take into account a larger set of data across both recognition tests and as discussed above, provide a measure of the extent to which different processes are used as bases for responding. In contrast, the relational measures provide specific indexes of binding at encoding or retrieval. The overall recollection estimate could thus be viewed in parallel to the *control* aspect of Nelson and Narens' (1990) model. Whilst objective recollection generally controls the accepting and rejecting of items dependent on the task requirements, the subjective experience of remembering can be seen as the *monitoring* component of the Nelson and Narens (1990) model. The interaction between the two guides subsequent memory 'behaviours'. In sum, these performance data add to the TLE literature and suggest associative memory impairments are observable in a more diverse range of patients.

For the confidence data, several different analyses all provided consistent evidence that TLE patients were metacognitively intact, despite their associative memory impairments. Overall confidence was lower in the TLE group, but patients showed similar sensitivity to controls at this lower level of confidence. For example, both groups showed significantly higher confidence to intact pairs in both tests. Moreover, the means from the associative memory estimates suggested left sided patients had the lowest associative memory performance and a significant laterality effect was found such that this group had the lowest confidence.

Metacognitive accuracy was assessed by comparing confidence to correct and incorrect answers across groups. The main items on which this analysis was based were the rearranged and intact pairs on each of the pair and associative identification tests. Patients' confidence was found not to be different to controls overall, and both groups showed a comparable significant increase for correct over incorrect responses. Moreover, FPs to rearranged items on the associative identification task (resulting from a failure in recalling-to-reject) are what characterise the TLE associative deficit; a metacognitive account would predict that this occurs because patients accept two familiar (but rearranged) words as an originally bound pairing due to inappropriately high confidence. However, this was not the case, as no difference was found between patients and controls' confidence to these items.

The results support two recent empirical studies by Andrés et al. (2010) and Howard et al. (2010) who similarly found that despite significant recall and recognition impairments, TLE patients had accurate metacognitive *monitoring* (using JOLs and FOK judgments) and appropriately shifted metacognitive judgments according to the difficulty of a task (they were able to adjust post-study metamemory predictions in the same way as controls). The assessment of confidence in Chapter 5 for such a variety of different item types builds on the two above studies because the data elucidated a range of associative memory impairments in TLE whilst simultaneously dispatching the hypothesis that these were a by-product of a metacognitive deficit. The empirical demonstration of recollection and binding impairments in the TLE group in the context of intact awareness confirms the existence of MTL damage and preservation of frontal functioning (as evidence by the neuropsychological assessment).

8.2.5 Chapter 6

Chapter 6 moved beyond the assessment of awareness and recollection and familiarity in the laboratory. Instead, two more *naturalistic* measures were employed in a much larger internet based sample, as well as a number of the participants recruited for the rest of the research in this thesis. First, drawing on the extant TLE literature that has shown patients to have significantly lowered subjective perceptions of memory function, the MMQ (Troyer & Rich, 2002) was administered to patients and controls. Second, a novel public events task was completed by participants which included questions designed to assess objective memory performance, the contribution of recollection to retrograde AM, as well as provide another measure of awareness.

Significant differences in overall MMQ score was found between the TLE group and controls. Significant differences were also found between each individual subscale (Contentment, Ability, and Strategy). The TLE group had the lowest score on the Contentment scale, suggesting high levels of dissatisfaction and negative affect related to their memory. The significantly lower score on the Ability scale indicated that people with TLE utilise memory aid strategies less than healthy adults. The low score on the Ability subscale indicated perceived difficulty with effectively using memory in everyday situations. There were no differences in subgroups of laterality and AED regime, nor was there an association between scores and age of onset or illness duration. These latter findings partially contradict a previous study by Hendriks et al. (2002), who found an inverse relationship between illness duration and perceived level of memory functioning. On the whole, however, the results are supportive of multiple studies in the literature that have suggested TLE patients subjectively complain of poor memory ability or have dissatisfaction with their memory (Corcoran & Thompson, 1992;

Elixhauser *et al*., 1999; Giovagnoli *et al*., 1997; Gleißner *et al*., 1998; Rayner *et al*., 2010; Thompson & Corcoran, 1992; Vermeulen *et al*., 1993). Moreover, this was evidenced through use of a different, reliable and valid questionnaire.

The objective findings from the public events task revealed people with TLE were just as accurate as healthy adults in correctly dating public events. Additionally, the relative degree of *inaccuracy* showed the same level of dispersion as controls. Consistent with my other findings of intact awareness, the TLE group, like controls, were more accurate in dating when they had previously stated that they *thought* they knew the answer. Therefore, both groups accurately monitored currently available knowledge. Other studies in the TLE literature have found impairments in public semantic knowledge in a variety of different tasks (Barr *et al*., 1990; Bergin *et al*., 2000; Haag *et al*., 2010; Lah *et al*., 2004, 2008; Leeman *et al*., 2009; Seidenberg *et al*., 2002; Viskontas *et al*., 2002). Dating accuracy has not however been examined before and the results here suggest that the integrity of the systems used in the correct dating of events is not completely compromised in TLE. The results from the subjective memory measures provided further insight into such processes.

The TLE group had significantly lower scores for all the subjective measures. These included the number of events recalled, the number of events where the initial encoding context could be recalled and vividness associated with recall of events. Because recollection is at least theoretically involved in all of these, the results are supportive of other TLE studies that have evidenced pervasive *episodic* AM impairments in this group (Addis *et al*., 2007; Butler *et al*., 2009; Herfurth *et al*., 2010; Illman *et al*., 2011; Lah *et al.*, 2004, 2006, 2008; Noulhiane *et al*., 2007; Park *et al*., 2011; St-Laurent *et al*., 2009).

Further analyses found that both groups' dating accuracy was better for events when they reported recall of the initial encoding context; this was more so for controls, however. Increased vividness accompanying memory for events was also associated with better dating accuracy in a comparable way between groups. These results suggested that despite a significant reduction in subjective measures associated with items, people with TLE were still able to utilise information arising from recollective experience of the event to correctly date it. Whereas the retrieval of public semantic knowledge is not typically assumed to rely on the episodic memory system, these results support previous suggestions that dating of historical events is achieved by retrieving contextual information pertaining to the self situated in the wider sociocultural context (Brown, 1990; Fradera & Ward, 2006; Petrican *et al*., 2010) Analogous to the independent but combined influence of recollection and familiarity in recognition memory, the results support the idea that a combination of the episodic and semantic memory systems is used in the retrieval of autobiographical information (Greve *et al*., 2007).

Finally, a positive association was found between perceived memory ability and contentment (as measured by the MMQ) and the number of events subjectively recalled in the public events task. This was in the TLE group only. As described above, neuropsychological tests dealing with anterograde memory often fail to corroborate TLE patients' subjective reports. One reason for the discrepancy between perception of memory and standardised scores has been suggested to be the fact that subjective memory follows a different time-scale. A recent study by Witt, Glöckner and Helmstaedter (2012) showed that delayed objective memory after a four week period was more diagnostic of subjective complaint than performance at 30 minutes or one week. The association between the MMQ Ability and Contentment scales and an experimental measure of subjective recollection-like autobiographical recall also suggests that the degradation of memory traces over time may contribute to subjective complaints.

8.3 Theoretical implications

The use of a diverse range of tasks and materials throughout this thesis allowed a comprehensive assessment of the extent to which subjective and objective recollection is reduced, or impaired in this TLE group. This was the main aim. However, because of the application of these different tasks in the same group of subjects, it was possible to contribute to a more theoretical aspect of the dual-process literature. Essentially, addressing the question of how comparable different forms and uses of recollection are.

As mentioned in Section 1.8, the dual-process theories on which different tasks are derived from conceptualise recollection in different ways. As Jacoby et al. (1997) describe, by using subjective reports, the R/K procedure "...identifies consciousness with awareness. The inclusion/exclusion procedure in contrast, defines consciousness with reference to intentional control of responding" (p.41). Moreover, as Gardiner et al. (1996) discuss, the R/K procedure embodies a first person perspective, whereas the PDP and objective methods provide a third person perspective. Due to these differences, the measures of recollection derived from each, although predicted to have some similarity, will not always be the same.

Despite this cautionary note, the results of this thesis have provided converging evidence between first and third-person measures of recollection. The dissociations seen between recollection and familiarity *across* tasks in itself strongly suggests that the subjective experience of remembering is related to its objective use as a basis for responding. Moreover, the two *within* task comparisons (source memory and repetition-lag) provided some evidence that patients' subjective experience is intrinsically linked to recollective cognitive processing. This convergence supports a number of previous studies that have compared different methods. For example, PDP estimates, ROC functions and IRK estimates have been found to be effected in similar ways under a number of experimental encoding and retrieval based manipulations in healthy adults (Jacoby, 1998; Yonelinas & Jacoby, 1995; Yonelinas, 2001); similar results using PDP and R/K estimates in the same study have been used to provide evidence for the contribution of automaticity to free recall (McCabe, Roediger, & Karpicke, 2011); deficits in recollection have converged through use of PDP, R/K and ROC methods in a within-subjects manipulation in older adults (Prull *et al*., 2006) and similar deficits in recollection or familiarity have been observed by comparing these three methods in hypoxia related amnesia (Yonelinas, 2001) and a post-surgical TLE patient (Bowles *et al*., 2007).

Rather than simply observing the similarities in patterns of recollection estimates across tasks, Chapter 7 went further and specifically analysed any potential statistical relationships between them. A number of significant correlations emerged between the anterograde recollection measures. For instance, subjective Remember responses between the face and word versions of the repetition-lag PDP task correlated with each other. This suggests that the probability of engaging in a state of awareness accompanied by contextual retrieval of previously studied information is similar even when the type of material is qualitatively different.

Multiple correlations were found between objective measures of recollection, which suggested that it is used in a similar way to aid task performance. For example, associative identification correlated significantly with the objective measures from all other tasks – both face and word PDP estimates and the level of contextual retrieval from the source memory task. As described above, associative identification is thought to rely on a complex interaction between MTL and frontal lobe dependent recollection like processes, involving relational binding and strategic search mechanisms (Cohn *et al*., 2009). Successful performance on the tasks that it correlated with are also reliant on such processes; source memory involves the binding and retrieval of multiple contextual features into a single coherent memory trace. Recollection estimates from the repetition-lag task are derived similarly from the ability to accept and reject repeated lures in inclusion/exclusion tests, which is dependent on the extent to which items are successfully bound to their source of acquisition (i.e. study or test list).

Similar to the subjective correlation, the objective recollection estimates from both repetition-lag tasks correlated with each other. Although caution has been noted about the highly constrained manner in which recollection operates in different versions of the PDP (Kelley & Jacoby, 1998; Yonelinas & Jacoby, 2012), these results provide compelling evidence that despite alterations in the context of the task, this version of the PDP appears to be isolating a similar process.

The correlational analysis between subjective and objective measures was most relevant to addressing the theoretical relationship between recollection as conceived by first, and third person perspectives. Within-task correlations were found for the source memory task and word repetition-lag PDP task. There are very few studies that have compared correlations between subjective and objective measures in the same task but this finding supports the study by Jacoby, Debner and Hay (2001). In a PDP word-fragment completion paradigm, they asked participants to subjectively report whether they had recollected completion words. This procedure did not, however, utilise the R/K paradigm like the experiments reported here as familiarity responses were not recorded. The authors found Pearson's correlations of .71 and .81 between objective PDP estimates and subjective Remember proportions for younger, and older participants, respectively. The present work extends upon this as it showed correlations between subjective and objective measures in two different tasks – therefore support is provided for Jacoby et al.'s (2001) conclusion: "These correlations suggest that participants were indeed aware of when they were recollecting" (p.692). Moreover, correlations were also found between subjective and objective measures of recollection from different tasks. So, it would seem that TLE patients' ability to use recollection, and their awareness of this process, transfers across different testing contexts.

Of further theoretical interest was the relationship between retrograde and anterograde measures. The analysis in Chapter 7 revealed that a measure that is likely to index some form of retrograde recollective process (subjective recall of public events) correlated with subjective and objective recollection on the word repetition-lag PDP task. Additionally, the objective recollective measure from the source memory task correlated with the absolute number of events correctly dated. From a neurobiological perspective, dual-process theories of anterograde recognition (Yonelinas, 2002) and multiple trace theory of AM (Moscovitch *et al*., 2005; Nadel & Moscovitch, 1997) both assert that the hippocampus is critical for the recollection of contextual and associative information for recently acquired information or previously experienced events. Therefore, there should theoretically be some overlap between antero-retrograde tasks. Although the present results cannot speak directly to this neurobiological debate, they at least provide some support for the relationship between the use of recollection in the retrieval of past and recently acquired memories. Importantly, the lack of correlations between the other measures also suggests that the tasks may be measuring different things. For example, although recollection supports binding and retrieval of information, anterograde tasks presumably require the activation of pre-existing *semantic* representations in long-term memory also. The kind of semantic information retrieved in retrograde memory is likely to differ to this; thus the interplay between recollection and other neurocognitive systems will vary in antero-retrograde tasks.

8.4 Clinical implications

The results of this thesis address some of the major clinical issues evident in the field of epileptology. These include the factors that mediate the relationship between subjective perceptions of memory and objective test performance; the diagnostic and localising value of memory tests and; the development of efficacious memory rehabilitation programs.

The extant literature has found that the discrepancy found between subjective and objective indexes of memory in TLE is unarguably influenced primarily by concomitant levels of increased anxiety and depression (Dulay *et al.,* 2004; Elixhauser *et al*., 1999; Giovagnoli *et al*., 1997; Hendriks, Aldenkamp, van der Vlugt, Alpherts, & Vermeulen, 2002; Piazzini, Canevini, Maggiori, & Canger, 2001). In the present research, anxiety and depression showed no relationship to measures of subjective perception of memory, or other neuropsychological and experimental measures. It was therefore concluded that any relationship between memory measures was not unduly influenced by mood in this sample. Contrary to the samples reported in many previous studies, the patients here in fact subjectively complained of memory both informally and through use of a standardised questionnaire, and neuropsychological and empirical findings corroborated this. The present results build on the above research – the correspondence between subjective awareness and objective measures throughout the dual-process driven approach suggests that metacognitive awareness is intact in the absence of high levels of anxiety and depression.

However, recent advances in the field suggest that the very way subjective and objective forms of memory are compared must be re-evaluated. As discussed in Chapter 7, current questionnaire based assessment may be fundamentally probing perceptions or awareness of longer-term memory, whereas typical neuropsychological tests constrain their assessment to shorter retention intervals of only up to one hour. Distinguishing between different fractions of the same cognitive function (e.g. shorter or longer-term declarative memory) has been shown to be useful in conceptualisations of awareness in Alzheimer's disease, such as in the Dissociable Interaction and Conscious Experience (DICE) model (Schacter, 1989; 1990). At the lowest level of this model, there are modules related to specific cognitive functions (such as memory). The output of these provides input to the conscious awareness system (CAS). Output arises when there is a change from the baseline state of the module, resulting in activation of the module and its link to the CAS. Once the CAS is stimulated, conscious awareness is experienced of the information being processed. The CAS then provides input into the executive system, which combines all the information needed for complex functions. Damage to the executive system or CAS will thus lead to widespread deficits in awareness. However, damage to specific modules or their individual input to the CAS will lead to differing levels of awareness across domains. For example, damage to the immediate memory module may lead to dysfunctional awareness of shorter-term memory ability but leave awareness of longer-term memory intact. This, and other more detailed cognitive models (e.g. Agnew & Morris, 1998) highlight the importance of considering how different levels of awareness interact with separable memory systems in light of neurological damage. Although they have been developed in the context of Alzheimer's disease, the prevailing discussion in the TLE literature regarding awareness of memory function suggests there is value in considering them in this condition also.

A body of evidence has emerged documenting patients whose memory impairment is more easily identifiable at longer delays, ranging from intervals of 24 hours to 6 weeks (Bell, Fine, Dow, Seidenberg, & Hermann, 2005; Blake, Wroe, Breen, & McCarthy, 2000; Cronel-Ohayon *et al*., 2006; Davidson, Dorris, O'Regan, & Zuberi, 2007; Giovagnoli, Casazza, & Avanzini, 1995; Holdstock, Mayes, Isaac, Gong, & Roberts, 2002; Mameniskiene, Jatuzis, Kaubrys, & Budrys, 2006; Manes, Graham, Zeman, de Luján Calcagno, & Hodges, 2005; Muhlert *et al*., 2011). This has been termed 'accelerated long-term forgetting' (ALF; Butler & Zeman, 2008; Butler *et al*., 2007). As Witt et al. (2012) found, subjective reports of memory function were most related to standardised neuropsychological memory performance after a 4 week interval. It is easy to see how taking a dual-process approach to this area would be useful. For example, research with healthy adults has showed that the trajectory in states of awareness changes as a function of learning over time; better immediate memory is associated with recollective experience but over time the schematization of knowledge means that accuracy is related also to subjective *knowing* as well as recollection (Conway, Gardiner, Perfect, Anderson, & Cohen, 1997; Dewhurst, Conway, & Brandt, 2009; Herbert & Burt, 2001, 2004; Herbert & Burt, 2003). It has been suggested that the cause of ALF in TLE patients is a result of a functional disturbance to memory consolidation mechanisms (Muhlert & Zeman, 2012). Therefore, assessing recollection, familiarity and their corresponding subjective states of awareness may contribute to this literature because it would further elucidate how consolidation deficits interfere with specific processes. This work could then provide a basis on which to identify the type of patients who are more likely to experience ALF.

That many of the neuropsychological test scores correlated with recollection estimates provides supporting evidence that these both index similar MTL functioning. An important overriding question here is whether there is any added value in synthesising results of empirical studies into well established testing protocols. Essentially, would including tasks like the PDP into neuropsychological assessment be any better at highlighting specific memory impairment than current tests? It appears that the word repetition-lag PDP task has particular benefit as it was sensitive to verbal memory impairment in LTLE and correlated with a number of other neuropsychological tests. As previously mentioned, the exclusion task also seems to be powerful in detecting memory failure in other MTL damaged groups (Tse *et al*., 2010).

There are clearly practical limitations with the application of experimental paradigms to a clinical setting. For example, many experimental tasks are too long to fit into routine appointments. As well as the application of them described above, the use of subjective reports may be more practical, however. Neuropsychological assessment involves engagement with the patient and noting observations about their behaviour – subjective reports would allow the clinician to directly observe the patient's phenomenology associated with their memory and gain a qualitative appreciation of their memory impairment alongside quantitative measures. One can also see how asking people to subjectively report on their memory throughout a test may help maintain focus and concentration. Given that patients' subjective Remember responses may reflect underlying cognitive impairment, it is not inconceivable that a brief test utilising the R/K procedure could provide an immediate measure of MTL function, or awareness of function. Incorporating these kinds of empirically derived measures is likely to be a challenge, though, not just because of time-constraints during testing sessions. As Loring (2010) discusses, the current direction toward evidence-based neuropsychology means that innovative test development and integration is likely to suffer.

Comprehensive anterograde test batteries are used all over the world. However, this is not the case for measures of AM. The recent acknowledgment in the field that TLE patients often have significant difficulties with retrograde memory as well as new learning urges development of such measures. As this thesis showed, dissociations may exist between different types of AM and it is important to gain a broader understanding of the exact processes involved in longer-term memory impairment. Although many empirical studies have utilised detailed and innovative testing protocols, the only currently commercially available AM tool for clinical assessment is the AMI (Kopelman *et al*., 1990). However, the AMI has been criticised because of a lack of sensitivity and the difficulty with validating the veracity of reported of memories. Addressing this issue, Leeman et al. (2009) recently presented a TLE study that utilised the 'Transient News Events Test' (TNET) – an instrument that has potential widespread use including measures of recall and recognition of public events. Their combination of subjective and objective measures of AM is consistent with the approach taken in the public events task presented here. The development of similar tools in the future will no doubt be instrumental in determining the extent of patients' AM problems; this may be particularly useful in assessing risk of post-operative decline.

So far, this thesis has concentrated only on the measurement of *impairment* of memory in TLE. One clinical implication here is the extent to which the findings can inform approaches to memory rehabilitation in this patient group. As Shulman and Barr (2002) discuss, management of cognitive impairment in TLE can be achieved with careful pharmacological intervention by reducing negative side effects associated with high serum levels or poorly tolerated AEDs. Moreover, targeting co morbid anxiety and depression with psychological intervention early on is also likely to alleviate both subjective and objective memory problems.

There are a number of published studies that have assessed memory rehabilitation in patients with organic memory impairment arising as a consequence of TLE itself (Bresson, Lespinet-Najib, Rougier, Claverie, & N'Kaoua, 2007; Engelberts *et al*., 2002; Gupta & Naorem, 2003; Cristoph Helmstaedter *et al*., 2008; Radford, Lah, Thayer, & Miller, 2011; Schefft *et al*., 2008). Training interventions can be broadly divided into two approaches. The first is the *compensation* method, which involves finding effective ways of circumventing the memory or cognitive deficit. For example, it has become common place to encourage patients to use external memory aids, such as smart phones or digital recorders (Shulman & Barr, 2002). Also, improving internal memory strategies can be of benefit. For example, by encouraging self-generation procedures and deeper levels of encoding (Bresson *et al*., 2007; Schefft *et al*., 2008). The second approach is the *retraining* method, which is predicated on the assumption that due to plasticity of the brain, repeated practice on tasks can lead to restoration of function.

The dual-process approach taken in this research may be useful for contributing to the rehabilitation literature. Drawing on the retraining approach, modified versions of the repetition-lag task have already been used with older adults and Alzheimer's patients in the context of memory training (Boller, Jennings, Dieudonné, Verny, & Ergis, 2012*b*; Jennings *et al*, 2005). These studies use an incremental difficulty approach, whereby the lag interval is slowly increased between repeating items, meaning recollective ability is gradually trained, or restored. Critically, these two studies have also found evidence for transfer effects to other tasks dependent on MTL function. It would seem then that by taking a theoretical approach to what causes the underlying memory disorder has much benefit. Like older adults and Alzheimer's patients, this thesis has consistently shown that people with TLE are deficient in their use of recollective processing to complete PDP tasks. Thus, there is clearly scope for similar training approaches in this clinical population.

Rehabilitation also involves drawing attention to a patient's awareness of their cognitive abilities (Engelberts *et al*. 2002). It has been shown here that TLE patients are indeed metacognitively aware of their impairments. As Jacoby and Kelley (1998) state, "...people on a training program are motivated by the perception that they are learning from that program" (p. 136). Subjective experience therefore plays a crucial supervisory role, and any training program should evaluate patients' awareness of training effectiveness, as well as typical objective measurements. Moreover, reporting on subjective experience in itself may aid memory - Naveh-Benjamin and Kilb (2012) recently showed that the very use of the R/K procedure enhanced associative memory in older adults, which they suggested was a result of participants initiating additional strategies to make conscious assessments about the contents of memory. In summary, drawing on dual-process theories is likely to be of benefit to further work in this field.

8.5 Further considerations and future directions

The overall aim was to make a contribution to the TLE literature by concurrently objective and subjective indexes of memory. The dual-process approach was adopted because it provides a useful empirical framework with pre-established experimental paradigms in which to assess this. The results have therefore been interpreted consistently in terms of the contribution of the independent processes of recollection and familiarity. However, it is important to consider alternative single-trace accounts of the data.

The ongoing debate in the literature between signal detection accounts and dual-process accounts typically concentrates on the assumptions of the R/K paradigm. Evidence for the contribution of two independent memory processes, or states of awareness to recognition has typically come from studies that have found dissociations between them (see Yonelinas, 2002, for a review). Single trace theorists, on the other hand, propose that a more parsimonious explanation is that recognition memory is characterised by a unidimensional continuum of trace strength. By this view, remembering and knowing simply reflect varying degrees of confidence; Remember responses in the R/K paradigm are proposed to stem from stronger memories that surpass a given decision criterion, whereas Familiar responses represent a wider range of weaker, or less confident memories (Donaldson, 1996; Dunn, 2004). This account would therefore suggest that in the current set of experiments, TLE patients have a general impairment in this single continuous process, meaning their ability to retrieve stronger, more highly confident memories is reduced. To provide a concrete test of these accounts, it is necessary to assess subjective experience responses after equating overall memory strength. This was only done in Chapter 3. The results showed that there were differences between patients and controls in the retrieval of qualitative information available even after proportions of subjective Remember responses were equal. Therefore, the importance of considering recollection as a graded process was highlighted (Parks & Yonelinas, 2008; Wais, Mickes, & Wixted, 2008; Yonelinas & Parks, 2007).

Yonelinas and Jacoby (2012) describe that, "...the single-process account is insufficient, because it fails to explain the occurrence of these two subjectively distinct states..." (p. 670). Moreover, because of the way single-trace accounts assume the existence of a continuous memory signal, there is no reason to believe there would be a correspondence between subjective interpretation of memory and objective measurement (Wixted & Micks, 2010). Yonelinas and Jacoby (2012) discuss how a combined approach using the R/K paradigm and the PDP provides robust evidence against single trace interpretations. Consistent with this, the evidence provided in this thesis suggests that the two processes are dissociable in terms of their strategic regulation and subjective experience.

Hirshman et al. (2002) suggested that "one critical purpose of the SDT model is through appropriate falsification to allow stronger inferences about the nature of consciousness and recognition memory processes" (p.153). Whilst this may be true, the novel assessment of subjective experience with objective uses of recollection and familiarity presented here has provided a useful insight into the conscious (and unconscious) aspects of memory in TLE. Moreover, the paradigmatic approach adopted indirectly assessed the *compatibility* of first and third person dual-process approaches; attempting to incorporate a single trace approach would have run risk of diluting the original purpose of the research. For example, there is no doubt that complex signal detection models could be applied to the confidence responses derived from the associative recognition task to make further assumptions about the underlying memory processes contributing to performance. However, they were included to assess the feasibility of a metacognitive account of objective memory performance. As Gardiner (2008) discusses, the application of sophisticated signal detection techniques does not necessarily have an advantage over more conceptually driven ones.

One general criticism of dual-process paradigms is that misunderstanding or misinterpretation of instructions can invalidate the recollection and familiarity estimates derived from the tasks (Dunn, 2004; Jacoby, 1998; Yonelinas & Jacoby, 2012). Indeed, evidence showing that participants can make Remember judgments in the absence of retrieval of qualitative information has been taken to suggest that they base these on high levels of confidence rather than a threshold based recollective process (Rotello *et al*., 2005). Every effort was taken to ensure participants in the current set of experiments understood and complied with instructions, but it is not impossible that idiosyncratic interpretations were made. The PDP is the task that has perhaps had the most scrutiny (see Curran & Hintzman, 1995, 1997, for examples) due to the difficulty of the inclusion and exclusion instructions. A recent study by Hudson et al. (2009) used a 'guided' PDP to overcome this problem, in which participants were given more detailed onscreen instructions on how to complete each test. Clearly, in patients who present with significant memory impairment and potentially low intellectual ability, it is important to make such considerations.

The ROC method is less prone to the problems associated with the R/K paradigm and the PDP. Confidence responses may be easier to understand and are not subject to differences in interpretation. Also, only a single recognition condition is needed to estimate recollection and familiarity. Although this method was not used in the current thesis, it has been used in the context of amnesia and TLE and shown converging results to other methods (Bowles *et al*., 2007; Yonelinas *et al*., 1998). As well as the criticisms raised above, the main motivation for not including this method here was because the aim was not to use TLE to assess the appropriateness of different signal detection accounts of recognition memory. The source memory, PDP and associative recognition tasks provided a suitable test bed on which to contribute to understanding about subjective and objective recollection in TLE. However, a future study could combine the ROC method with subjective experience judgments in TLE to provide a 'missing piece to the puzzle'. The combined use of the R/K paradigm and ROC method has seen little attention in the literature. Two previous studies using this approach have found mixed results. For example, Rotello et al. (2005) found that ROC recollection estimates converged with subjective proportions only when conservative instructions were used to define a true Remember response. Moreover, Kapucu, Macmillan, and Rotello (2010) analysed ROC and R/K data by applying a number of different mathematical models. They found that participants could be classified in two ways based on which model provided the best fit to the data. For participants whose data was best fit by a dual-process high threshold signal detection model, the expected convergence between R/K and ROC measures was found. For participants whose data was best fit by a pure signal detection model, ROC intercepts did not predict subjective Remember rates. The noise created by variability in memory strength in groups such as TLE patients may make replication of this work a challenge. Nevertheless, such a project would no doubt appeal to a broad audience.

An important point to note about the current research is that the results are based on the analysis of a highly diverse sample of patients. The benefits of this are that the reductions found in levels of recollection suggest this pattern is observable at the group level in patients with varying aetiologies and epileptic profiles. Previous TLE studies have typically assessed strictly defined groups of left and right sided patients, or pre- or post surgical cases with clear evidence of focal lesions. Using samples with well documented lesion data is highly useful for contributing to neurobiological debate regarding functional separation within the MTL. For example, the work of Cohn et al. (2009) and Bowles and colleagues (2007; 2010) has provided compelling support for the role of the hippocampus in recollective processing. In the current research, it was only possible to make *inferences* about the likely neuroanatomical areas involved in the tasks.

An important extension of the current research would thus be to conduct similar subjective-objective comparisons of recollection in TLE patients with well circumscribed lesions. As was seen in Chapter 7, the evidence is suggestive that a common recollective process operates between tasks, and further examination would reveal the extent to which familiarity measures do also. Work with patients who have restricted damage to extrahippocampal structures, like the case presented in Bowles et al. (2007), is likely to aid further understanding of this.

Whereas as the results here provided some evidence in favour of a preferential verbal impairment in recognition and recollection in LTLE, it was difficult to draw firm conclusions due to the unequal sizes of the laterality subgroups. The TLE literature is mixed on this topic regarding recollection, although two recent studies have found rather more compelling evidence for the material specific basis of familiarity (Cohn *et al*., 2009; Martin *et al*., 2011). The *comparison* of verbal and non-verbal PDP tasks in this thesis made some contribution to this area, but it must be acknowledged that the difficulty in tasks was not matched.

Associative recognition paradigms seem particularly suited to this area, because comparisons can be made between verbal and non-verbal binding ability individually (e.g. word-word or face-face pairs), and combined (e.g. face-word pairs). Whereas recent functional neuroimaging studies in healthy subjects have provided evidence that the hippocampus is involved in cross-domain binding (Kirwan & Stark, 2004; Westerberg, Voss, Reber, & Paller, 2012), the study of recollection and familiarity in unilateral TLE patients is likely to contribute significantly to our understanding of the neuroanatomical structures involved in the processing and integration in different types of material.

One of the critical findings of this thesis was that subjective and objective indices of recollection and familiarity appear to converge to a large extent in TLE. It would be advantageous to apply this kind of work to other memory impaired groups. For example, in older adults and patients with Alzheimer's disease, where frontal damage leads to problems in awareness, it would be interesting to explore whether there is a breakdown in the relationship between subjective and objective forms of recollection. Older adults are known to make more FPs than younger adults, and this has been previously linked to frontally mediated failures in, or erroneous recollection (McCabe *et al.*, 2009). Therefore, exploring the subjective experience associated with cognitive errors is likely to add to ongoing discussion of how conscious experience relates to behaviour.

8.6 Conclusions

This thesis aimed to elucidate the nature and extent of memory impairments in TLE empirically through the application of the dual-process framework. The studies presented here have added to an emerging literature which has begun to understand memory dysfunction in this group as a specific impairment in *recollection*. The novel approach taken was to compare measures of subjective experience alongside estimated contributions of a more strictly defined objective recollective process. Significant reductions or impairments in recollection were seen in patients across a number of tasks, whilst familiarity was found to be largely intact. By evidencing that a relationship exists between the experience of memory and its underlying activity, this work provided an important theoretical contribution. Moreover, by showing that patients have intact awareness in the context of identifiable episodic memory impairment, the research was also able to address a number of outstanding clinical issues in the field of TLE.

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Appendices

APPENDIX A – RFG Instructions

You should make a ***remember*** **(R)** judgment if you can consciously recollect its prior occurrence. Remember is the ability to become consciously aware again of some aspect or aspects of what happened or what was experienced at the time the item was presented (e.g., aspects of the physical appearance of the item, or of something that happened in the room, or of what you were thinking or doing at the time). In other words, the ‘‘remembered” item should bring back to mind a particular association, image, or something more personal from the time of study, or something about its appearance or position (i.e., what came before or after that item).

You should make a ***familiar*** **(F)** judgment if you recognize the item, but you cannot consciously recollect anything about its actual occurrence or what happened or what was experienced at the time of its occurrence. In other words, respond ‘‘familiar” (F) when you are certain that you recognize the item, but it fails to evoke any specific conscious recollection from the study list.

Finally, you may have responded YES to an item but neither remember or know that it was originally studied. In this case, you must respond ***guess*** **(G).**

To further clarify the difference between remembering and familiarity, here are some examples. You may see someone in the supermarket that is highly familiar to you and you are sure you have met them before, yet you cannot place where or when. Alternatively, when asked the last movie you saw, you would typically respond in the ‘‘remember” sense, that is, becoming consciously aware again of some aspects of the experience of seeing the movie.

APPENDIX B – Individual patient neuropsychological test scores

			BMIPB (z-score)						WRMT (raw score/50)		Working memory (raw score)		Fluency (z-score)	
Patient	Age: M/F	WASI FSIQ	Figure Imm%	Figure Del%	List A1-5	List 6	Story Imm.	Story Del.	Words	Faces	Digits Forward	Digits Backward	FAS	Categories
1	55: F	73	-3.90	-1.90	-1.17	-0.33	-1.12	-0.81	42	37	5	2	-0.05	-1.65
2	54:M	89	-3.28	-1.48	-2.10	-3.00	-2.66	-2.14	42	28	5	4	-2.19	-2.27
3	55:F	105	-1.88	-0.96	-2.83	-1.00	-1.56	-1.70	39	44	7	4	0.33	0.59
4	33:M	-	-	-	-	-	-	-	-	-	-	-	-	-
5	30:M	84	-1.99	-1.46	-0.60	-0.78	-1.94	-2.22	38	43	7	6	-2.66	-1.36
6	26:F	74			-2.90	-1.89	-1.64	-1.82	36	29	-	-	-2.94	-2.18
7	36:F	110	-1.00	-1.60	-1.97	-2.84	-1.64	-2.30	-	-	-	-	-	-
8	24:F	100	-1.66	-2.13	-0.04	-1.09	-0.69	-0.33	47	35	6	5	0.51	0.02
9	48:F	109	0.05	0.59	0.81	-0.67	-1.34	-1.37	44	46	8	6	-1.13	-0.17
10	38:F	116	-1.48	-1.23	1.78	1.16	-0.92	-1.30	49	34	9	7	-0.06	1.36
11	42:F	111	-	-	-	-	-	-	41	40	7	5	0.38	-0.40
12	45:F	98	0.59	0.87	0.71	1.00	-0.02	0.30	48	46	5	4	-1.22	-0.64
13	46:F	104	-0.60	0.10	0.10	-0.70	-2.10	-1.50	47	39	9	7	-0.98	-0.88
14	56:F	117	-0.61	-0.44	-0.23	0.00	-0.24	-0.48	47	30	7	7	0.98	-0.84
15	47:F	92	-1.28	-0.52	-0.33	-1.33	-2.44	-2.70	41	36	8	5	-1.26	-0.17
16	38:F	115	-1.71	-0.64	-0.86	-0.04	-2.12	-1.80	46	40	6	5	-1.17	-0.82
17	39:F	100	-2.27	-2.19	-1.14	-2.44	-2.00	-2.18	38	29	8	5	-1.94	-1.90
18	18:F	114	-0.19	0.16	1.17	0.33	2.30	1.55	48	48	6	4	0.03	0.80
19	49:M	123	-2.61	-1.32	-2.63	-2.67	-1.56	-2.59	32	29	8	7	-0.60	-1.60
20	38:F	110	-1.71	-1.60	1.78	1.16	-1.28	-1.43	46	45	6	6	-0.15	-0.81
21	38:M	87	-1.79	-1.38	-3.22	-2.84	-2.60	-2.43	40	40	7	6	-2.19	0.81
22	43:F	96	-1.63	-1.60	-1.56	-1.64	-1.52	-1.93	46	42	6	3	-0.69	-1.36
23	44:F	120	0.11	0.55	2.06	-0.04	0.17	-0.18	48	44	7	6	1.54	-0.64
24	57:F	126	-0.48	0.03	0.92	1.33	0.86	0.30	48	48	8	6	0.21	0.80
25	23:F	87	0.22	0.09	-0.29	-0.04	-1.23	-1.31	46	40	7	6	-1.45	0.62
26	30:F	109	-0.05	-1.67	-0.44	-0.44	-1.04	-0.93	49	42	7	4	-1.26	0.45
27	37:M	85	-3.86	-3.82	-2.81	-3.64	-	-	-	-	-	-	-	-

Note:M = Male, F = Female, WASI FSIQ = Wechsler Abbreviated Scale of Intelligence (Psychological Corporation, 1999) Full-Scale IQ, BMIPB = BIRT Memory and Information Processing Battery (Coughlan *et al*., 2007), WRMT = Warrington Recognition Memory Test (Warrington, 1984). Dashes (-) indicate missing data resulting from participants dropping out from study before test was administered, declining to take part in test, or where alternative tests were carried out as part of routine clinical assessment.

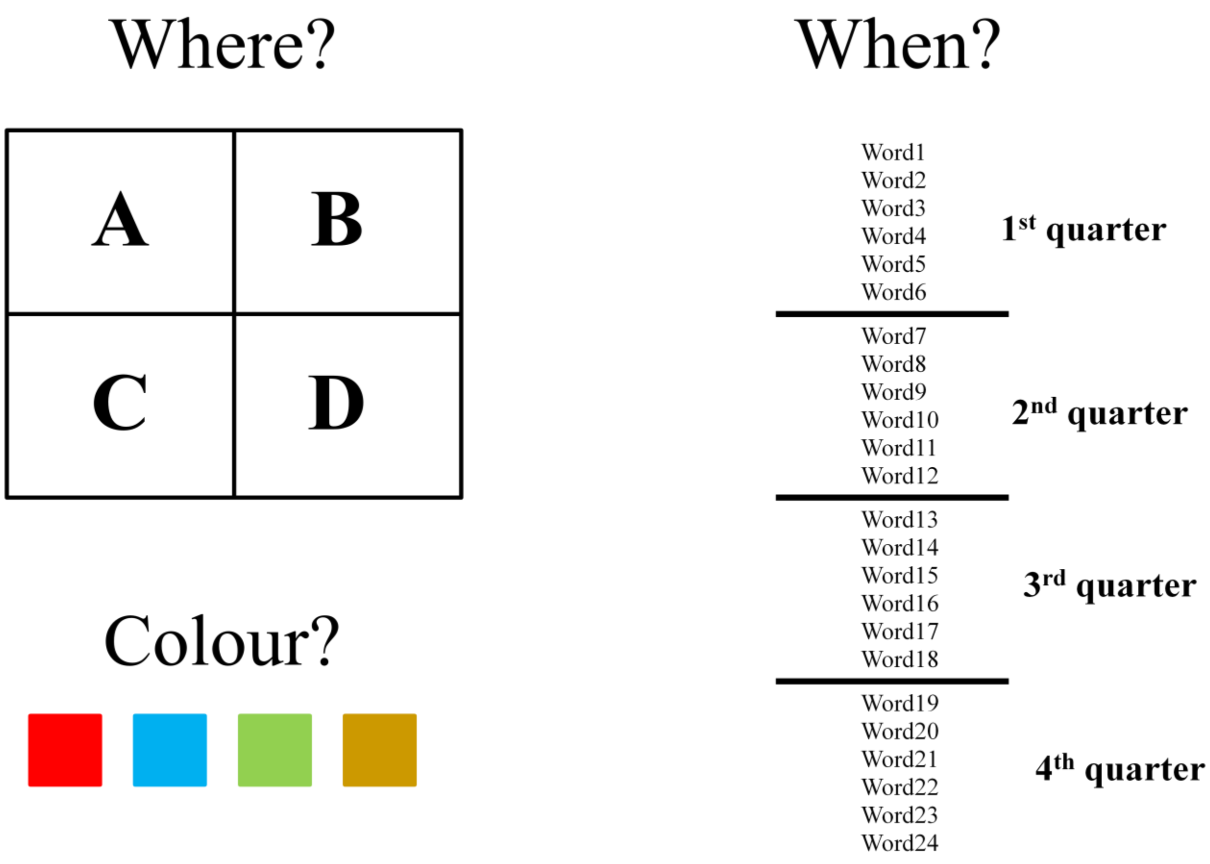
APPENDIX C

Number of participants included in each demographic and neuropsychological assessment analysis

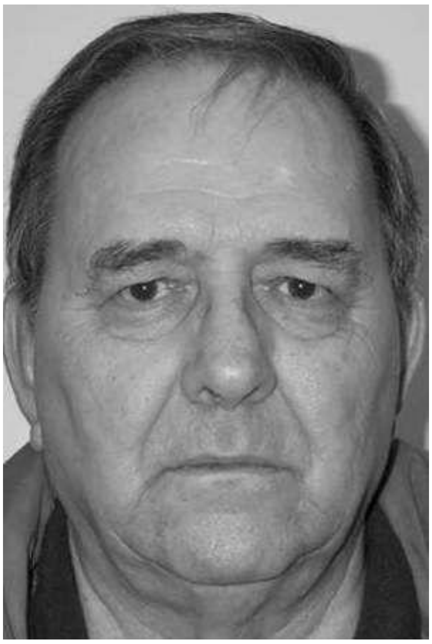
Variable	Control *N*	TLE *N*	LTLE *N*	RTLE *N*	BTLE *N*
Demographics					
Age	19	26	12	9	5
Gender (Male:Female)	19	26	12	9	5
Yrs. Education	19	26	12	9	5
Handedness (Right:Left)	19	26	12	9	5
Mood: HADscale (raw score/21)					
Anxiety	19	24	11	9	4
Depression	19	24	11	9	4
IQ (standard scores)					
NART pred. FSIQ	19	24	11	9	4
WASI VIQ	19	23	10	8	5
WASI PIQ	19	23	10	8	5
WASI FSIQ	19	25	11	9	5
Memory: BMIPB (z-scores)					
Figure Imm %	19	24	10	9	5
Figure Del %	19	24	10	9	5
List A1-5	19	24	10	9	5
List 6	19	24	10	9	5
Story Imm	19	24	11	9	4
Story Del	19	24	11	9	4
WRMT (raw score/50)					
Words	19	23	10	9	4
Faces	19	23	10	9	4
Working memory (raw scores)					
Digits forward	19	22	10	8	4
Digits backward	19	22	10	8	4
Fluency (z-scores)					
FAS	19	23	10	9	4
Categories	19	23	10	9	4

Note: HADs = Hospital Anxiety and Depression rating scale (Zigmond & Snaith, 1983), NART = National Adult Reading Test (Nelson, 1982), FSIQ = Full-scale IQ, WASI = Wechsler Abbreviated Scale of Intelligence (Psychological Corporation, 1999), VIQ = Verbal IQ, PIQ = Performance IQ, BMIPB = BIRT Memory and Information Processing Battery (Coughlan *et al*., 2007), WRMT = Warrington Recognition Memory Test (Warrington, 1984). TLE = Temporal lobe epilepsy, LTLE = left temporal lobe epilepsy, RTLE = right temporal lobe epilepsy, BTLE = bilateral temporal lobe epilepsy.

APPENDIX D – Prompt sheet used for source memory task (Chapter 3)



APPENDIX E – Example of facial stimuli used in Experiment 4.2



APPENDIX F – List of public events and correct years (Chapter 6)

1) Queen Elizabeth II of England marks 50 years as monarch with the Golden Jubilee (2002).

2) Hurricane Katrina makes land fall along the U.S. Gulf Coast causing severe damage (2005).

3) Global protests are held against the IRAQ war, with more than 10 million people in over 600 cities across the world (2003).

4) Former President of Iraq Saddam Hussein is executed by hanging, following conviction of committing war crimes by the Iraqi Special Tribunal (2006).

5) The deadliest bushfires in Australian history begin; they kill 173, injure 500 more, and leave 7,500 homeless (2009).

6) Barack Obama is sworn into office as the 44th President of the USA – the first black president in history (2008).

7) The British livestock epidemic, foot and mouth disease, reaches crisis levels and causes postponement of the general election (2001).

8) A 9.3 magnitude earthquake, epicentered just off the west coast of the Indonesian island of Sumatra, generates enormous tsunami waves that crash into the coastal areas of a number of nations in South East Asia (2004).

9) British toddler Madeleine McCann disappears from an apartment in Praia da Luz, Portugal (2007).

10) Thirty-three miners near Copiapó, Chile, trapped 700 metres underground in a mining accident in San José Mine, are brought back to the surface after surviving for a record 69 days (2010).

11) The death of American entertainer Michael Jackson (2009).

12) Terrorists attack the USA by crashing aircraft into the twin towers of the World Trade Centre and the Pentagon, killing more than 3000 people (2001).

13) Pope John Paul II dies; over 4 million people travel to the Vatican to mourn him (2005).

14) The Columbia space shuttle disintegrates over Texas, killing all 7 astronauts on-board (2003).

15) The Simpsons Movie releases in theatres (2007).

16) A 7.0-magnitude earthquake occurs in Haiti, devastating the nation's capital, Port-au-Prince (2010).

17) Former building society Northern Rock is the first bank in Europe to be taken into state control, due to the U.S. subprime mortgage financial crisis (2008).

18) Brazil beat Germany in the FIFA World Cup final held in South Korea and Japan, to win a record 5th title.

19) A series of coordinated bomb attacks strikes several commuter trains in Mumbai, India (2006).

20) Armed robbers in Northern Ireland steal over £22 million from the headquarters of the Northern Bank (2004).

APPENDIX G – Analysis of gender differences for Chapter 6

Overview

Gender differences in AM have been established by a number of studies, with women showing more accurate recall and higher degree of specificity than males in their AMs (*see* Piefke, Weiss, Markowitch, & Fink, 2005, for a review). Pertinent to the investigation in Chapter 6, women have also been shown to be more accurate at dating events in their life (Skowronski & Thompson, 1990) and shown to have superior semantic memory, which was driven by better performance on fluency tasks (Maitland, Herlitz, Nyberg, Backman, & Nilsson, 2004). ANCOVA analyses were conducted to evaluate the influence of this variable on the data. These analyses are presented below under the same subheadings that appear in the Results section of Chapter 6.

Multifactorial Memory Questionnaire

The main analysis was conducted again using ANCOVA, controlling for gender. The main effects of group and subscale remained significant, as did the interaction term: $F(1, 161) = 115.95$, $p = .001$, $\eta_p^2 = .42$; $F(2, 322) = 5.23$, $p = .007$, $\eta_p^2 = .03$; $F(2, 322) = 24.41$, $p = .001$, $\eta_p^2 = .13$. A near significant association of gender was found, however, $F(1, 161) = 3.69$, $p = .06$, $\eta_p^2 = .02$. To investigate, further one-way ANOVAs were conducted looking at gender differences in individual subscales for the sample overall. For the Ability scale, males scores (*Mean* = 44.96, *SD* = 13.57) were significantly higher than females (*Mean* = 40.21, *SD* = 12.46); $F(1, 163) = 4.56$, $p = .03$, $\eta^2 = .03$. Similarly, males had significantly higher scores on the Contentment scale (Male *Mean* = 37.62, *SD* = 15.70; Female *Mean* = 32.00, *SD* = 16.21); $F(1, 163) = 4.05$, $p = .05$, $\eta^2 = .02$. Finally, males had significantly higher scores on the Strategy subscale also (Male *Mean* = 42.78, *SD* = 12.25; Female *Mean* = 36.08, *SD* = 13.15); $F(1, 163) = 8.90$, $p = .003$, $\eta^2 = .05$. In summary, males in the sample tended to be more positive about their memory, and reported using more memory aid strategies than females.

Public events task

Subjective measures

The analyses were repeated using univariate ANCOVA to control for gender differences. For the proportion of events subjectively recalled, the main effect of group remained significant, $F(1, 161) = 27.63$, $p = .001$, $\eta_p^2 = .04$. However, a significant association was found between gender and these scores, $F(1, 161) = 7.27$, $p = .01$, $\eta_p^2 = .04$. One-way ANOVA in the sample overall displayed males (*Mean* = .79, *SD* = .14) to have significantly higher scores than females (*Mean* = .71, *SD* = .1); $F(1, 163) = 10.17$, $p = .002$, $\eta^2 = .06$. For the proportion of events where the context was subjectively recalled, mean vividness ratings and the proportion of events participants said they knew the year of (metacognitive measure), the main effects of group remained: $F(1, 161) = 4.34$, $p = .04$, $\eta^2 = .03$; $F(1, 161) = 8.43$, $p = .004$, $\eta^2 = .05$; $F(1, 159) = 10.05$, $p = .002$, $\eta^2 = .06$. There was no significant association between gender and these three scores (*Fs* < 1). Similarly, there was still no main effect of group on personal significance ratings after controlling for gender and gender had no significant association with this variable either (*F*s < 1). In summary, just as males subjectively perceived their memory to be better as through the MMQ, they also reported recalling more public events than females.

Objective measures

ANCOVA analyses using gender as a covariate revealed this variable to have no significant association with the proportion of years attempted, proportion of years correctly dated, or the absolute and mean difference accuracy scores (*F*s < 1). Therefore, although various subjective measures were found to be higher overall in males, objective accuracy was not different between the sexes.

Subjective-Objective comparisons

The first analysis looked at dating accuracy following participants' metacognitive judgment about whether they thought they knew the correct answer. This analysis was conducted using ANCOVA controlling for gender. There was again no significant effect of group, $F(1, 145) = 2.00$, $p = .16$, $\eta^2 = .01$. The effect of accuracy type remained significant, $F(1, 145) = 16.78$, $p = .001$, $\eta^2 = .10$. The interaction between group and accuracy type was also again non-significant, $F < 1$. A significant association was found with gender, however, $F(1, 145) = 3.93$, $p = .05$, $\eta_p^2 = .03$. The means of the whole sample revealed that dating accuracy for years predicted to be known by participants was higher in females (*Mean* = .61, *SD* = .30) than males (*Mean* = .53, *SD* = .31). This difference was not statistically reliable, $F(1, 148) = 2.10$, $p = .15$, $\eta^2 = .01$. Similarly, the mean dating accuracy for items that were predicted *not* to be known was also higher in females (*Mean* = .10, *SD* = .13) compared to males (*Mean* = .06, *SD* = .11). One-way ANOVA showed this to be a near significant trend $F(1, 148) = 3.38$, $p = .07$, $\eta^2 = .02$. This data presents a mixed picture regarding differences in metacognitive monitoring between males and females; the data first suggest that females are more able to correctly date events when they think they think they know the answer. However, the second analysis also suggests that despite claiming they do not know the correct answer, they provide more correct dates than males. Interestingly, these differences (although non-significant) are in the context of equivalent overall objective dating accuracy between the sexes (as reported above).

The next analysis looked at dating accuracy for events where the participant had stated they recalled the encoding context versus events they could not recall the encoding context. ANCOVA analysis revealed no significant association with gender ($F < 1$), suggesting no difference between males and females.

The final analysis compared the mean vividness for correctly dated items versus vividness for incorrectly dated items (or items where no response was made regarding the year). ANCOVA analyses revealed a significant association with gender, $F(1, 143) = 4.98$, $p = .03$, $\eta_p^2 = .03$. When controlling for gender, the marginal effect of group was removed, $F(1, 143) = 2.37$, $p = .13$, $\eta_p^2 = .02$. The main effect of vividness item type remained, $F(1, 143) = 31.55$, $p = .001$, $\eta_p^2 = .18$ and the interaction between group and vividness item type remained non-significant ($F = 1.10$). To investigate the effect of gender, one-way ANOVAs were conducted on the mean vividness for correct and incorrect items. Vividness for correctly dated items showed men to have significantly higher scores than women (Male *Mean* = 5.14, *SD* = 1.39; Female *Mean* = 4.41, *SD* = 1.53); $F(1, 145) = 6.79$, $p = .01$, $\eta^2 = .05$. Moreover, higher scores in males for the mean vividness for incorrect or undated items was of borderline statistical significance (Male *Mean* = 3.26, *SD* = 1.14; Female *Mean* = 2.90, *SD* = 1.05); $F(1, 162) = 3.67$, $p = .06$, $\eta2 = .02$. These data suggest that males overall have higher levels of vividness associated with memories than females; however, they must be interpreted cautiously because the vividness for correct years analysis was based on smaller sample numbers than the overall mean vividness analysis, where no gender difference emerged.

Summary

The results found here consistently suggest males have higher levels of subjective phenomenological experience associated with AMs for public events. This is matched by overall higher levels of perceived day-to-day memory function. These data contrast a variety of studies that have found women to have higher scores on a number of AM measures (Davis, 1999; Maitland *et al*., 2004; Skowronski & Thompson, 1990). However, other neuroimaging studies have found no difference in behavioural measures of AM, but varying patterns of neural activity between males and females (Piefke *et al*., 2005; St Jacques, Conway, & Cabeza, 2011). In TLE, gender differences in declarative memory appear more complex, being affected to a great extent by language dominance and lateralisation of lesion (Helmstaedter, Brosch, Kurten, & Elger, 2004; Trenerry, Jack, Cascino, Sharbrough, & Ivnik, 1995). Whilst the male advantage here is interesting, further research is needed with equal numbers of participants in each of the neurological and normal control groups.

APPENDIX H - Pearson's correlations for TLE and control groups on selected predictor and outcome measures from Chapter 6 (original *N* for both groups = 82).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TLE														
1. Age	-													
2. Education yrs	-.15	-												
3. Age diagnosed	.44	-.06	-											
4. Illness onset	.20	.10	-.46	-										
5. MMQ Ability	.08	.12	-.04	-.08	-									
6. MMQ Contentment	-.08	.07	.00	-.13	.64	-								
7. MMQ Strategy	.13	-.03	-.09	.03	.71	.59	-							
8. Prop events recalled	.12	.21	.03	-.03	.26	.27	.17	-						
9. Prop context recalled	.16	.26	-.09	-.25	.05	.10	.14	.34	-					
10.Prop yrs claimed to know	.00	-.25	-.07	.04	.02	.02	.06	.02	-.03	-				
11. Accuracy for yrs predicted to know	.19	.09	.17	-.10	.03	.03	-.05	.14	-.20	-.20	-			
12. Accuracy all attempted yrs	.09	-.09	.07	-.01	-.07	-.11	-.13	.00	-.27	.02	.61	-		
13. Mean personal sig.	-.07	.01	-.05	.02	.06	.17	.15	.01	.10	.31	-.10	.03	-	
14. Mean vividness	.05	-.07	-.06	.11	-.12	-.05	-.05	.02	.10	.43	-.02	.07	.37	-
Controls														
1. Age	-													
2. Education yrs	-.28	-												
5. MMQ Ability	.06	.00			-									
6. MMQ Contentment	.08	-.03			.70	-								
7. MMQ Strategy	.36	-.24			.61	.49	-							
8. Prop events recalled	.06	-.01			.04	.04	.07	-						
9. Prop context recalled	.04	-.15			.03	-.01	.16	.17	-					
10. Prop yrs claimed to know	-.13	.02			.07	.05	-.01	.15	.23	-				
11. Accuracy for yrs predicted to know	-.07	.23			.09	-.02	.07	.08	-.02	-.21	-			
12. Accuracy all attempted yrs	-.17	.15			.07	-.04	.01	.02	.14	.03	.58	-		
13. Mean personal sig.	-.17	.13			-.01	-.07	-.03	.36	.38	.14	.16	.19	-	
14. Mean vividness	-.12	.10			.01	-.07	-.03	.45	.47	.19	.19	.15	.55	-

Note: TLE = temporal lobe epilepsy, HAC = healthy adult controls, MMQ = Multifactorial memory questionnaire (Troyer & Rich, 2002), prop = proportion, sig = significant. Pearson correlations underlined are significant at $p < .05$; correlations with solid underline are significant at $p < .01$.

APPENDIX I – Supplementary Correlational analyses for Chapter 7 (TLE only)

Correlation matrix between anterograde recognition recollection measures and MMQ subscales.

	MMQ subscales		
	Ability	Contentment	Strategy
Source Memory R	.02	.03	-.16
Source Memory Total Context Prop	-.18	-.18	-.24
Word PDP Combined Lag R	.10	.44	.08
Word PDP Hit Subjective R	-.03	.25	-.34
Face PDP Combined Lag R	-.11	-.07	-.14
Face PDP Hit Subjective R	<u>-.46</u>	-.13	-.34
AR Associative Reinstatement d'	-.19	.02	-.36
AR Associative Identification d'	-.38	-.18	-.38
AR R estimate	-.07	.03	-.10

Note: R = remember, Prop = proportion, Word PDP = word repetition-lag process-dissociation procedure, Face PDP = face repetition-lag process-dissociation procedure, AR = associative recognition, MMQ = Multifactorial Memory Questionnaire (Troyer & Rich, 2002).

Correlation matrix between neuropsychological measures and MMQ subscales.

	MMQ subscale		
	Ability	Contentment	Strategy
BMIPB Figure Imm	-.10	.28	-.03
BMIPB Figure Del	-.07	.26	-.05
BMIPB List A1-5	.05	.07	-.08
BMIPB List 6	.14	.18	.00
BMIPB Story Imm	-.26	.18	-.37
BMIPB Story Del	-.23	.19	-.27
WRMT Words	-.10	.06	-.06
WRMT Faces	-.23	.06	-.25
FAS verbal fluency	-.43	-.26	<u>-.67</u>
Category fluency	-.22	.14	-.26
Digits forward	-.12	-.15	-.14
Digits backward	.10	-.09	.03

Note: BMIPB = BIRT Memory and Information Processing Battery (Coughlan *et al.*,2007) , WRMT = Warrington Recognition Memory Test (Warrington, 1984), MMQ = Multifactorial Memory Questionnaire (Troyer & Rich, 2002). Pearson correlation coefficient values underlined are significant at the $p < .05$ level; values underlined in solid line are significant at the $p < .01$ level.

Correlation matrix between anterograde recognition recollection and public events measures.

	Public events measures					
	Prop events subjectively recalled	Prop events context recalled	Number of events correctly dated	Prop years attempted that were correct	Mean vividness all events	Mean vividness events subjectively recalled
Source Memory R	.48	.22	.43	-.30	.15	-.04
Source Memory Total Context Prop	.33	.41	.55	.17	.24	.12
Word PDP Combined Lag R	.64	.31	.36	-.26	.26	-.15
Word PDP Hit Subjective R	.78	.32	.32	-.05	.38	-.18
Face PDP Combined Lag R	.32	.00	.31	-.14	.08	-.14
Face PDP Hit Subjective R	.33	-.08	.02	.28	.07	-.30
AR Associative Reinstatement d’	.29	.12	.21	.29	.05	-.21
AR Associative Identification d’	.52	-.09	.40	-.28	.47	.22
AR R estimate	.31	-.10	.22	-.31	.15	.17

Note: R = remember, Prop = proportion, Word PDP = word repetition-lag process-dissociation procedure, Face PDP = face repetition-lag process-dissociation procedure, AR = associative recognition. Pearson correlation coefficient values underlined are significant at the $p < .05$ level; values underlined in solid line are significant at the $p < .01$ level.

Correlation matrix between anxiety, depression and subjective and objective anterograde recollection, public events and MMQ measures.

		HADs Anxiety	HADs Depression
	HADs Anxiety	-	
	HADs Depression	.64	-
Subjective	Source Memory R	-.21	-.20
	Word PDP Subjective Hit R	.03	-.19
	Face PDP Subjective Hit R	.36	.25
Objective	Source Memory Correct Context Prop	.00	.04
	Word PDP Combined Lag R	.01	.11
	Face PDP Combined Lag R	.00	.08
	AR Associative Reinstatement d’	-.22	-.10
	AR Associative Identification d’	.01	.13
	AR R estimate	.02	.16
Public events	PE Prop events subjectively recalled	.08	-.18
	PE Prop events context recalled	-.23	-.50
	PE Number of events correctly dated	-.06	-.19
	PE Prop years attempted that were correct	.20	.30
	PE Mean vividness all events	.18	-.01
	PE Mean vividness events subjectively recalled	.04	.08
MMQ	Ability subscale	-.41	-.27
	Contentment subscale	-.30	-.34
	Strategy subscale	-.48	-.22

Note: HADs, Hospital Anxiety and Depression rating scale (Zigmond & Snaith, 1983); PDP, Process dissociation procedure; AR, Associative recognition; MMQ, Multifactorial Memory Questionnaire (Troyer & Rich, 2002).