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MEMORY AND METAMEMORY IN PATIENTS WITH TEMPORAL LOBE EPILEPSY

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MEMORY AND METAMEMORY IN PATIENTS WITH TEMPORAL LOBE EPILEPSY

by

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Memory and Metamemory in Patients with Temporal Lobe Epilepsy

Charlotte Emma Howard

Abstract

It is well established that patients with temporal lobe epilepsy (TLE) commonly report memory difficulties. The aim of this thesis was to use a novel approach adopting Nelson & Narens' (1990) theoretical framework to investigate whether metacognitive knowledge and memory performance were differentially disrupted in patients with TLE. More specifically, investigating to what extent poor memory in TLE could result from inadequate metamemory monitoring, inadequate metamemory control or both.

Experiment 1 employed a combined Judgement-of-Learning and Feeling-of-Knowing task to investigate whether participants could monitor their memory successfully at both the item-by-item and global levels. The results revealed a dissociation between memory and metamemory in TLE patients. TLE patients presented with a clear episodic memory deficit compared with controls yet preserved metamemory abilities. Experiments 2 and 3 explored the sensitivity approach to examine metacognitive processes that operate during encoding in TLE patients and controls. Both these experiments demonstrated that TLE patients were sensitive to monitoring and control processes at encoding. The final experiment further investigated memory performance by examining the role of lateralisation of the seizure focus using material specific information and the 'Remember-Know' paradigm. The findings from the verbal task provided partial support to the material-specific hypothesis.

The results from these experiments are discussed in terms of their association with executive functioning and memory deficits in TLE, and have important implications for future research examining memory and metamemory in TLE patients and other clinical populations.

Keywords: temporal lobe epilepsy, metacognitive, Judgement-of-Learning, and Feeling-of-Knowing.

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Abbreviations

AD	Alzheimer's disease
AED	anti-epileptic drug
AF	accelerated forgetting
ANOVA	analysis of variance
ANCOVA	analysis of covariance
CT	computed tomography
D-KEFS	Delis-Kaplan Executive Function System
D-R	Difficult-Related
D-U	Difficult-Unrelated
EEG	electroencephalogram
EMQ	Everyday Memory Questionnaire
EOL	Ease-of-Learning
E-R	Easy-Related
E-U	Easy-Unrelated
FLE	frontal lobe epilepsy
FOK	Feeling-of-Knowing
FSIQ	full scale intelligence quotient
HADS	Hospital Anxiety and Depression Scale
ICD-10	The International Classification of Diseases – Version 10
IAP	Intracarotid Amobarbital Procedure
JOL	Judgement-of-Learning
LTL	lateral temporal lobe
L-TLE	left temporal lobe epilepsy
M	mean
MFQ	Memory Functioning Questionnaire

MQ	Metamemory Questionnaire
MRI	magnetic resonance imaging
MTL	mesial temporal lobe
NART	National Adult Reading Test
NICE	National Institute for Health and Clinical Excellence
R-K	Remember-Know
RJR	Recall-Judgement-Recognition
R-TLE	right temporal lobe epilepsy
SD	standard deviation
SPSS	Statistical Package for Social Sciences
TEA	transient epileptic amnesia
TLE	temporal lobe epilepsy
WAIS-III	Wechsler Adult Intelligence Scale – 3rd Ed.
WMS-III	Wechsler Memory Scale – 3rd Ed.

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Author's Declaration

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Chapter 1: Introduction

1.1 Temporal Lobe Epilepsy

1.1.1 Epidemiology

Epilepsy is a chronic neurological disorder characterised by recurrent seizures (Blume et al., 2001; International League Against Epilepsy, 1993). It affects approximately one in 131 people in the UK (Epilepsy Action, 2009). Epilepsy is most prevalent in children and adults over the age of 65; however the condition can occur in anyone at anytime (The National Society for Epilepsy, 2009). An epileptic seizure is the clinical manifestation of excessive and hypersynchronous neuronal activity in the cerebral cortex. Seizures can take many forms. The International Classification of Diseases (ICD-10) classifies epilepsy as a paroxysmal disorder which can be subcategorised in terms of underlying brain pathology and seizure type (see ICD-10 blocks G40-G41.9, Retrieved http://apps.who.int/classifications/apps/icd/icd10online/, 25th August 2009). A broad distinction is made between 'partial' and 'generalised' seizures. Partial seizures result from paroxysmal activity in a localised area of the brain, whereas generalised seizures involve diffuse brain disturbance. There are simple and complex forms of partial seizures, consciousness remaining unaltered in the former and altered during the latter. Epilepsy should be viewed as a symptom of an underlying neurological disorder rather than a single condition as the symptomatology varies greatly between cases. Signs and symptoms of simple partial seizures originating from the temporal lobes include, and are not limited to, sweating, sensory hallucinations such as smelling non-existent smells and tasting non-existent tastes, feelings of déjà vu and feelings of fear and panic. Signs and symptoms of complex partial seizures originating from the temporal lobes include, and are no limited to, chewing, lip smacking and fiddling with buttons, zips on items of clothing. Both simple and complex partial

seizures can develop into generalised seizures ('secondary generalised seizures'). Generalised seizures also take various forms and include tonic-clonic, absences, myoclonic, tonic and clonic seizures. Around 70% of partial seizures have a temporal lobe focus with frontal lobe pathology accounting for most other cases, although seizures may also have origins in occipital or parietal regions. In contrast, generalised seizures are thought to originate in deep central structures which propagate diffuse effects throughout the brain. The signs and symptoms of generalised seizures vary according to which brain areas are implicated (see Panayiotopoulos, 2005 for a comprehensive review). In temporal lobe epilepsy (TLE) secondary generalised seizures are common and typically follow on from a simple or a complex partial seizure. The onset of such a seizure is focal in nature and can then spread to other brain regions.

1.1.2 Classification of Epilepsy

In TLE seizures can occur in either or both of the temporal lobes. TLE can be classified further into epilepsy of the mesial temporal lobe (MTL) and epilepsy of the lateral temporal lobe (LTL), the former arising from hippocampal pathology and the latter from the neocortex. Where causes can be identified they vary widely, including birth injury, traumatic brain injury, infections, cerebrovascular disease and tumours.

In many cases the cause of the seizure disorder is unknown. Idiopathic epilepsies concern cases which have no apparent cause, and are often marked by genetic aetiology which lowers the seizure threshold. In this type of epilepsy no structural abnormalities are detected. In cryptogenic epilepsies again no underlying cause is detected however, structural abnormalities are suspected but are not visible on neuroimaging data. Advantages of classifying the type of epilepsy can allow for the underlying aetiology to be defined, which can be useful in selecting the most appropriate form of treatment for a patient, thus determining the prognosis of their condition for seizure freedom. Despite

seizure onset always occurring from one or both of the temporal lobes, TLE is regarded as a heterogeneous disorder, as evaluation of single cases requires consideration of a number of clinical variables, for instance age of onset, duration, type of seizures and management programme.

1.1.3 Neurological Markers

The neuropathology of TLE is usually marked by the mesial temporal area but can also be found in the lateral temporal area. The most common cause of refractory seizures in TLE is due to hippocampal sclerosis (cell loss in the hippocampus and surrounding areas).

Investigations into seizures are usually made after an individual has experienced their first attack and treatment normally begins if a second is recorded. Accurate diagnosis of epilepsy is important in implementing an effective management programme. The diagnostic process usually begins with obtaining a detailed clinical history from the patient to determine any possible hereditary links and previous medical conditions. It is very useful at this stage in the diagnostic process to obtain a witness account from a relative or friend of the patient having a seizure which is central to diagnosing the seizure type. In addition to obtaining a clinical history, Magnetic Resonance Imaging (MRI) and electroencephalography (EEG) techniques are commonly used together to help diagnose the seizure type and any underlying causes. EEG recording is usually the first investigative procedure in the diagnostic process. EEG is a technique used to confirm lowered epileptic threshold by recording electrical activity in the brain. It is readily used in individuals suspected of having epilepsy, as it allows a non-invasive method of detecting the location and duration of any abnormal electrical activity (see Plummer, Harvey & Cook, 2008 for a review on using EEG as a source localisation in focal epilepsy). Ambulatory EEG and video-telemetry may be

used as follow-up investigations in individuals whose epilepsy is difficult to diagnose. EGG is a widely used tool in assessing epilepsy, particularly due to its level of convenience and lower costs than using neuroimaging techniques. However, EGG recording is not without its limitations. When using EEG as a diagnostic tool it is not always possible to record an actual seizure, as the duration of recording time (~ 20 minutes) is rarely long enough. Therefore, EEGs frequently rely on interictal epileptic discharges to diagnose the presence of epilepsy. However, false negative recordings are often attributed to limited recording time and restricted coverage of surface electrodes, therefore a normal EEG recording does not necessarily exclude the presence of epilepsy. The sensitivity of EEG in detecting epilepsy is relatively low ranging between 25%-56% (Smith, 2005), therefore this technique is often used in conjunction with neuroimaging data.

Neuroimaging techniques have been used to examine the relationship between neuropsychological functioning and temporal lobe epilepsy (Baxendale et al., 1998; Jansky et al., 2005; Keopp & Woermann, 2005). MRI is the neuroimaging technique typically used to identify underlying structural pathologies. As well as identifying structure abnormalities, MRI can provide volumetric measurements of the hippocampus and can identify the epileptogenic lesion.

1.1.4 Epilepsy Management

Effective epilepsy management is paramount, as it not only has the potential to prevent the recurrence of seizures, but also has implications on social restrictions such as driving and swimming. The National Institute for Health and Clinical Excellence (NICE) guidelines suggests that anti-epileptic drug (AED) therapy is recommended as the core treatment after the second seizure (Stokes, Shaw, Juarez-Garcia, Camosso-Stefinovia & Baker, 2004). AEDs work by reducing the excessive abnormal neural

activity in the brain which causes seizures. Different AEDs work in different ways and thus have different effects on the brain. The aim of clinicians is to prescribe monotherapy in the hope that it will permanently relieve the patient from their seizures to become seizure free. Unfortunately, this is not always possible and the introduction of a combination of AEDs (polytherapy) maybe necessary. The high prevalence of epilepsy has lead to a large number of AEDs being licensed in the UK (see British National Formulary Number 58, 2009 for a full comprehensive list). The progress and response to monotherapy or polytherapy is unique to the individual, as a number of clinical variables (e.g. seizure origin, seizure frequency, age of onset, duration) all have an affect on the success of the treatment and prognosis for seizure freedom.

When the use of AEDs has failed, it may be possible for TLE patients to undergo surgery to remove completely or significantly reduce the frequency of seizures. Temporal lobectomy surgery has a high success rate with 60% to 70% of patients becoming seizure free, 20% to 25% of patients still experiencing seizures but less frequently, and only 10% to 15% of patients seeing no worthwhile improvement (Retrieved http://www.epilepsy.com/epilepsy/temporal_lobectomy, 25th August 2009).

A comprehensive pre-operative evaluation is crucial prior to surgery to establish the location of the epileptogenic zone and also the relationship of the seizure focus to language and memory functions. To determine which hemisphere controls the ability to speak and understand language the Intracarotid Amobarbital Procedure (IAP), also known as the Wada test, is frequently used. The IAP involves briefly anesthetising one of the hemispheres whilst the opposite hemisphere is tested to determine language dominance and can also be used to determine the risk of memory loss following surgery (see Kneebone, Chelune & Lüders, 1997 for a comparison between neuropsychological measures and the IAP). A comprehensive neuropsychological assessment is also

administered to obtain baseline measures in intellectual ability, memory and language functioning prior to surgery.

Alternative epilepsy therapies include the ketogenic diet, which can be used to help reduce seizures in children with epilepsy, by increasing the build up of ketones which helps suppress seizures in this population (see Freeman et al., 1998; Lefevre & Aronson, 2000 for reviews). A more invasive alternative treatment for epilepsy is the intermittent stimulation of the left vagus nerve, which has been used as a method to help reduce the length and intensity of seizures in patients with intractable epilepsy. The vagus nerve stimulator works by way of sending regular electrical pulses to the left vagus nerve which can help reduce the severity of seizures (see Binnie, 2000; Schacter & Saper, 1998 for reviews).

Although there are a variety of management interventions for TLE, the primary treatment for all newly diagnosed patients remains the prescription of AEDs. Only once polytherapy had been introduced and failed would surgery normally be considered an option.

1.1.5 Cognitive Function in TLE

The relationship between persistent epilepsy and cognitive functioning has been of particular interest in the field of neuropsychology (see Hermann & Seidenberg, 2007 for review). Cognitive impairment in epilepsy can be due to a number of contributory factors. Firstly, recurrent seizures, interictal (epileptic discharges between seizures) and subclinical activity can all have a marked disturbance on cognitive processing. Secondly, the underlying brain pathology which gives rise to the seizures can also have an affect on cognitive abilities. Thirdly, the AEDs prescribed to reduce the frequency and severity of seizures can have an adverse effect on cognitive functioning, and particularly on memory (Meador, 2006). Drug effects are particularly apparent in

patients with refractory epilepsy on polytherapy in which a combination of AEDs are typically used. The possibility of switching to another AED is often considered when the introduction of a particular drug has a profound affect on cognitive functioning. However, a careful balance between the side effects of an AED and reducing the frequency of seizures has to be considered and is case specific. Finally, psychosocial effects such as depression and anxiety can also have an effect on cognitive functioning in patients with epilepsy. These contributory factors are not necessarily mutually exclusive, and therefore the extent to which each has an impact on cognitive functioning is difficult to determine. Furthermore, the assessment of cognitive impairment in epilepsy is complex due to the number of clinical variables that differ between cases (e.g. age of onset, seizure type, duration). Marked heterogeneity between cases makes it difficult to control for important differences between specific epilepsy variables, which could have an affect on cognitive performance. The nature and risk of progressive cognitive impairment in patients with epilepsy has been of interest within the field of neuropsychology. Early age of onset, prolonged duration and lack of seizure control have been associated with poor cognitive functioning (Elger, Helmstaedter & Kurthen, 2004). The examination of cognitive impairment in focal epilepsies has been of particular interest due to impairments associated with the site of the lesion (see Elger et al., 2004 for review). The perceived impact of cognitive functioning is clearly apparent in epilepsy populations. Fisher et al. (2000) revealed that 46% of patients reported that having epilepsy had an effect on their cognitive functioning, including the ability to remember, think clearly and concentrate as well as on their emotional and mental well being. Unlike certain other neurological conditions, epilepsy cannot be characterised by a specific cognitive deficit (Elger et al., 2004) but patient complaints about disturbed memory represent the most frequently reported problem (Thompson, 1997). Objective neuropsychological measures have also shown that long-term memory and learning

problems are more commonly observed in TLE (Helmstaedter, Kurthen, Lux, Reuber & Elger, 2003; Thompson, 1997), than in fontal lobe epilepsy (FLE) which has been associated with working memory and executive function (Helmstaedter, Kemper & Elger, 1996).

1.1.6 Memory in TLE

As mentioned earlier, TLE is associated with cell loss in the hippocampus and the surrounding areas, which can result in memory difficulties such as poor episodic memory, long-term consolidation and remote memory. The clinical and theoretical implications of these interlinked forms of memory deficits associated with epilepsy have received much attention (see Bell & Giovagnoli, 2007; Leritz, Grande & Bauer, 2006 for reviews). There is substantial documented evidence of anterograde memory deficits among patients with TLE, which has contributed to the field of neuropsychology. The bilateral mesial temporal resection performed to relieve severe epilepsy in patient HM, now known as Henry Gustav Molaison after his death in 2008, established that structures within the medial temporal lobe were important for memory functioning (Scoville & Milner, 1957). This pioneering research acted as the catalyst for further contributions into memory functioning in patients with temporal lobe epilepsy.

Interestingly, several studies have shown discrepancies between subjective reports of memory problems and objective measures from neuropsychological tasks in TLE patients (Gleissner, Helmstaedter, Quiske & Elger, 1998; Thompson & Corcoran, 1992; Vermeulen, Aldenkamp & Alpherts, 1993). For example, some studies have shown that TLE patients present with memory complaints, but perform adequately when assessed objectively with standardised memory tasks (Gallassi, Morreale, Lorusso, Pazzaglia & Lugaresi, 1988; Hermann, Wyler, Steenman & Richey, 1988; O'Shea, Saling, Bladin & Berkovic, 1996; Thompson & Corcoran, 1992). There is

currently no clear explanation of the lack of consistency between subjective reports and objective data, which is surprising given the extent to which both are used as clinical outcome measures (Trenerry, 1996). Not only do memory complaints affect how patients perceive their condition, but they may also affect how patients perceive the effectiveness of treatment in reducing seizures, in turn having a negative impact on a patient's quality of life. Furthermore, it has been reported that patients with epilepsy report more memory problems than do individuals without the condition (Glone & Wands, 1991; Thompson & Corcoran, 1992; Vermeulen et al, 1993).

Three main factors have been suggested to explain these underestimations of memory in TLE patients. The first is the existence of accelerated forgetting (AF) which may be attributed to a number of contributing factors, such as the presence of seizures during the retention period, evidence of structural brain pathology and negative effects of AEDs on cognition (see Butler & Zeman, 2008 for a review). The AF phenomenon is said to occur when the long-term consolidation process is disrupted in TLE patients. For instance, if the consolidation process is disrupted in TLE patients, immediate recall would not be affected, and therefore, only delayed recall tasks would show differences in memory performance between control participants and TLE patients. Blake, Wroe, Breen & McCarthy (2000; also see Mameniskiene, Jatuzis, Kaubrys & Budrys, 2006) showed for example significant differences between TLE patients and controls at delayed recall for complex verbal material for which the initial level of encoding was equated between TLE patients and controls. AF, however, is far from being a constant feature of TLE, and numerous studies have shown equivalent differences between TLE patients and controls in immediate and delayed recall (Bell, 2006; Bell, Fine, Seidenberg & Hermann, 2005; Giovagnoli et al., 1995; Helmstaedter et al., 1998).

The second factor refers to the presence of mood disturbances (notably anxiety and depression), which interfere with the subjective perception of memory performance,

leading to underestimations (Baños et al., 2004; Elixhauser, Leidy, Meador, Means & Willian, 1999; Giovagnoli, Mascheroni & Avanzini, 1997; Vermeulen et al., 1993). A more general problem of negative self-perception which has been associated with depressed mood can in turn have a negative influence on self efficacy of one's own cognitive abilities and treatment outcomes (see Gilliam, 2005 for review). Decreased mood levels and low self-esteem may go some way to explain the possibly exaggerated memory complaints in subjective reports. The third factor is a specific deficit in metamemory. Metamemory plays a central role in human learning through development (Flavell & Wellman, 1977), and a deficit in this set of processes has been proposed as a major contributor to episodic memory dysfunction in clinical populations (e.g., Light, 1991; Shimamura & Squire, 1986). Metacognitive processes are now discussed in further detail, as the rationale for this thesis surrounds the interplay of memory and metamemory in TLE.

1.2 Metacognition and Memory Awareness

Metamemory is one component of metacognition, which can be broadly defined as the knowledge about one's own cognitive abilities. Flavell (1979) highlighted the importance of understanding the role of metacognition in development, and his ideas have been influential in guiding subsequent research.

> *'I believe that metacognitive knowledge can have a number of concrete and important effects on the cognitive enterprises of children and adults. It can lead you to select, evaluate, revise, and abandon cognitive tasks, goals, and strategies in light of their relationships with one another and with your own abilities and interests with respect to that enterprise.'*
>
> (Flavell, 1979, p. 908)

Nelson and Narens (1990) proposed a theoretical framework for research into metamemory, which has been adopted for the present research. Their model (see Figure 1.1) seeks to integrate metamemory and memory which consists of two key processes: 'monitoring' and 'control'. Monitoring refers to the collection of information and the awareness about one's own memory processes, including encoding, level of knowledge, retrieval, and performance outcome, whereas control acts as a self regulation process, activating and directing these same cognitive processes. Nelson and Narens proposed that monitoring and control was influenced by two levels of information processing. The first refers to the 'object level' and the second to the 'meta level'. In terms of monitoring, the 'meta-level' is influenced by information from the 'object-level'. The 'meta-level' is considered dynamic in that it works by monitoring the state of the current situation, by acquiring information from the 'object level'. The 'object level' controls actions based on information from the meta-level. It was further proposed that modification at the 'object-level' could either (a) initiate an action, (b) continue an action or (c) terminate an action (Nelson & Narens, 1990). The meta-level is *'informed'* by the object-level, whereas the 'meta-level' *'modifies'* the 'object-level'. Monitoring and control processes are therefore defined by the constant feedback of information from these two levels.

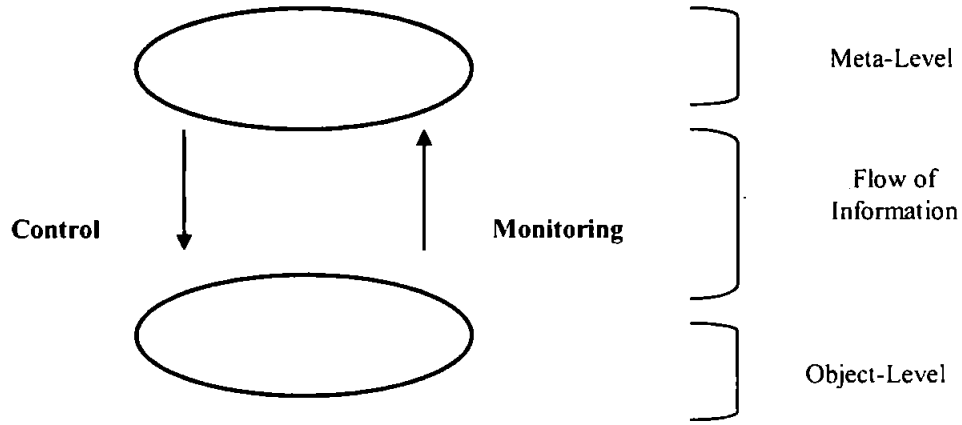


Figure 1.1. Monitoring and control processes influenced by the flow of information between the meta-level and the object-level as illustrated by Nelson and Narens (1990).

One example of control processes is allocating sufficient time to studying material for successful recall. Depending on the difficulty of the material, different amounts of study-time should be allocated, with more time allocated to more difficult items which are closer to the recall threshold (Mazzoni & Cornoldi, 1993; Son & Metcalfe, 2000). Study-time allocation is examined in three of the experiments within this thesis (Experiments 1, 2 & 3). Memory monitoring is usually measured with tasks which include making judgements about future performance, providing an indicator of self-awareness of one's own memory ability.

Nelson and Narens' (1990) theoretical framework is illustrated in Figure 1.2, which shows monitoring and control processes at acquisition, retention and retrieval stages of memory. Memory and metamemory are in continual interplay and cannot be isolated and fully understood as independent processes. Individual monitoring paradigms are discussed in detail in section 1.2.1.

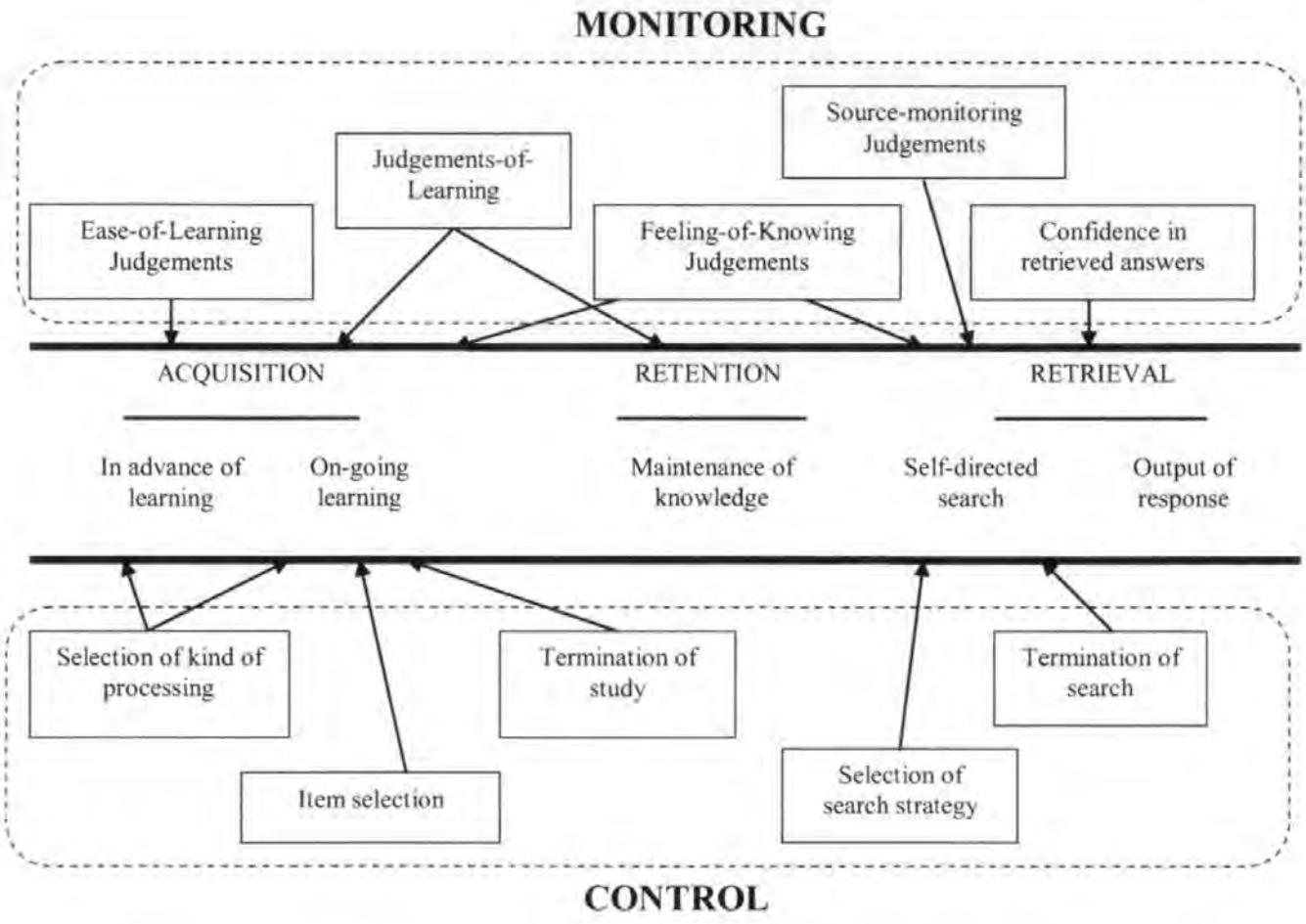


Figure 1.2. A theoretical framework for research into metacognitive processes, showing examples of monitoring components (above) and control components (below) (Adapted from Nelson and Narens, 1990, as adapted by Dunlosky, Serra & Baker, 2007).

1.2.1 Empirical Measures

Nelson and Narens (1990) suggest that metamemory monitoring processes can be explored through the following paradigms, which tap into the different memory stages of their theoretical framework, as illustrated in Figure 1.2.

Ease-of-Learning (EOL)

EOL judgements, although not tested in this thesis but mentioned here for completeness, are made in advance of learning the to-be-remembered items on a trial. Therefore, EOL concern metamemory judgements about how easy it will be to learn items that have not yet been mastered in memory (See Schwartz, 1994 for a review of

EOL). For example, participants may be asked to evaluate how much study-time they would need to master the items. Nelson and Narens (1990) suggest that EOL judgements are predictions that are made about the difficulty of the to-be-remembered items, in terms of which items will be the most effortless to learn and which strategies will make learning easiest. In support of Nelson and Narens' theoretical framework, and as illustrated in Figure 1.2., Leonesio and Nelson (1990) found that EOL judgements showed low intercorrelations with other metamemory judgements, such as Judgements-of-Learning and Feeling-of-Knowing, indicating that the source of these measures varied.

Judgements-of-Learning (JOL)

Item-by-item JOLs assess how well each item has been learnt, by individuals making predictions on their perceived ability to later recall these items, whilst they are still currently available in memory. JOLs are therefore made at the time of acquisition and involve making a prediction about their perceived future memory performance (see Schwartz, 1994 for a review of JOLs). The time at which JOLs are requested in a study phase can vary (immediate vs. delayed) and also by the type of prediction requested (item-by-item vs. global). Immediate JOLs are taken at the time of acquisition without delay, whereas delayed JOLs are taken shortly after acquisition, which has been suggested to result in the "*Delayed-JOL-Effect*" (Nelson & Dunlosky, 1991). Nelson and Dunlosky conducted an experiment using a paired-associates task (i.e. cue-target). In this experiment, half the sample were requested to make JOLs immediately following the trial, whereas the remaining half made their JOLs 30 seconds after the learning trial. Nelson and Dunlosky's findings suggested that participants in the delayed JOL condition were more accurate than those in the immediate JOL condition, confirmed by a greater Gamma correlation (see section 1.2.2 for a description of Gamma

correlations). Nelson and Dunlosky (1992) explained this effect by suggesting that immediate JOLs are made on information retrieved from short-term memory, whereas delayed JOLs are made on retrieval information (information which is available at the time of retrieval), which is more likely to be representative of the information available at test.

More recently, Kimball & Metcalfe (2003) proposed a different explanation which focuses on a 'memory hypothesis' instead of metamemory. Kimball & Metcalfe suggest that the "delayed-JOL-effect" is a consequence of spaced study opportunities. Delayed JOLs are requested after an interval and therefore the attempt to retrieve the item is also delayed. Successful retrieval attempts are awarded higher JOL ratings, whereas unsuccessful retrieval attempts are given low JOL ratings. Re-exposure to the study items following initial JOLs removed the "delayed-JOL-effect", a finding which is consistent with their proposed explanation.

Global JOLs or aggregate measures have been used to obtain a prediction of recalling all items from an entire list, whereas item-by-item JOLs are based on predictions for each single item in a list, which are assumed to reflect online monitoring processes. It could be argued that global JOLs are nothing more than the sum of item-by-item JOLs. However, if this hypothesis were true, then any variable that affects one type of JOL should have the equivalent effect on the other. Although the majority of research has focused on researching the two JOLs methods separately, Mazzoni and Nelson (1995) examined the accuracy of item-by-item JOLs and global JOLs in the same task to see if both measures were equated. Mazzoni and Nelson concluded that, whereas item-by-item JOLs typically yielded over-confidence, global JOLs yielded under-confidence. Mazzoni and Nelson's findings suggest that JOLs were 'theoretically rich' and were not merely judgements based on future recall performance. Furthermore, Mazzoni and Nelson's findings refute the hypothesis that global JOLs are nothing more

than the sum of the item-by-item JOLs, and would therefore suggest that both these measures rely on different mechanisms. JOLs are explored in all experiments in this thesis (Experiments 1, 2, 3 & 4).

Feeling-of-Knowing (FOK)

FOK judgements assess items that cannot currently be retrieved from memory. FOK judgements are made on the likelihood of whether these items can be subsequently retrieved at a later stage in a recognition task (see Schwartz, 1994 for a review of FOK judgements). FOK judgements were first investigated by Hart (1965). Hart first established the Recall-Judgement-Recognition (RJR) procedure to investigate accuracy of FOK judgements in participants. This procedure is still commonly used in metamemory experiments today. Using the RJR procedure, Hart found that FOK judgements made on general-information questions, which were incorrectly answered at recall, were accurate at predicting which items would be correctly recognised. The investigation of FOK judgements has progressed since Hart. Episodic FOK judgements for newly learned information have since been measured and the previously 'yes/no' responses at recognition have been replaced by a more preferred 6-point rating scale (see Dunlosky & Nelson, 1992; Dunlosky & Nelson, 1994; Kelemen & Weaver, 1997; Pinon, Allain, Kefi, Dubas & Le Gall, 2005 for examples of studies using the 6-point rating scale). FOK judgements are explored in two of the experiments in this thesis (Experiments 1 & 3).

Source-Monitoring Judgements

Source-monitoring judgements, although not tested in this thesis but mentioned here for completeness, concern the ability to monitor the origin or source of one's memory and the accuracy of the beliefs about that memory. An example of everyday

source monitoring is given by Batchelder & Batchelder (2008, in Dunlosky & Bjork, 2008) whereby if an individual was asked to learn a particular political fact, asking them whether they leant this fact from either hearing it on the news or reading about it in the newspaper. In such a situation the individual has to first recall the political fact and then correctly attribute the source of this memory. Experimental tasks are usually designed to examine whether participants misattribute the source of information, once an item or memory has been retrieved.

Confidence in Retrieved Answers

Confidence in retrieved answers, although not tested in this thesis but mentioned here for completeness, concern whether participants can judge if they have given the correct answer at recall. As previously mentioned, FOK judgements relate to the future likelihood of recognising items which were omission or commission errors at recall. Confidence in retrieved answers can be distinguished from FOK judgements as they concern whether participants can judge, after an item has been retrieved, whether they have recalled the correct answer or committed an error. Such confidence ratings are usually measured in postdictions and are diagnostic of retrieval correctness. A postdiction is a retrospective monitoring judgement made after retrieval about one's self-belief in the correctness of their responses on a test.

Metamemory Control

Metamemory control processes are most commonly examined by assessing the amount of study-time allocated to a to-be-remembered list (Mazzoni & Cornoldi, 1993; Mazzoni, Cornoldi & Marchitelli, 1990). Depending on the difficulty of the material, different amounts of study-time should be allocated, with more time devoted to more difficult items which are closer to the recall threshold (see Son & Metcalfe, 2000 for

review). Tasks designed to include self-paced study (as apposed to experimenter-paced) have allowed the relationship between metamemory monitoring and control to be explored. For instance, Mazzoni and Cornoldi (1993) indicated that participants consider item difficulty on a task, by devoting more study-time to items that are perceived more difficult to learn. Furthermore, Mazzoni and Cornoldi indicate that participants also consider the nature of the task when assessing task difficulty (i.e. recall, recognition). Study-time is affected by the nature of the task expected, devoting more study-time on a free recall task than when a recognition task is anticipated. Such findings support Nelson and Narens' (1990) theoretical concept that monitoring affects control processes.

In other circumstances, allowing endless study-time has also been found to be counterproductive, coined the "*labor-in-vain effect*" (Nelson & Leonesio, 1988). Nelson and Leonesio (1988) found that unlimited study-time can yield little or no increased chances of recalling the item studied. The effects of study-time allocation are explored in several of the experiments in this thesis (Experiments 1, 2 & 3).

1.2.2 Metacognitive Accuracy

The type of monitoring processes investigated, determines how metacognitive accuracy is calculated. For instance, item-by-item JOLs and FOKs are both online monitoring measures, from which inferences are made about the degree to which a participant correctly predicts performance for one item relative to another. Such online measures are calculated using a measure of *relative accuracy*. Relative accuracy (also referred to as *resolution*) is an index of the ability to discriminate which items may or may not be recalled and whether the judgements are predictive of future recall. Relative accuracy is usually calculated using Goodman-Kruskal Gamma correlation coefficients (Nelson, 1984). Goodman-Kruskal Gamma correlations (G) are a non-parametric test of

the relationship between predicted and actual recall on an item, calculated by the difference between concordant and discordant pairs, with tied pairs not being counted. Gamma values range from +1 to -1. A score nearer +1 indicates a high relationship between the item-by-item JOLs and recall, whereas a score of 0 would reveal no significant relationship between the items predicted and actual recall performance (see Appendix A for calculating Gamma correlations). Goodman-Kruskal Gamma correlations are widely used in the field of metacognition as a measure of accuracy (Bacon, Izaute & Danion, 2007; Moulin, Perfect & Jones 2000c; Nelson & Dunlosky, 1991; Pinon et al., 2005; Souchay 2007). Despite its popularity in metamemory research, in certain experimental situations it may be more suitable to use a different measure of accuracy (see Masson & Rotello, 2009). Spellman, Bloomfield and Bjork (2008, in Dunlosky & Bjork, 2008) highlighted that the Goodman-Kruskal Gamma correlation can be used when certain experimental design issues are taken into account. For instance, study items should include a range of difficulty, as many observations as possible to calculate *G* and a wide JOL rating scale should be used. Given the wide ranging use of *G* in the literature and following these recommendations, the Goodman-Kruskal Gamma correlation coefficient will be adopted in this thesis to determine relative metamemory accuracy in TLE patients.

An alternative measure of metacognitive accuracy is normally used when measuring global predictions. Accuracy of global predictions are calculated by means of *absolute accuracy* measures. Absolute accuracy refers to the degree to which the overall prediction corresponds/calibrates to the mean of actual memory performance. Absolute accuracy can inform about the degree to which an individual's prediction either under or overestimates when compared with their actual recall performance. Calibration curves can be used to plot individual participants' recall performance as a function of their global predictions. The calibration curve allows participants who underestimated and

overestimated their performance to be detected. Despite providing an indication of under- and overestimation, a number of studies have highlighted a potential confound of this method (Hertzog, Saylor, Fleece & Dixon, 1994; McGlynn & Kaszniak, 1991; Moulin, Perfect & Jones, 2000a). For instance, if two participants in the same group were to over- and under-estimate by two items, this would lead to a group mean of zero, as both participants scores would cancel each other out. It is for this reason that Experiments 1 and 2 in this thesis will calculate non-directional discrepancy scores as an absolute measure of accuracy. Therefore, the unsigned absolute difference between predictions and actual recall performance will be calculated to determine accuracy in global predictions and thus removing any potential confound of participants within the same group having identical means.

Relative and absolute measures of metacognitive accuracy provide different information, but are nonetheless important indicators of metamemory abilities. Relative and absolute accuracy measures will both be calculated in this thesis to determine metacognitive accuracy in TLE patients.

1.2.3 Metacognitive Sensitivity

The majority of research on metamemory has focused on accuracy-based measures (relative and absolute), to explore the relationship between predictions and actual recall performance. Another approach which has received less attention, but is just as important, is metacognitive sensitivity. Metacognitive sensitivity relates to the appropriateness of judgements made at encoding irrespective of actual recall performance. Connor, Dunlosky & Hertzog (1997, see also Hertzog et al., 1994) examined accuracy of global predictions before and after study in normal ageing. Connor et al. (1997) showed that both younger and older adults behaved similarly in providing their predictions and postdictions. They also showed that both younger and

older adults' global estimates became more accurate from their pre-study prediction to their postdiction. Connor et al. concluded that older adults had the same level of sensitivity as younger adults by revising their predictions following study.

Moulin, Perfect and Jones (2000a,b,c) labelled this revision in predictions the 'sensitivity approach' and employed it to examine metamemory in Alzheimer's disease patients (AD). Moulin et al.'s (2000a,b,c) experiments explored the sensitivity approach at encoding to investigate whether episodic dysfunction in AD was related to an encoding deficit. By employing the sensitivity approach Moulin et al. were able to examine metamemory monitoring processes at encoding in AD patients regardless of any memory impairment. In doing so, they removed the potential confound of impaired memory performance and were able to examine whether metamemory processes were intact or impaired in this group. Moulin et al. revealed that AD patients on the whole were found to have intact metamemory monitoring processes at encoding. Moulin et al.'s research has explored a unique approach to investigating metamemory processes in a population known to have a substantial memory impairment. The sensitivity approach can therefore be applied to other neurological populations that are known to have or suspected of having problems at encoding. The sensitivity approach will be examined in Experiments 2 and 3 of this thesis.

1.2.4 Metacognition in Neurological Populations

When applying the study of metacognition to clinical populations, the main idea is that poor memory could result from inadequate metamemory monitoring, inadequate metamemory control, or both. Deficits in metamemory have been observed in some types of neurological patients, but not in others (see review by Pannu & Kaszniak, 2005). The advantages of studying metamemory in neurological patients are vast. Not only can metamemory tasks help us to further understand monitoring and control

processes of memory, but also provide an insight into how brain damage and disease can have an effect on these processes.

In the case of AD, it has been proposed that the loss in episodic memory experienced by these patients can be explained by the observed impairment in metamemory functions, and in particular by the deficit in metacognitive monitoring (e.g., Correa, Graves, & Costa, 1996; McGlynn & Kaszniak, 1991; Souchay, 2007). However, it has also been shown that a metamemory deficit is not an obligatory trait of AD, and that some patients can also show unimpaired metamemory ability (Moulin et al., 2000a,b,c). In that context, Cosentino, Metcalfe, Butterfield and Stern (2007) have recently shown that AD patients who have poor awareness of memory loss show poor monitoring processes, whereas patients who are aware of their memory loss demonstrate metamemory that is comparable to healthy older adults. It has also been shown that patients with severe anterograde amnesia can produce accurate metamemory (feeling-of-knowing) judgements (Shimamura & Squire, 1986). Thus, impaired metamemory accuracy is not an obligatory feature of amnesia.

A relationship has been suggested between metacognition and executive processes (Fernandez-Duque, Baird & Posner, 2000; Shimamura, 2000; Souchay, Isingrini & Espagnet, 2000). Neuroimaging (Kikyo, Ohki & Miyashita, 2002; Maril, Simons, Mitchell, Schwartz & Schacter, 2003) and neuropsychological (Janowsky, Shimamura & Squire, 1989; Modirrousta & Fellows, 2008; Schnyer et al., 2004; Vilkki, Servo & Surma-aho, 1998; Vilkki, Surma-aho & Servo, 1999) studies have confirmed a primary role of the prefrontal cortex in metamemory processing. Although metamemory problems seem to be more likely linked to deficits in the prefrontal areas, there are reasons to predict that patients with TLE would present with metamemory deficits too. First, executive functions in general are sustained by a diffuse neural network rather than by only prefrontal areas (Andrés, 2003; Collette & Van der Linden, 2002). Second,

in a study in which the neural correlates of FOK judgements were assessed in a face-name association task, Kikyo and Miyashita (2004; see also Schnyer et al., 2005) showed activations within temporal lobe regions when making FOKs on higher-order information processing of face images or semantic information processing of the to-be-remembered person. Additionally, Modirrousta and Fellows (2008) showed an interesting dissociation between impaired FOK judgements and intact JOLs in patients with prefrontal damage. Pannu, Kaszniak and Rapcsak (2005) and Schnyer et al. (2004) also showed important dissociations in frontal patients, with some metamemory tasks (for example, FOKs) impaired and others (for example, JOLs) within normal range. These findings suggest that JOL accuracy is likely to be dependent on other areas than the prefrontal cortex, for example the temporal cortex. Thirdly, it has been shown that patients with early AD, who, like TLE patients suffer from hippocampal and temporal atrophy, sometimes present with metamemory deficits (see Souchay, 2007 for a review, but see Cosentino et al., 2007). Finally, several studies have documented that cognitive dysfunction in TLE affects functions supported by the frontal cortex such as mental flexibility and inhibition (Corcoran & Upton, 1993; Hermann et al., 1996; Martin et al., 2000). More specifically, Hermann, Seidenberg, Haltiner and Wyler (1991; also see Keller, Baker, Downes & Roberts, 2009) postulated that executive impairment in TLE patients could result from the "spread of temporal lobe hypometabolism to the thalamus secondarily affecting the frontal lobe" or possibly the direct "spread of temporal lobe hypometabolism to the frontal lobe" (p. 1214). This has lead to the 'nociferous cortex hypothesis', postulating that there are electrophysiological abnormalities in distal extratemporal brain regions in TLE that affect executive functions. It is therefore likely that metamemory processes, intimately related to executive functions (Fernandez-Duque et al., 2000; Shimamura, 2000; Souchay et al., 2000), are also disrupted in TLE patients. This hypothesis will be explored in this thesis.

1.2.5 Metacognition in TLE

Although scarce, some neuropsychological studies have looked at metacognitive deficits in TLE using experimental tasks. In two studies, Prevey, Delaney and Mattson (1988) and Prevey, Delaney, Mattson and Tice (1991) concluded that TLE patients presented with a deficit in metacognitive monitoring. Prevey et al. (1988) conducted two experiments in which metamemory functioning was explored at encoding and retrieval in TLE patients and controls. In Experiment 1, participants were presented with two memory span tasks consisting of lists of single syllable nouns (verbal task) and non-meaningful geometrical shapes (visual task). Lists were of increasing length, from one to ten items per list, and after learning each list, participants were instructed to provide a yes/no judgement as to whether they thought they could remember the words/non meaningful geometric shapes in the list in the order presented. The results showed that TLE patients anticipated that they would perform just as well as the controls, but in fact, they performed less well than the controls on the recall tasks. It was also noted that the site of the lesion (left-right) mediated prediction accuracy depending on the experimental materials used (verbal/non-verbal).

In Experiment 2 participants were asked to make FOK judgements on general information questions they had previously answered incorrectly, by providing a 'yes' or 'no' response as to whether they would be able to recognise the correct answer from a range of six alternatives. Although also in this case the authors conclude that monitoring was impaired in TLE patients, the results are actually not clear, and depend on which measure of FOK accuracy is used. Gamma correlations, which are the most commonly used measures of relative metamemory accuracy (the ability to discriminate between which items will or will not be recalled and whether judgements are predictive of performance) showed no significant differences between controls and patients, either left or right. Only when proportion of positive FOK recognitions was used to assess

accuracy, TLE patients resulted to be less accurate than controls and apparently overestimated their memory abilities. This measure reflects the proportion of correctly recognised items over the total number of items for which positive (yes) recognition was predicted. In the assessment of relative metamnemonic accuracy, this conditional probability measure has long been abandoned in favour of the use of Gamma, owing to the influential paper by Nelson (1984) in which Gamma was demonstrated to be superior to a number of other measures of association, including scores based on conditional probabilities (see Benjamin & Díaz, 2008, for a more thorough exam of accuracy measures in metacognition, in Dunlosky & Bjork, 2008).

In two subsequent experiments examining Feeling-of-Knowing in TLE patients and using the same procedure as Experiment 2 in Prevey et al.'s (1988) study, Prevey et al. (1991) replicated this mixed pattern of differences between TLE patients and controls when making FOK judgements. In both Experiment 1 and Experiment 2, Gamma correlations were statistically not different between controls and TLE patients, although numerically they were higher in controls. Statistically significant differences were found in Experiment 1 in the proportion of correct FOK, calculated as proportion of positive FOK recognition. Also for these two experiments, the authors concluded that FOK accuracy was lower in TLE patients than controls, reflecting poor memory monitoring in this population. Prevey et al.'s studies (1988, 1991) suggest that TLE patients overestimated their memory performance and as a consequence were found to have a metamemory impairment. Prevey et al.'s findings are criticised in Chapter 2 and served as a basis for the first experiment in this thesis.

1.2.6 Summary and Justification of Research

To summarise, TLE is neurologically marked by cell loss in the hippocampus and surrounding areas, which has been linked to memory problems (see Bell &

Giovagnoli, 2007; Leritz et al., 2006 for reviews). Despite the large amount of subjective complaints from patients, some research has failed to find a relationship between these reports and objective memory measures (Gallassi et al., 1988; Hermann et al., 1988; O'Shea et al., 1996; Thompson & Corcoran, 1992). This alone, raises problems within a clinical setting as how best to assess and treat TLE patients who complain about their memory.

Accelerated forgetting and mood disturbances have been explored in TLE and have been put forward as possible answers to the disparity between subjective reports and objective evidence. A final consideration is that metamemory processes may play a role in poor memory in TLE patients. Specifically, inadequate metamemory monitoring and control processes might be responsible for the memory problems commonly affecting patients with TLE.

The purpose of this research was to establish whether TLE patients had a memory and/or metamemory impairment. A limited amount of research has investigated metamemory abilities in TLE (Prevey et al., 1988, 1991), and despite such efforts, the findings are mixed and unclear (see Chapter 2). It was therefore the aim of this thesis to explore whether memory and metamemory processes were disrupted in TLE patients by applying Nelson and Narens' (1990) theoretical framework. Understanding of memory processes in isolation cannot provide a complete picture without understanding metamemory processes and the interplay between the two. This thesis is novel in that it explores both memory and metamemory processes in TLE patients.

In the following chapter, a study is reported in which a combined JOL and FOK task is employed in a group of TLE patients and control participants, and memory performance is tested over two intervals. Item-by-item JOLs and global JOLs feature in this chapter. In the study reported in Chapter 3, the objective difficulty of the to-be-remembered material is manipulated across four trials in TLE patients and control

participants. Metamemory monitoring (global JOLs) is measured pre-study and post-study for each list. Metamemory control processes are measured by the amount of study-time allocated to each list. In Chapter 4 the effects of word-pair repetition at encoding on item-by-item JOLs and study-time are examined in TLE patients and control participants. Chapter 5 will explore the material-specific hypothesis in unilateral TLE patients and control participants on a verbal and non verbal task examining item-by-item JOLs at encoding, whilst utilising the 'Remember-Know' paradigm at retrieval. In the final chapter (Chapter 6), a summary of the thesis findings will be presented, methodological issues and limitations of the research and suggestions for future follow up experiments will be discussed.

Chapter 2: Metamemory in TLE – Item-by-Item and Global JOLs

2.1 Introduction

The experiment described in this chapter is based on an article accepted for publication in Neuropsychologia[2].

As mentioned earlier in Chapter 1, AF has been put forward as one possible answer to the disparity between subjective reports and objective measures. This phenomenon could be attributed to a number of contributing factors affecting the consolidation process, in which the retention of information over relatively brief delays is unaffected but memory is severely impaired over longer delays (see Bell & Giovagnoli, 2007 for review of AF findings). The following experiment examines whether metamemory processes may play a role in the poor memory performance typically observed in TLE patients. Memory performance is examined over two retention intervals.

There are only two published studies examining metacognitive process in TLE patients (Prevey et al., 1988; Prevey et al., 1991) and both concluded that TLE patients presented with a deficit in metacognitive monitoring. However, given the procedure and the data analysis, this conclusion does not seem warranted (see Chapter 1 for experiment details). First, the memory task was a span task, which assesses serial short-term and working memory, and not typical episodic long-term memory. Second, the memory task used to assess FOK was a fact retrieval task, commonly used in those years. As such, however, it tests semantic memory, not episodic memory, and thus these data have little to say about possible monitoring deficits in episodic memory in TLE patients. Third, even when using this semantic memory task, Gamma correlations

[2] Howard, C. E., et al. (in press). Memory, metamemory and their dissociation in temporal lobe epilepsy. *Neuropsychologia.*

showed no significant difference in FOK accuracy between controls and patients, only proportion of correctly predicted recognition did. Finally, no difference between groups was found in span recall prediction, only in actual span recall, and the conclusion about impaired monitoring in patients was an inference based on this rough comparison not supported by any data analysis.

It is thus possible that no difference in memory monitoring exists between TLE and controls, as shown in an unpublished single case study reported by Pannu & Kaszniak (2005) in their review of metamemory experiments in different types of neurological patients. Rapscak, Pannu and Kaszniak (2005, as in Pannu & Kaszniak, 2005, p.116) examined a patient with prosopagnosia due most likely to a right temporal epilepsy focus. The accuracy of this patient's FOK about her ability to recognise faces was almost perfect (Gamma = .90). This result was not simply due to this patient giving constantly very low ratings. Rather, it was due to this patient giving higher ratings to faces she was then able to recognise, and lower ratings to faces she was not able to recognise.

Given these previous unclear and mixed results, the objective of Experiment 1 was to investigate whether monitoring processes were disrupted in TLE patients when monitoring was tested using the common procedure examining predictions about long-term episodic memory. Metacognitive monitoring was assessed for both recall (Judgement-of-Learning predictions) and recognition (Feeling-of-Knowing predictions) tasks using item-by-item judgements, which are assumed to reflect online monitoring processes. In addition, global predictions of episodic memory (Global JOLs) were examined, which have been found to be impaired in Alzheimer's patients (e.g. Correa, Graves & Costa, 1996; McGlynn & Kaszniak, 1991; however see Cosentino, Metcalfe, Butterfield & Stern, 2007 and Moulin, Jones & Perfect, 2000a for clinical variability in AD).

Finally, Experiment 1 also tested whether impaired control processes might be responsible for the memory problems commonly affecting TLE patients. Control processes were examined by assessing how study-time is allocated (Mazzoni & Cornoldi, 1993; Mazzoni, Cornoldi & Marchitelli, 1990). Study-time allocation represents a metacognitive strategy that helps successful encoding by devoting more time to items that are either more difficult to learn, or are closer to the recall threshold (Metcalfe & Kornell, 2003; Son & Metcalfe, 2000). A deficit in the use of this strategy, which would be revealed if more time is devoted to items that are easy to recall could be responsible for observed deficits in episodic memory in TLE patients.

2.1.1 Experiment 1

In this experiment a paired-associates learning task was presented to 15 patients with TLE and 15 matched healthy controls, and memory was tested at two set intervals. To establish to what extent TLE patients can accurately predict their memory abilities in metamemory tasks, a combined JOL and FOK task was employed. A memory questionnaire (MFQ, Gilewski, Zelinski & Warner Schaie, 1990) was administered in order to evaluate their subjective perception of memory performance. Furthermore, anxiety and depression was assessed to control for the possible effect of these variables on metamemory performance. Finally, executive function measures were included to detect any executive dysfunction in groups.

2.1.2 Predictions

Based on the results of previous studies (see Bell & Giovagnoli, 2007; Leritz et al., 2006 for reviews), it was predicted that TLE patients would present with a deficit in episodic memory, which would be greater at delayed recall (i.e. four weeks after encoding). Similarities between metacognition and executive control processes as

suggested in previous literature (Fernandez-Duque et al., 2000; Shimamura, 2000; Souchay et al., 2000) supported the prediction that there could also be the potential for a degree of executive dysfunction in TLE patients. Finally, and crucially, based on the methodological problems in previous studies (Prevey et al., 1988, 1991) and the mixed results obtained in the literature, Experiment 1 aimed at exploring further metamemory abilities in TLE patients. In TLE patients the observed discrepancy between severe complaints about memory loss and their relatively adequate performance in objective memory tests (e.g. Gallassi et al., 1988; Hermann et al., 1988; O'Shea et al., 1996) suggests that a metamemory deficit should be characterised by an underestimation of their actual memory performance. At the same time, the findings by Prevey et al. (1998) would suggest the opposite, i.e. a clear overestimation of memory performance in TLE patients. Given this disparity, in the present study it was difficult to predict the specific direction of the discrepancy between memory evaluations and memory performance.

2.1.3 Method

Participants

Fifteen TLE patients (M = 38.33 years; SD = 12.41; range 18-63) and 15 controls (M = 33.67 years; SD = 10.90; range 18-52) participated in this study. TLE patients were recruited from Derriford Hospital's (Plymouth Hospitals NHS Trust) neurology out-patients clinic, whereas control participants were recruited from the University of Plymouth's School of Psychology undergraduate and volunteers group. TLE patients and non-student controls from the Paid Supporters Group received a small remuneration to cover any travel or parking expenses. Undergraduate participants received participation points as part of their course credit.

TLE patients were considered suitable for investigation based on the following screening criteria: (1) TLE out-patients; (2) aged between 18 and 65 years; (3) English

as their native language; (4) normal hearing and normal/corrected vision; (5) a minimum of 8 years education; (6) evidence of an abnormal EEG recording and/or MRI/CT scan to confirm condition and epileptic focus; (7) dosage and type of anti-epileptic drugs stable for a minimum of 1 month; (8) no presence of any current or past psychiatric disorders (including alcohol, substance abuse or clinical depression); (9) no other degenerative or cognitive disease that may prevent them from participating (e.g. learning disability, aphasia); (10) not undergone corrective surgery for their epilepsy; (11) not experienced a seizure in the past 24 hours prior to testing (determined on day of testing).

Recruitment of TLE patients

Patients were initially approached about the research through either their consultant or epilepsy specialist nurse at the time of their prearranged health care check-up. Patients identified by their consultant or epilepsy specialist nurse as meeting the above criteria were informed of the research and provided with an information sheet specific to the experiment, outlining the purpose of the research and their involvement if they chose to participate. Patients who showed an interest in participating and gave permission for their contact details to be passed onto the experimenter were contacted about taking part in the research. It was made clear to patients that they were in no way obligated to take part by receiving the information sheet. Patients were officially recruited into the experiment when they had read and signed the informed consent form relating to the experiment on the day of testing. Eighteen TLE patients were initially tested from which 15 suitable patients were included in the final analysis. Patients were excluded due to various underlying neurological factors and psychiatric disorders that were discovered after the experiment, when clinical records were thoroughly reviewed.

Demographic characteristics

Demographic characteristics of both groups and epilepsy features of the TLE patients can be found in Table 2.1. Control participants and TLE patients did not significantly differ in terms of age [F (1, 28) = 1.20, MSE = 136.45, p = .28, η^2_p = .04], years of formal education [F (1, 28) = .25, MSE = 5.66, p = .62, η^2_p = .01], gender [F (1, 28) = 3.57, MSE = .23, p = .07, η^2_p = .11] and predicted full scale IQ (FSIQ) [F (1, 28) = .87, MSE = 99.22, p = .36, η^2_p = .03]. Twelve (80 %) of the TLE patients were diagnosed as having complex partial seizures, one (7 %) patient experienced complex partial seizures with secondary generalisation, another (7 %) had simple partial seizures and one (7 %) other patient was classified as having both complex partial and simple partial seizures. Two (13 %) patients were seizure free[3] at the time of testing. Eight (53 %) were on monotherapy and seven (47 %) were on polytherapy (maximum combination of 3 AEDs). Eleven (73 %) TLE patients had seizures during the 4-week interval between Session 1 and 2. The number of seizures experienced during the 4-week interval did not significantly correlate with recall performance at Time 2 [r = -.33, p = .23].

[3] These two seizure free patients reported not having experienced a seizure for at least six months at the time of testing (one for over a year and the other for six months). Patients were advised by their medical team to keep their own seizure diary, which enabled the experimenter to consult the frequency of the seizures, although it should be noted that Experiment 1 cannot completely rule out the possibility that patients experienced seizures that were not recorded.

Table 2.1

Demographic characteristics and epilepsy features for TLE and control groups (standard deviations are in parentheses).

	TLE *n* = 15 *M*	Controls *n* = 15 *M*
Age	38.33 (12.41)	33.67 (10.90)
Gender (female/male)	6 / 9	11 / 4
Education (yrs)	14.67 (2.50)	15.10 (2.25)
NART (FSIQ)	116.67 (9.79)	120.07 (10.13)
Age of onset	24.53 (14.83)	—
Seizure Frequency (# per month)	2.40 (3.85)	—
Duration (years)	13.77 (10.44)	—
Laterality (right/left) * bilaterally	5 / 7 * 3	—
Evidence provided by only an abnormal EEG[1], MRI[2] or combination of both[3]	[1] 9 [2] 0 [3] 6	—

Stimuli/Materials

The paired-associates learning task was programmed into Microsoft Office PowerPoint 2003 and run on a Toshiba Tablet laptop computer. One-hundred and twenty word items (see Appendix B1) were selected from the MRC Psycholinguistics Database (Retrieved http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm, 19th September 2006) to form the sixty paired-associates for this task. Words chosen were of similar length, frequency of occurrence and level of concreteness in the English language. Words differed in their level of relatedness. Thirty of the word pairs were semantically related (e.g. hammer – saw), and the remaining thirty were not related (e.g. duck – cloth). Word pairs were presented to participants one at a time in the centre of

the screen in Arial font size 44 in black on a white background. Presentation time (study-time) of all word pairs was self-paced.

Procedure

All participants were individually tested in a quiet room at either the University of Plymouth, School of Psychology, or in one of the neurology clinic rooms at Derriford Hospital. All participants gave written consent prior to taking part in the study. The protocol was approved by the South West Devon Research Ethics Committee (NHS REC) and also by the University of Plymouth, Faculty of Science Human Ethics Committee. Participants were made aware that the study would be completed over two sessions. Session 2 (Time 2) followed on 4 weeks from Session 1 (Time 1).

JOL task

Participants were informed that they were going to be shown sixty-word pairs for study and later recall. They were asked to study each word pair for as long as necessary to maximise their chances of recall (self-paced learning). Each word pair was presented one at a time and participants used the spacebar to declare recall readiness and proceed onto the next item. A practise block consisting of four word pairs were given before test to ensure that participants understood the task procedure and the words could be clearly read. Practise word pairs were not included in the recall phase.

Immediately after studying each word pair, participants were asked to rate how certain they felt they would recall the second part of that particular word pair, if presented with only the first word as a cue later on in the session. The actual time at which participants would be asked to recall the words was not mentioned. Item-by-item JOLs were requested on a 6-point scale set at 20% intervals (0% = definitely will not recall, 20% = 20% sure, 40% = 40% sure, 60% = 60% sure, 80% = 80% sure, 100% =

definitely will recall; Kelemen & Weaver, 1997). Participants verbally responded to give their rating on a particular word pair and the experimenter recorded their responses on a record sheet. The time taken studying each word pair was recorded by the laptop in order to measure study-time allocation. At the time of making a JOL the word pair was no longer visible to the participant. After JOLs had been recorded for all sixty-word pairs, participants were asked to make a global JOL as to how many of the sixty items they thought they would recall later on in the session. Responses were given as a figure out of sixty. A thirty minute delay was then introduced in which non-verbal neuropsychological tests were administered (see Table 2.2).

After this timed interval, participants were presented with the cue word for each of the sixty-word pairs (one by one) and asked to recall aloud the target word. At test, the presentation order of the cue words was different from the order presented during the study phase, to prevent possible recency and primacy effects at recall. Participants were given five seconds to respond to each uncompleted word pair before the screen refreshed and moved onto the next word pair. Responses were recorded by the experimenter on a record sheet.

FOK task

For every non-recalled or incorrectly recalled word pair, participants were then asked to make FOK judgements, which were made on the same 6-point scale described for JOLs (from 0% to 100% at 20% intervals) as to whether they would be able to recognise the second part of the word pair when the first part was presented along with four possible alternatives, one of which was the target word. The recognition task was presented after the FOK judgement had been completed for all non recalled word pairs.

Recognition of the word pairs was measured by presenting the target word along with three distracters (semantic, phonological and neutral) (see Appendix B2). It was

emphasised to participants not to guess at a particular word but to only respond if they thought it was the correct word. Participants were given eight seconds in which to read the four alternatives and choose the answer. Responses were recorded by the experimenter on a record sheet.

At Session 2 (4 weeks later) participants were asked again to make a global JOL as to how many of the word pairs they thought they could remember from four weeks ago (as a figure out of 60). Participants were then tested as previously at Session 1, by presenting the cue word for five seconds and asking to recall the target word. Participants then followed the same procedure for the FOK task for all the word pairs they either failed to recall or incorrectly recalled at the time of test. The final neuropsychological tests followed to complete the battery (see Table 2.2).

Memory Functioning Questionnaire

The Memory Functioning Questionnaire (MFQ, Gilewski et al., 1990) was included as a method of collecting individuals' perception of everyday memory functioning. The questionnaire consists of 64 items separated into four factors; General Frequency of Forgetting, Seriousness of Forgetting, Retrospective Functioning and Mnemonic Usage.

Neuropsychological evaluation

A standard neuropsychological test battery (see Table 2.2 for a summary of the individual tests) was completed by all participants. The battery was split between the two sessions. The following tests were administered to form the neuropsychological test battery;

(1) The Harris Test of Lateral Dominance (Harris, 1974) was used to determine hand dominance in all participants.

(2) The Hospital Anxiety and Depression Scale (HADS, Zigmond & Snaith, 1983) was selected to provide a severity score of anxiety and depression for each participant.

(3) The Delis-Kaplan Executive Function System (D-KEFS, Delis, Kaplan & Kramer, 2001) Design Fluency Test, D-KEFS Color-Word Interference Test (Delis et al., 2001) and the Hayling Sentence Completion Test (Burgess & Shallice, 1997) were administered to measure executive functions.

(4) Similarities, Arithmetic and Comprehension subtests were selected from the Wechsler Adult Intelligence Scale – 3rd Ed. (WAIS-III, Wechsler, 1997a).

(5) Logical Memory I, Faces I, Digit Span (forward and backwards) and Logical Memory II were chosen from the Wechsler Memory Scale – 3rd Ed. (WMS-III, Wechsler, 1997b).

(6) The National Adult Reading Test revised version (NART; Nelson & Willison, 1991) provided a test of pre-morbid intelligence. Predicted full scale IQ, verbal IQ and performance IQ scores were obtained in both control participants and TLE patients.

2.1.4 Results

All statistical comparisons were conducted using SPSS (Statistical Package for Social Sciences) 16.0. Effect sizes and the level of the p-value are reported for each analysis. Statistical assumptions were checked and corrected to take account of any violations, where necessary.

Neuropsychological test battery

The results from the neuropsychological test battery are presented in Table 2.2. The neuropsychological tests which yielded a significant difference between TLE

patients and controls included the depression scores of the HADS [F (1, 28) = 7.83, MSE = 10.65, $p < .01$, $\eta^2_p = .22$], conditions one [F (1, 28) = 6.70, MSE = 6.45, $p < .05$, $\eta^2_p = .19$], two [F (1, 28) = 4.67, MSE = 6.01, $p < .05$, $\eta^2_p = .14$] and four [F (1, 28) = 6.39, MSE = 11.03, $p < .05$, $\eta^2_p = .19$] of the D-KEFS Color-Word Interference Test, the subtests Similarities [F (1, 28) = 4.22, MSE = 3.82, $p < .05$, $\eta^2_p = .13$] and Comprehension [F (1, 28) = 7.84, MSE = 6.81, $p < .01$, $\eta^2_p = .22$] from the WAIS-III, and the subtests Logical Memory I [F (1, 28) = 6.49, MSE = 6.65, $p < .05$, $\eta^2_p = .19$], Logical Memory II [F (1, 28) = 17.98, MSE = 6.45, $p < .001$, $\eta^2_p = .39$] and Faces I [F (1, 28) = 5.37, MSE = 6.76, $p < .05$, $\eta^2_p = .16$] from the WMS-III. The percentage retention scores from the story recall subtests (Logical Memory I & II) in the WMS-III also yielded a significant difference between groups [F (1, 28) = 13.92, MSE = 152.80, $p < .001$, $\eta^2_p = .33$]. The direction of these differences indicated that the TLE patients performed more poorly than the controls. The findings from the subtests of the WMS-III provided the first indication of a memory deficit in the TLE patients for both immediate and delayed recall.

It is also worth noting that the overall scaled score of the Hayling Sentence Completion Test showed a tendency in TLE patients to have some level of executive dysfunction [F (1, 28) = 3.21, MSE = 1.50, $p = .08$, $\eta^2_p = .10$].

No significant differences were obtained on the NART predicted FSIQ scores [F (1, 28) = .87, MSE = 99.22, $p = .36$, $\eta^2_p = .03$], predicted verbal IQ scores [F (1, 28) = .95, MSE = 84.60, $p = .34$, $\eta^2_p = .03$] and predicted performance IQ scores [F (1, 28) = 1.05, MSE = 79.16, $p = .31$, $\eta^2_p = .04$] or number of years of education [F (1, 28) = .25, MSE = 5.66, $p = .62$, $\eta^2_p = .01$].

Table 2.2

Summary of the neuropsychological test battery and MFQ results. (standard deviations are in parentheses).

Test	TLE $n = 15$ *M*	Controls $n = 15$ *M*	*F* statistic	*p* value
Harris Test of Lateral Dominance (Handedness)	1.07 (.26)	1.07 (.26)	0.00	1.00
HADS				
Anxiety	8.40 (5.22)	6.27 (4.27)	1.50	.23
Depression	5.20 (4.35)	1.87 (1.55)	7.83	.01
D-KEFS Design Fluency				
Condition 1*	8.13 (2.83)	9.93 (3.28)	2.59	.12
Condition 2*	9.00 (2.90)	10.00 (1.69)	1.33	.26
Condition 3*	10.93 (3.24)	11.20 (2.78)	0.06	.81
D-KEFS Color- Word Interference				
Condition 1*	7.87 (3.18)	10.27 (1.67)	6.70	.02
Condition 2*	8.87 (2.97)	10.80 (1.78)	4.67	.04
Condition 3*	9.27 (3.62)	10.80 (1.32)	2.38	.13
Condition 4*	6.93 (3.96)	10.00 (2.54)	6.39	.02
Hayling Sentence Completion Test	5.27 (1.53)	6.07 (.80)	3.21	.08
WAIS-III				
Similarities*	8.67 (1.80)	10.13 (2.10)	4.22	.05
Arithmetic*	10.47 (2.23)	10.33 (2.77)	0.02	.89
Comprehension*	9.60 (2.77)	12.27 (2.43)	7.84	.01
WMS-III				
Logical Memory I*	9.27 (3.17)	11.67 (1.80)	6.49	.02
Faces I*	9.40 (2.90)	11.60 (2.26)	5.37	.03
Logical Memory II*	9.13 (3.09)	13.07 (1.83)	17.98	.00
Digit Span*	10.13 (3.25)	11.67 (3.20)	1.70	.20
NART				
Predictive FSIQ	116.67 (9.79)	120.07 (10.13)	0.87	.36
Predictive Verbal IQ	114.47 (9.06)	117.73 (9.33)	0.95	.34
Predictive Performance IQ	115.27 (8.74)	118.60 (9.05)	1.05	.31
MFQ				
General Frequency of Forgetting	4.00 (.82)	4.79 (1.02)	5.49	.03
Seriousness of Forgetting	3.91 (1.13)	3.93 (.92)	0.00	.97
Retrospective Functioning	3.02 (1.33)	3.53 (1.08)	1.35	.26
Mnemonics Usage	4.02 (1.16)	4.85 (1.17)	3.84	.06

Abbreviations: HADS = Hospital Anxiety and Depression Scale, D-KEFS = Delis-Kaplan Executive Function System, WAIS-III = Wechsler Adult Intelligence Scale 3rd Edition, WMS-III = Wechsler Memory Scale 3rd Edition, NART = National Adult Reading Test, MFQ = Memory Functioning Questionnaire. * Age-adjusted scaled scores.

Given the significant results in the D-KEFS Color-Word Interference Test, further analysis of the components within this test were carried out. The number of uncorrected and self-corrected errors produced in each of the four conditions of the D-KEFS Color-Word Interference Test were rare (see Table 2.3), and were consequently not analysed. Latency times for the four conditions (see Table 2.3) were analysed using a 2 (group) x 4 (condition) repeated measures ANOVA. The results showed a main effect of group [F (1, 28) = 10.50, MSE = 259.58, $p < .01$, $\eta^2_p = .27$], condition [F (3, 84) = 128.70, MSE = 107.77, $p < .001$, $\eta^2_p = .82$] and an interaction between condition and group [F (3, 84) = 3.89, MSE = 107.77, $p < .01$ $\eta^2_p = .12$]. The analysis of the interaction showed that the greatest difference between TLE patients and controls was revealed in the inhibition/switching condition [t (28) = -2.97, $p < .01$]. Moreover, the interference (inhibition – colour naming) and switching cost (inhibition/switching – colour naming) effects were also analysed and showed equivalent interference effects in the two groups [t (28) = -.76, $p = .46$], but a greater switching cost [t (28) = -2.26, $p < .05$] in the TLE patients than in the control participants.

Table 2.3

Number of errors (Mean and SD) in the four conditions of the D-KEFS Color-Word Interference Test for TLE and control groups. Cor = self corrected; Non Cor = uncorrected. Mean (SD) latencies to complete each of the four tasks are also included.

Group	Colour Naming	Word Reading	Inhibition	Inhibition / Switching
TLE – Cor Errors	0.07 (0.26)	0.00 (0.00)	0.33 (0.82)	0.80 (1.70)
Controls – Cor Errors	0.07 (0.26)	0.00 (0.00)	0.33 (0.49)	0.20 (0.56)
TLE – Non Cor Errors	0.13 (0.35)	0.00 (0.00)	0.80 (1.52)	1.80 (1.66)
Controls – Non Cor Errors	0.00 (0.00)	0.07 (0.26)	0.60 (0.74)	1.20 0(.94)
TLE Latency times	33.07 (7.26)	24.27 (4.64)	58.93 (18.24)	79.13 (23.93)
Controls Latency times	27.40 (3.29)	20.80 (2.83)	50.20 (6.38)	58.87 (11.25)

Individual items from the subjective memory questionnaire (MFQ) were rated on a Likert scale ranging from 1 to 7, whereby lower values signify more of a perceived memory problem. The cumulative mean scores for all four factors in both groups were calculated and analysed. The factor 'General Frequency of Forgetting', which measures memory self-efficacy, was the only factor to yield a significant result. This factor indicated that TLE patients rated the occurrence of forgetting more frequently (represented by a lower cumulative mean score, M = 4.00, SD = .82) than control participants (M = 4.79, SD = 1.02), [F (1, 28) = 5.49, MSE = .86, $p < .05$, $\eta^2_p = .16$]. The factor 'Mnemonic Usage', which measures whether participants frequently implement daily strategies to support memory or the effort is made to avoid failures of memory, showed an almost significant difference [F (1, 28) = 3.84, MSE = 1.36, p = .06, η^2_p = .12] between TLE patients and controls, suggesting that TLE patients tended to state that they use more mnemonic strategies than controls. The remaining two factors showed ratings which did not significantly differ between control participants and TLE

patients (Seriousness of Forgetting [F (1, 28) = .00, MSE = 1.06, p = .97, η^2_p = .00], Retrospective Functioning [F (1, 28) = 1.35, MSE = 1.47, p = .26, η^2_p = .05]).

Recall performance

Recall performance at sessions 1 and 2 are illustrated in Table 2.4 (percentages). A 2 (group) x 2 (list type) x 2 (time of recall) repeated measures ANOVA was carried out on the items recalled at Time 1 and Time 2. There was a main effect of group [F (1, 28) = 13.82, MSE = 40.13, p < .001, η^2_p = .33], indicating that total recall was lower in TLE patients than in control participants, a main effect of time of recall [F (1, 28) = 149.33, MSE = 14.06, p < .001, η^2_p = .84], showing that controls and TLE patients recalled fewer items at Time 2 than at Time 1, and a main effect of list type (related, unrelated) [F (1, 28) = 196.28, MSE = 19.40, p < .001, η^2_p = .88], indicating that participants recalled more items from the related list. These main effects, however, were qualified by significant two-way interactions between group and time of recall [F (1, 28) = 16.73, MSE = 14.06, p < .001, η^2_p = .37], and between time of recall and list type [F (1, 28) = 12.59, MSE = 10.51, p < .001, η^2_p = .31]. None of the other interactions reached significance.

Table 2.4

Percentage of total recall and percentage of related and unrelated word pairs recalled at Time 1 and Time 2 for controls and TLE patients *(standard deviations are in parentheses).*

Time of recall	TLE $n = 15$ *M*	Controls $n = 15$ *M*
Time 1 total recall performance	34.78 (15.01)	58.44 (13.99)
Time 1 related word pairs recalled	55.33 (18.16)	82.44 (12.25)
Time 1 unrelated word pairs recalled	14.22 (17.07)	34.44 (18.80)
Time 2 total recall performance	16.22 (9.81)	21.22 (9.20)
Time 2 related word pairs recalled	31.33 (19.26)	36.67 (18.43)
Time 2 unrelated word pairs recalled	1.11 (2.72)	5.78 (5.11)

Note: Time 2 (Session 2) followed on 4 weeks from Time 1 (Session 1)

The interaction between group and time of recall is illustrated in Figure 2.1 (percentages), which shows a steep decline in recall over time among controls but not among patients. However, the steeper decline could be due to differences in initial baseline recall scores. To further investigate this interaction, between-group differences at Time 1 were analysed, and differences in change between Time 1 and Time 2 in two separate analyses of variance. The latter analysis was conducted with and without using Time 1 recall as a covariate. At Time 1 controls recalled a greater number of words (M = 35.07, SD = 8.40) than TLE patients (M = 20.87, SD = 9.01), [F (1, 28) = 19.95, MSE = 75.81, $p < .001$, $\eta^2_p = .42$]. Between Time 1 and Time 2 their recall decreased more than that of patients, [F (1, 28) = 16.73, MSE = 56.25, $p < .001$, $\eta^2_p = .37$]. However, when recall at Time 1 was added as a covariate, the effect of group was no longer significant, [F (1, 27) = .63, MSE = 24.48, p = .43, η^2_p = .02], indicating that the

apparent difference between controls and patients on rate of decline in recall was due to baseline differences.

To further investigate this interaction between time of recall and list type, differences in recall for related and unrelated words at Time 1 were analysed, and differences in change scores between Time 1 and Time 2. The latter analysis was conducted with and without using Time 1 recall scores for related and unrelated words as covariates. At Time 1, recall for related items was greater than for unrelated items [F (1, 29) = 209.22, MSE = 12.81, $p < .001$, $\eta^2_p = .88$]. Recall decreased between Time 1 and Time 2 more for related than for unrelated items, [F (1, 29) = 12.76, MSE = 20.74, $p < .001$, $\eta^2_p = .31$]. However, when recall at Time 1 was added as a covariate, the effect of type of items was no longer significant, [F (1, 27) = 0.07, MSE = 15.13, $p <$ .79, $\eta^2_p = .00$], indicating that the apparent differences between related and unrelated items on rate of decline in recall was due to baseline differences.

Given significant differences between groups in depression levels ($p < .01$) and the subtests Similarities ($p < .05$) and Comprehension ($p < .01$), these measures were entered separately as covariates into the main initial 2 x 2 x 2 ANOVA to control for possible effects on recall performance. The analysis revealed that depression [F (1, 25) = 1.91, MSE = 37.80, p =.18, $\eta^2_p = .07$], Similarities [F (1, 25) = 3.03, MSE = 37.80, p = .09, $\eta^2_p = .11$] and Comprehension [F (1, 25) = .01, MSE = 37.80, p = .94, $\eta^2_p = .00$] failed to reach significance and had no influence on recall performance.

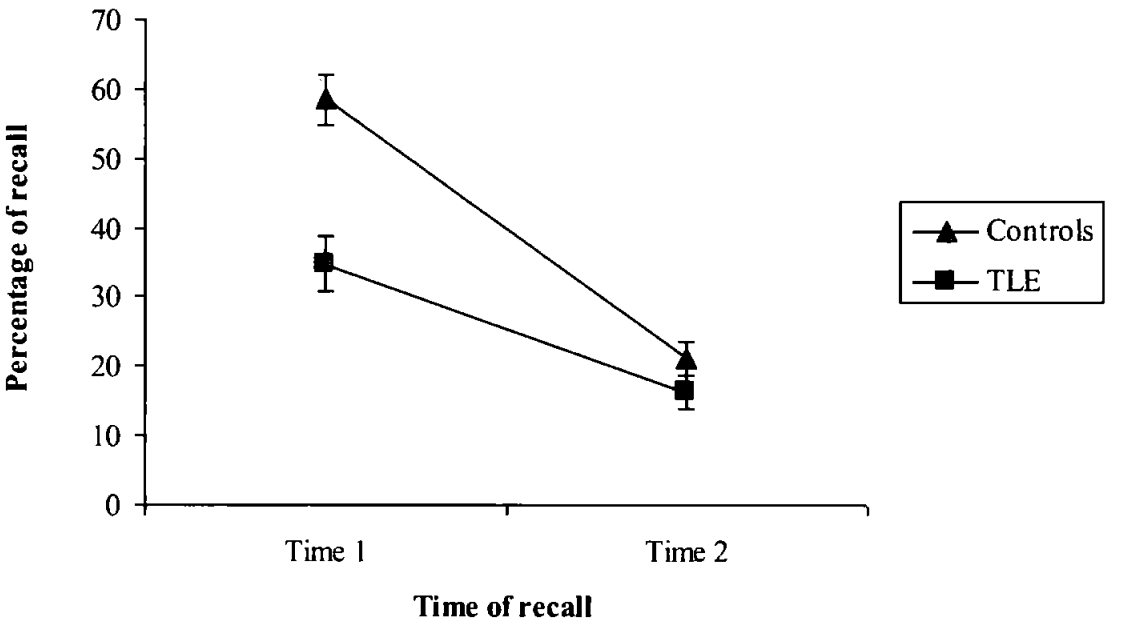


Figure 2.1. Recall performance at Time 1 and Time 2 for TLE and control groups. Error bars relate to standard error.

Metamemory accuracy: Judgement-of-Learning paradigm

Item-by-item JOLs

Item-by-item JOLs were collected only at Time 1. The Goodman-Kruskal's Gamma correlation (which ranges from +1 to -1) was used to calculate the relationship between item-by-item JOL predictions and actual recall performance for all sixty-word pairs (30 semantically related and 30 unrelated) at Time 1 (see Table 2.5 for Gamma correlations). A score nearer +1 indicates a high relationship between the item-by-item JOLs and recall, whereas a score of 0 would reveal no significant relationship between the two.

One-sample t-tests revealed that control participants' [t (14) = 12.24, $p < .001$] and TLE patients' [t (14) = 12.55, $p < .001$] JOL Gamma correlations were significantly different from zero, indicating that both groups demonstrated a level of metacognitive ability and that their item-by-item JOLs were not made by chance. This analysis

indicates that both TLE patients and controls demonstrated a degree of metacognitive competence when making their item-by-item JOLs. Moreover, independent-samples t-tests revealed no significant differences in JOL Gammas between controls and TLE patients, [t (28) = 1.09, p = .29] when considering all sixty-word pairs.

It was not possible to analyse separately related and unrelated word pairs as five TLE patients (one third of the sample) had to be excluded from the sample since they recalled zero unrelated word pairs and therefore Gamma correlations could not be computed for them. This would create an extreme variability in the Gamma values of the remaining 10 TLE patients further reducing the potential reliability of the analyses. For this reason, the effect of list type was not calculated on JOLs.

Table 2.5

JOL and FOK Gamma correlations for TLE and control groups. (standard deviations are in parentheses).

	TLE n = 15 γ	Controls n = 15 γ	p value
JOL Gamma (Time 1)	+.61 (.19)	+.70 (.22)	.29
FOK Gamma (Time 1)	+.27 (.51)	+.44 (.41)	.34
FOK Gamma (Time 2)	+.13 (.42)	+.09 (.26)	.79

Note: For FOK Gamma Time 1 TLE n = 14, Controls n = 13.

In order to test whether the two groups used the ratings for JOLs differently, a 2 (group) x 6 (6-point ratings) repeated measures ANOVA was also carried out on the number of times (proportions of use) each JOL rating was used (see Figure 2.2). There was no main effect of group [F (1, 28) = 2.47, MSE = 8.10, p = .13, η^2_p = .08], indicating that overall use of ratings did not significantly differ between groups, a main effect of rating type [F (5, 140) = 2.67, MSE = 190.68, $p < .05$, η^2_p = .09], showing that some ratings were more frequently used than others. Finally, the interaction between

group and rating type did not reach significance [F (5, 140) = .58, MSE = 190.68, p = .71, η^2_p = .02], an indication that both groups used a similar distribution of JOL ratings across the entire list.

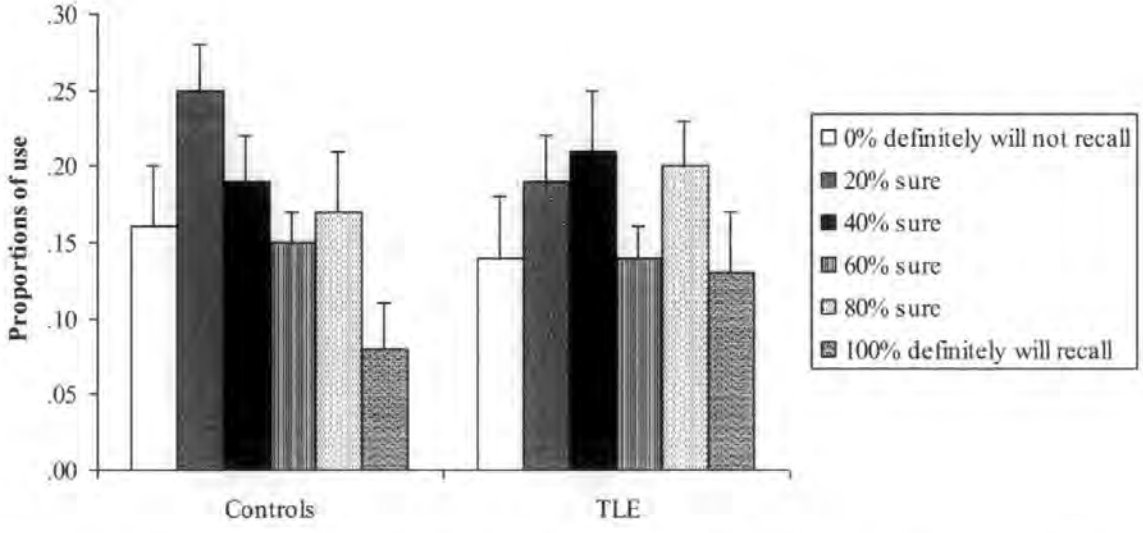


Figure 2.2. Judgement-of-Learning ratings' proportions of use in TLE patients and controls. Error bars relate to standard errors.

Recall readiness/study-time allocation

Metamemory control was measured as the overall study-time allocated to studying the sixty-word pairs between groups. The overall mean study-time (in seconds) for the sixty-word pairs was calculated for both groups, as well as the mean time spent studying the semantically related and the unrelated word pairs in each group (see Table 2.6). To determine whether there was a difference in the groups' ability to adjust the time spent studying the words dependent on their level of difficulty, a 2 (group) x 2 (list type) ANOVA was carried out on study-time allocation. The results showed no main effect of group, [F (1, 28) = 1.96, MSE = 17435.22, p = .17, η^2_p = .07], indicating that both control participants and TLE patients spent overall similar amounts of time studying the words. Moreover, the significant main effect of list type, [F (1, 28) = 21.62, MSE = 3962.81, $p < .001$, η^2_p = .44] indicated that both groups spent more time

studying the unrelated than the semantically related word pairs. The interaction between group and list type did not reach significance, [F (1, 28) = 2.74, MSE = 3962.81, p = .11, η^2_p =.09], providing evidence for intact metamemory control at the item-by-item level in patients with TLE.

Table 2.6

Study-allocation at Time 1 between groups (seconds). (standard deviations are in parentheses).

	TLE n = 15 M	Controls n = 15 M
Total study-time	446.07 (204.94)	350.67 (166.55)
Related word pair study-time	171.80 (63.90)	151.00 (77.87)
Unrelated word pair study-time	274.27 (155.02)	199.67 (92.83)

Global JOLs

A 2 (group) x 2 (time of global JOL) repeated measures ANOVA was carried out on the global JOL predictions made at Time 1 and Time 2. There was no main effect of group [F (1, 28) = .00, MSE = 134.16, p = .99 η^2_p = .00], indicating that global JOLs were not significantly different between groups. As expected, the main effect of time of global JOLs [F (1, 28) = 27.81, MSE = 72.16, p < .001, η^2_p = .50] demonstrated that global JOLs were higher at Time 1 (nearer to the time of encoding) than at Time 2. There was no evidence of an interaction between group and time of global JOLs [F (1, 28) = .60, MSE = 72.16, p = .45, η^2_p = .02], revealing that groups were not significantly different at either Time 1 or Time 2 and suggesting that both groups were able to adjust the global prediction after the Time 1 recall.

Finally, a 'total JOL' was calculated by adding the number of items that received a positive JOL (60%, 80%, and 100%) and compared it with the global JOL at Time 1 made by each participant with the group as the independent variable. The results

showed that this new 'measure of metacognitive awareness' did not significantly differ between TLE patients and controls either [F (1, 28) = 1.10, MSE = 41.49, p = .30, η^2_p = .04].

Metamemory accuracy: non-directional discrepancy scores

In line with the argument already proposed by Moulin et al. (2000a) for AD patients (see Chapter 1), here too, non-directional discrepancy scores (Hertzog et al., 1994) were used as a direct measure of the participants' accuracy in predicting their memory performance (instead of simply inferring under- or overestimations from differences between groups in memory recall accompanied by similar predictions between groups, Prevey et al., 1988). These were calculated as the modulus of difference between global JOLs (predictions) and actual recall both at Time 1 and Time 2, and for both controls and TLE patients (see Figure 2.3.). The rationale for using a non-directional method is discussed in Chapter 1.

The unsigned absolute difference for each group at both Time 1 and Time 2 was analysed in a 2 (group) x 2 (time of non-directional discrepancy score) repeated measures ANOVA. The results revealed no main effect of group [F (1, 28) = .69, MSE = 83.55, p = .41, η^2_p = .02]. There was a main effect of time [F (1, 28) = 10.36, MSE = 35.72, p < .01, η^2_p = .27], with Time 1 having higher levels than Time 2. No evidence of an interaction was revealed between group x time of the discrepancy score [F (1, 28) = 2.22, MSE = 35.72, p = .15, η^2_p = .07].

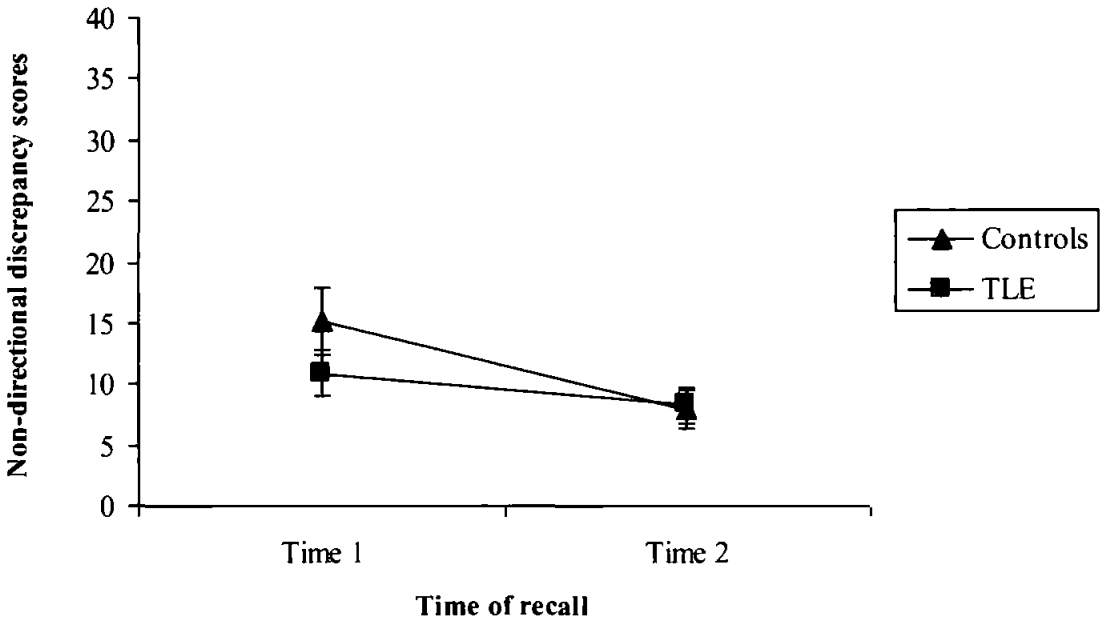


Figure 2.3. Non-directional discrepancy scores at Time 1 and Time 2 between groups. The modulus difference between global JOL scores (predictions) and actual recall performance was used to calculate non-directional discrepancy scores in controls and TLE patients.

Metamemory accuracy: recognition and Feeling-of-Knowing results

Non-recalled or incorrectly recalled items were used in a recognition task. This was done separately for Time 1 and Time 2. A 2 (group) x 2 (Time) ANOVA was carried out on the proportion of correctly recognised items. The results revealed that control participants (Time 1: $M = 76.74$, $SD = 14.16$; Time 2: $M = 60.87$, $SD = 13.60$) recognised a significantly greater percentage of target words than the TLE patients (Time 1: $M = 51.26$, $SD = 23.50$; Time 2: $M = 40.71$, $SD = 20.56$) [$F(1, 28) = 13.32$, $MSE = 586.53$, $p < .001$; $\eta^2_p = .32$], that both groups recognised more items at Time 1 than at Time 2 [$F(1, 28) = 27.95$, $MSE = 93.64$, $p < .001$, $\eta^2_p = .50$], and an absence of a significant interaction between group and time of recognition [$F(1, 28) = 1.13$, $MSE = 93.64$, $p = .30$, $\eta^2_p = .04$].

Rate of forgetting in recognition was also examined in the two groups. Similarly to the results shown at recall, the analysis showed that the two groups had identical rates

of forgetting (controls $M = .19$, $SD = .19$; TLE patients $M = .21$, $SD = .22$), $t\ (28) = .19$; $p = .85$, between 30 minutes and four weeks.

FOK

Goodman-Kruskal Gamma correlations between the FOK judgements[4] and recognition performance were calculated at Time 1 and Time 2 for both groups (see Table 2.5). Two control participants answering correctly to all word pairs tested and one TLE patient responding with the same rating (20%) for all word pairs in this part of the task at Time 1 were excluded from the analysis.

One-sample t-tests revealed that at Time 1 control participants FOK Gamma correlations were significantly different from zero for the control participants [$t\ (12) = 3.95$, $p < .01$] and marginally from zero for the TLE patients [$t\ (13) = 1.98$, $p = .07$], indicating that both groups tended to be metacognitively competent when making their FOK Gamma correlations at Time 1. FOK Gamma correlations made at Time 2 were not significantly different from zero ($p > .05$) for either group.

Independent-samples t-tests revealed that FOK Gamma correlations were not significantly different between the control group ($M = .44$, $SD = .41$) and TLE patients ($M = .27$, $SD = .51$) at Time 1, [$t\ (25) = .96$, $p = .34$], nor at Time 2, [$t\ (28) = -.27$, $p = .79$] (controls: $M = .09$, $SD = .26$; and TLE patients: $M = .13$, $SD = .42$).

Correlation analysis of the MFQ factors with recall performance

In order to determine whether there was any relationship between subjective views of memory measured by the MFQ and actual recall performance, Pearson's

[4] The effect of list type on FOKs was not analysed because during recall a significantly greater proportion of related word pairs were recalled than unrelated in both groups (see Table 2.4). As the FOK task only involves testing the word pairs that were not recalled, the majority of word pairs tested would therefore be unrelated in the recognition test, creating an unbalanced set of data. Altogether, although it would be interesting to look at the effects of list type (or difficulty, in general) on metamemory abilities in future research, the current data set was considered not suitable for this purpose.

correlation coefficients (r) were computed between the four factors of the MFQ and recall performance at Time 1 and Time 2 for controls and TLE patients. The General Frequency of Forgetting score (high scores indicate less perceived forgetting) correlated [$r = .57$, $p < .05$] with recall performance at Time 2 in the TLE patients ($n = 15$), indicating that recall was higher in patients who reported lower forgetting rates. No other significant correlations between the MFQ factors and recall performance were found for either the controls or TLE patients.

Correlation analysis of epilepsy variables and recall performance

In order to determine whether there were any specific epilepsy variables (laterality, seizure type, age of onset, duration, frequency of seizures, number of AEDs, number of seizures within the 4-week interval) which had an influence on recall performance at Time 1 and Time 2, Pearson's correlation coefficients (r) were computed. None of the epilepsy variables significantly correlated with recall performance ($p > .05$) (see Table 2.7 for correlations).

Table 2.7

Correlations of epilepsy variables with recall at Time 1 and Time 2.

	Recall at Time 1		Recall at Time 2	
	Pearson's correlation coefficient (r)	p value	Pearson's correlation coefficient (r)	p value
Laterality	0.04	.88	0.08	.79
Seizure type	0.06	.83	0.33	.23
Age of onset	-0.46	.09	-0.46	.08
Duration	0.06	.83	0.28	.32
Frequency # per month	-0.06	.83	0.06	.83
Number of AEDs	-0.40	.14	-0.11	.70
Number of seizures recorded in 4 week interval	-0.13	.64	-0.33	.23

Pearson's correlation coefficients (r) were also computed between all epilepsy variables and standardised subtests of the WMS-III (n = 15). Significant correlations were revealed between the subtest Digit Span of the WMS-III and laterality [r = -.73, p < .001], showing that laterality appeared to be negatively related to scores on the Digit Span task accounting for 53% of the variation in scores, with bilateral TLE patients performing less well than TLE patients with a right or left focus. Age of onset [r = .59, p < .05] appeared to be positively related to scores on the Digit Span task accounting for 35% of the variance; and duration [r = -.61, p < .05] appeared to be negatively related to scores accounting for 37% of the variance. Significant correlations were also detected between the number of AEDs with Logical Memory I [r = -.53, p < .05] indicating that AEDs appeared to be negatively related to Logical Memory I accounting for 28% of the variation in scores.

Correlation analysis of executive function measures and metamemory accuracy

The executive function measures (Color-Word Interference Test latency times in inhibition and inhibition/switching conditions, interference and switching costs and latency times in Hayling B (inhibition section)) were computed into a correlation matrix with the metamemory accuracy measures (discrepancy scores, global JOLs, FOK Gammas and JOL Gammas). Bonferroni's correction analysis was applied for multiple comparisons ($p < .001$). After applying Bonferroni's correction none of the executive function measures significantly correlated with the metamemory measures in either controls or TLE patients ($p > .01$) (or both groups together) ($p > .01$).

2.1.5 Discussion

The aim of Experiment 1 was to investigate for the first time whether the episodic memory impairment typically observed in TLE patients (Bell & Giovagnoli, 2007; Leritz, et al., 2006) could be related to a metamemory deficit. Metamemory experiments in other clinical populations with episodic memory declines have shown poor metamemory abilities (Light, 1991; Janowsky et al., 1989; Souchay, 2007) and hence a link between metamemory and memory might help to understand the memory deficits observed in TLE patients. This is the first experiment to investigate the existence of a metamemory deficit in TLE patients using a verbal episodic memory task to try and explain the memory problems observed in this clinical population.

In previous research examining metamemory abilities in TLE patients, Prevey et al. (1988, 1991) concluded that metamemory, and specifically monitoring processes, were impaired in TLE patients after observing that, differently from controls, patients tended to overestimate their memory performance. However, in those studies this conclusion was based solely on the fact that whereas memory predictions were equivalent for TLE patients and controls, the recall performance was lower for TLE

patients than for controls. No adequate measure of accuracy was reported to support this claim, such as the non-directional discrepancy scores which were calculated in the current experiment, and therefore this previous literature implies misleading results, suggesting TLE patients overestimate their memory capabilities. Moreover, these studies did not examine monitoring for episodic memory, but measured metamemory for short-term memory span (serial memory), and for factual (semantic) information.

Experiment 1 specifically examined verbal episodic memory and metamemory abilities related to it in TLE patients and healthy matched controls. Accuracy in monitoring processes for verbal episodic memory was assessed by measuring item-by-item Judgements-of-Learning (JOL) and Feeling-of-Knowing (FOK), which are two measures of online monitoring. Experiment 1 also assessed accuracy of a more global form of recall prediction (Global JOL). Finally, a measure of metacognitive control processes (study-time allocation, see Chapter 1) was also added, which has never been tested before in TLE patients.

Overall the findings from Experiment 1 showed TLE patients had a clear and significant impairment in episodic memory. However, no impairment in metamemory was observed in either monitoring or control processes. The results are now discussed separately in more detail.

Memory performance

In line with previous results (see Bell & Giovagnoli, 2007 and Leritz et al., 2006 for reviews), in this experiment TLE patients performed significantly worse than controls in recall when memory was measured 30 minutes after acquisition. TLE patients also showed poorer performance at this time when testing recognition for the non recalled/incorrectly recalled items (FOK task).

Four weeks after acquisition, and contrary to the hypothesis of accelerated forgetting (AF); according to which the retention of information over relatively brief delays is unaffected, but memory is severely impaired over longer delays in TLE patients; the current results showed in both groups no significant difference in forgetting rates for recall. After four weeks, recognition of non recalled items was still significantly different, revealing poorer scores for TLE participants than control participants, although the forgetting rate was not significantly different between the two groups. This persistent difficulty of TLE patients to recognise the words they could not recall is consistent with the notion that the memory deficits observed in TLE patients are mainly due to a deficit at the encoding stage of the memory process, which is typically observed in patients with damage in their temporal lobes (Shimamura, Janowsky & Squire, 1991). Indeed, if the information had been encoded to a similar level as in the control participants, presentation of the non-recalled items would have facilitated their retrieval, as is typically observed in patients with intact temporal lobes but damaged frontal cortex (Aggleton & Brown, 1999).

On the whole, the results do not favour the hypothesis of AF. Although directly testing AF was not the main aim of this study, and thus initial encoding levels were not equated between groups prior to testing, there was sufficient room in patients' recall at the four-week interval to observe a greater decline. Furthermore, there is no indication that the TLE patients tended to forget more quickly than controls during the 4 week retention interval. AF cannot account for the initial poorer recall performance in TLE patients at Time 1. In further support of a negative AF result, the subtests Logical Memory I and Logical Memory II which measure immediate and delayed story recall after 30 minutes, revealed that controls outperformed TLE at both these intervals indicating that a memory deficit was detected immediately here also. Failing to find evidence of AF in the current experiment is in line with previous research indicating

that AF is not always present in TLE patients (Bell, 2006; Bell et al., 2005; Giovagnoli et al., 1995; Helmstaedter et al., 1998). Experiment 1 has added further support that AF is clearly not a constant feature in TLE patients as past research has provided positive, negative and mixed results in group studies (see Bell & Giovagnoli, 2007 for a review). Inconsistent AF findings suggest that there are perhaps certain conditions which are needed in order to observe this phenomenon. One possibility is that superior intelligence plays a role in observing AF, as Bell and Giovagnoli (2007) noticed that four of five case studies reported AF patients had superior intelligence (Holdstock, Mayes, Isaac, Gong & Roberts, 2002; Kapur et al., 1997; Lucchelli & Spinnler, 1998; O'Connor, Sieggreen, Ahern, Schomer & Mesulam, 1997). AF may also be more prominent in certain subtypes of TLE, such as transient epileptic amnesia (TEA). Butler et al. (2007) reveal that 44% of their TEA patients reported symptoms of AF. Other possible factors determining when AF is more likely to be present in TLE have been discussed by Bell and Giovagnoli and Butler and Zeman (2008) in their recent reviews.

Of particular interest in Experiment 1 was whether a divergence between TLE subjective reports (as measured by the MFQ) and objective measures would be apparent. Experiment 1 revealed that the relationship between the factor 'General Frequency of Forgetting' from the MFQ and actual recall performance correlated at Time 2 for TLE patients, indicating that recall was higher in patients who reported lower forgetting rates. Furthermore, the factor 'Mnemonic Usage', which measures whether participants frequently implement daily strategies to support memory or the effort is made to avoid failures of memory, showed an almost significant difference between TLE patients and controls, suggesting a trend that TLE patients used more mnemonic strategies than controls. These findings suggest that subjective memory impairment can be observed; specifically the MFQ indicated that TLE patients were

aware of their memory deficit to a certain extent and therefore the need to implement coping strategies to aid their memory in everyday situations.

The MFQ was chosen as the subjective measure in this experiment, firstly because the factor structure had been thoroughly examined and secondly because the length of the questionnaire was not deemed too long. The MFQ was derived from the Metamemory Questionnaire (MQ; Zelinski, Gilewski & Thompson, 1980). The MQ consisted of 92 items from which 64 items created the MFQ. Despite its wide spread use in research and the analysis of its factor structure, the MFQ is not without its potential limitations. Firstly, the MFQ was created typically for use in adulthood and older adult populations and perhaps was not relevant for use in younger adults and the wide age range (18-63 years) used in Experiment 1. Secondly, and perhaps most importantly, is that some of the statements in the questionnaire may not have been relevant to the sample tested. For instance, *'losing the thread of thought in public speaking'* and *'keeping up correspondence'* are perhaps activities that are not undertaken by all, and as a consequence participants rated such statements as *never* causing them problems by default of not actually doing the activity. Finally, the techniques listed in the mnemonics usage factor could be replaced with more up to date examples which participants could relate to better. For instance, electronic reminders on mobile phones, laptops and palm computers will have replaced the use of an appointment book and making reminder notes in some of the participants tested.

Finally, it is worth mentioning that the differences between TLE patients and control participants in memory performance observed in the current experiment could not be explained by greater levels of depression or lower levels of crystallised intelligence (performance on the Similarities and Comprehension subscales of the WAIS scale) as this was ruled out by controlling for these variables (see ANCOVAs). Mood disturbances did not play a role in the clear episodic memory deficit observed in

the TLE patients in this experiment. However, laterality, age of onset, duration of the epilepsy, and number of anti-epileptic drugs had an effect on subtests of the WMS-III which confirms that these variables may be important to predict the extent to which a patient is likely to experience memory difficulties.

Metacognitive monitoring and control (metamemory)

Although some research has suggested and found that deficits in memory in TLE patients can be attributed to poor metacognitive monitoring and control processes (Prevey et al., 1988, 1991), this hypothesis is not supported by this experiment. TLE patients were not different from controls in any of the online metacognitive measures used in this study. In Experiment 1 both control participants and TLE patients were able to predict with relative accuracy which items they would have been able to recall and which they would have not, as Judgements-of-Learning accuracy was above chance in both groups, and not significantly different in the two groups. This suggests that TLE patients, similarly to controls, were able to monitor effectively online learning of the verbal material. In immediate item-by-item JOLs monitoring is based on the perceived ease with which each single item is learned. In this case accuracy depends on the extent to which perceived ease of learning corresponds to later probability of retrieval.

Similarly, no differences in metacognitive control existed between groups, measured by the amount of study-time allocated to the list. In both groups overall more time was systematically devoted to studying more difficult pairs, and no interaction involved groups although numerically patients tended to devote more study time than controls. In spite of this similarity, however, patients recalled initially fewer items than controls, an effect that suggests encoding problems more than monitoring and control problems.

Accuracy of FOK judgements was also not significantly different between the two groups. FOK ratings are supposedly based on partial accessibility of unrecallable items, and on the sense of familiarity triggered by them. Accuracy depends on how these characteristics correspond to the outcome of the recognition task, which is also determined by accessibility and familiarity.

Overall, the results on accuracy of these online monitoring tasks fail to show any clear metacognitive deficit in TLE patients, suggesting that online monitoring might be adequate and memory problems in this group should be attributed to a deficit in other processes, for example encoding processes. In data from Experiment 1, this claim is supported by the observation that differences in memory between TLE patients and controls obtained after 4 weeks disappear when the difference in initial performance is taken into account.

No difference was even found in groups' predictions about future recall (global JOLs), neither in magnitude nor in accuracy. But if anything, patients tended to be more accurate. During Time 1 controls numerically underestimated their performance (Global JOL = 22.47, recall = 35.07), while patients slightly overestimated it (Global JOL = 24.13; recall = 20.87). Although this slight overestimation in TLE patients might be indicative of a mild metacognitive deficit, there are however, two reasons that suggest that this is unlikely to be the case. Firstly, the absolute amount of overestimation is marginal and not significant [(14) = .98, p = .35]. Patients appear to be somewhat 'on target', and there is no theoretical reason to suggest that 'on target' judgements imply a metacognitive deficit. Secondly, the non-directional discrepancy score analysis did not reveal a significant main effect of group, and failed to find evidence of an interaction, indicating that the discrepancy between judgement and recall was no different in TLE patients than compared to controls. Furthermore, TLE patients and control participants accuracy was not significantly different when online item by

item metacognitive judgements were considered. Although global and item-by-item judgements are probably based on partly different information (see Mazzoni & Nelson, 1995), this additional lack of difference in accuracy of judgements between groups provides further support to the claim that metacognitive abilities are not impaired in TLE patients.

In the event that the difference (between underestimation in control participants and on-target estimation in TLE patients) had been significant, it might have suggested that TLE patients were more aware of their memory abilities than control participants. Although this conclusion cannot be drawn from Experiment 1, the self-report measure (MFQ) administered provides some support to it. TLE patients reported more frequent forgetting [p = .03], and a clear trend in using more strategies than controls [p = .06]. Results from the MFQ indicate that patients might demonstrate good awareness of their memory problems and capabilities. It is apparent from the findings in Experiment 1 that TLE patients present with a memory impairment, yet patients also report a trend of greater use of strategies to aid everyday memory. Such an attempt to implement strategies to support memory may demonstrate efforts to compensate for their perceived memory impairment.

A possible explanation for patients better awareness of their memory capabilities could be due to greater previous exposure to memory difficulties in real life, and greater awareness of their specific memory problems, which is also reflected in their awareness featured in the factor 'General Frequency of Forgetting' in the MFQ. However, it is important to note that the similarity in magnitude of global JOLs might derive from both groups basing their global JOLs on the only information available at the beginning of the experiment, i.e. the number of words contained in the list (N = 60). Both groups might have tended to use approximately the middle of the list as an anchor for their global judgement (Connor et al., 1997; Hertzog et al., 1994). When individuals know

little about the memory task they are about to perform they 'anchor' their predictions around the midpoint of the scale as this is considered a conceivable target to reach.

Evaluation of the metacognitive results, disconfirm the hypothesis of a metacognitive deficit in TLE patients, which provides additional support to previous dissociations between memory and metamemory in neuropsychological patients with temporal damage (Shimamura & Squire, 1986). On the contrary, they suggest that patients seem to be aware of their memory problems, and may be better at predicting global memory performance (global JOLs). It is also necessary to consider that individuals rely on different information when making different types of metacognitive judgements (i.e. global vs. item-by-item) and also for the type of test (i.e. recall vs. recognition, as measured by JOLs and FOKs respectively). Global judgements reflect beliefs about oneself, past experiences on tests and about task difficulty. Thus, individuals who believe to be poor at memory tasks tend to give themselves lower global estimates than those who believe to be good, and this affects the measure of accuracy used, i.e. non-discrepancy scores. Item-by-item JOLs on the other hand are more concerned with the online monitoring of performance on individual trials specific to a particular task.

In Experiment 1 the findings indicate that both item-by-item and global JOLs did not significantly differ between groups. It is important to consider whether testing item-by-item JOLs at encoding had the potential to increase accuracy in their global JOLs. Could asking participants to give item-by-item JOLs for the sixty word pairs have potentially increased their accuracy when making their global JOL for the entire list? This concept is entirely possible in this experiment. However, previous research by Mazzoni and Nelson (1995) suggests that item-by-item JOLs and global JOLs rely on different metacognitive mechanisms (see Chapter 1 for further details). The findings from Experiment 1 indicate that both control participants and TLE patients were well

calibrated with their actual performance in terms of their item-by-item JOLs and no differences were found between their non-directional discrepancy scores for their global predictions.

Executive functions

TLE patients showed some extent of executive dysfunction in the Delis-Kaplan Executive Function System Test, with a significantly greater switch cost in the inhibition/switching condition in the Color-Word Interference test and a tendency (p = .08) to show a difficulty to inhibit the automatic response in the inhibition section of the Hayling test. Both these tests measure inhibition abilities, and confirm that a focal frontal lesion is not necessary to observe this type of deficit in clinical populations (Andrés, 2003; Andrés & Van der Linden, 2001). The presence of this relative executive dysfunction in a sample of TLE patients with intact metamemory abilities indicates that metamemory is likely to run independently at least from inhibitory mechanisms. It would therefore be interesting to investigate to what extent metamemory is dependent from other executive abilities such as updating or working memory (Miyake et al., 2000).

In summary, Experiment 1 revealed a clear episodic memory deficit in TLE patients compared with control participants. Metamemory monitoring and control processes were intact in TLE patients indicating that in this sample TLE patients were aware of their online monitoring processes. Furthermore, independently from the memory and metamemory tasks, TLE patients revealed a degree of executive dysfunction. Experiment 1 provided the first insight into episodic memory and metamemory functioning in TLE patients. Taking into consideration the results from the memory and metamemory tasks, the picture that has emerged from Experiment 1

suggests a dissociation between memory and metamemory in TLE patients, a finding which has also been reported in Alzheimer's disease patients (Moulin et al., 2000a) and a single case study of a patient with prosopagnosia (Rapcsak et al., 2005). Contrary to what has been suggested in previous studies, TLE's memory deficits are not explained by metamemory problems (Prevey et al., 1988, 1991), accelerated forgetting (Blake et al., 2000) or mood disturbances (e.g. Baños et al., 2004). It is more likely that the poor memory performance shown by the TLE patients in Experiment 1 is due to impairments occurring at encoding resulting from temporal damage (see Aggleton & Brown, 1999; Squire, 1992 for reviews), and similar to the deficits observed in stronger forms of amnesia (Mayes et al., 2003; O'Connor et al., 1997).

In Chapter 3, the objective difficulty of the to-be-remembered material is manipulated across four lists and recall performance measured in TLE patients and control participants. Metamemory monitoring (global JOLs) is measured pre-study and post-study for each list. Global JOLs for each list are examined in isolation, removing any potential confound that item-by-item JOLs may have on accuracy for the entire list. Metamemory control processes are also examined by the amount of study-time allocated to each list between groups.

Chapter 3: Metamemory in TLE – Sensitivity Approach

3.1 Introduction

Experiment 1 (Howard et al., in press) indicated evidence of a dissociation between memory and metamemory in TLE patients, whereby memory performance was impaired and metamemory abilities were intact at both the item-by-item level and global level. Contrary to what has been suggested in previous research, Howard et al. revealed that TLE patients memory deficits could not be explained by metamemory difficulties (Prevey et al., 1988, 1991), accelerated forgetting (Blake et al., 2000) or mood disturbances (e.g. Baños et al., 2004). It would therefore seem possible from this initial experiment at least, that TLE patient's memory deficits are more likely due to problems at encoding, as a consequence of temporal lobe damage (Shimamura et al., 1991), than due to monitoring and control problems.

Previous studies examining the relationship between subjective memory and actual performance on objective memory tests in TLE have provided contradictory findings in the literature (see Piazzini, Canevini, Maggiori & Canger, 2001 for review). For instance, some studies have found that TLE patients perform adequately on neuropsychological measures despite complaining of memory difficulties (Gallassi et al., 1988; Hermann et al., 1988; O'Shea et al., 1996; Thompson & Corcoran, 1992), whilst other researchers have suggested that TLE patients overestimate their performance on a given memory task (Prevey et al., 1988, 1991). Similar discrepancies are also apparent in normal ageing research (see Connor, Dunlosky & Hertzog, 1997 for review).

Connor, Dunlosky and Hertzog (1997) highlight inconsistencies in research into global predictions from the normal ageing literature. Similar to the TLE literature, normal ageing studies are also marked by discrepancies between subjective predictions

and actual memory performance. Connor et al. (1997) propose that such inconsistencies may be a result of the magnitude of predictions made around the midpoint of the scale in a memory test.

> *'A critical factor that may influence the magnitude of the global prediction - and hence the accuracy of this prediction – is the midpoint of the scale for memory performance.'*
>
> (Connor et al., 1997, p. 51)

Connor et al. (1997) propose that as individuals know little about the memory task they are about to perform they 'anchor' their predictions around the midpoint of the scale as this is considered a conceivable target to reach. Connor et al. suggest that anchoring of global predictions could be responsible for such reported variations in accuracy in the ageing literature. They argue that overestimating memory performance is not necessarily indicative of a metacognitive monitoring deficit in older adults, because age-related differences may be a consequence of the length of the to-be-remembered material and also midpoint anchoring. Thus, in a scenario where younger and older adults' predictions are close to the midpoint of the scale, but in terms of actual performance younger adults achieve closer to their prediction of 50% than the older adults, younger adults would appear to be relatively on target, whereas the older adults would appear to have overestimated their performance. This hypothesis, together with studies which use directional discrepancy scores to interpret such findings, suggests that the interpretation of global predictions should be made with caution and is particularly pertinent to the previously published results in which it was suggested TLE patients overestimated their memory performance (Prevey et al., 1988, 1991) (see Chapter 2). Connor et al. reveal that younger and older adults behave similarly in providing predictions and postdictions in a given memory task. In Experiment 1, Connor et al.

showed that both younger and older adults' global estimates became more accurate from their pre-study prediction to their postdiction. They revealed that, despite differences in absolute accuracy between groups due to midpoint anchoring, both younger and older adults revised their predictions following study to become more accurate in their postdictions than their initial predictions. Connor et al. concluded that older adults had the same level of sensitivity as younger adults by revising their predictions following study.

Experiment 2 employed the sensitivity approach[5] adopted by Connor et al. (1997) in normal ageing research. The sensitivity approach examines metacognitive processes at encoding that are independent from recall performance, thus removing any potential confound that different levels of recall performance may have on metamemory processes between groups (Moulin, Perfect & Jones, 2000a). The sensitivity approach can be used as a tool to observe monitoring and control processes. For instance, if the objective difficulty of the to-be-remembered material is manipulated across trials, not only could changes in the pre-study and post-study predictions be observed, but one could also observe whether changes in terms of the magnitude of the post-study predictions depend on task difficulty. Furthermore, presenting a self-paced study task would determine whether the amount of study-time allocated to each list depends upon the difficulty of the to-be-remembered material. Therefore, if metacognitive monitoring and control processes at encoding were intact, then participants would be able to adjust their post-study predictions from their pre-study predictions based on the objective difficulty of the list. Preserved metacognitive control would be evident by participants allocating appropriate amounts of study-time to individual lists dependent on their objective difficulty. As such, a higher increase in global post-study predictions would

[5] The 'sensitivity approach' was introduced by Moulin et al. (2000a) who used it to describe the concept initially explored by Connor et al. (1997) and Hertzog et al. (1994), in which the accuracy of predictions were measured over different stages of a memory task (see Moulin 2002, in Perfect & Schwartz, 2002). Moulin et al. (2000a,b,c) applied this concept to examine whether AD patients were sensitive to intrinsic and extrinsic cues at encoding.

be expected for easier lists and less time would be devoted to lists perceived as easier to recall.

Moulin, Perfect and Jones (2000a) conducted a study in AD patients (who also present with damage to their temporal lobes) whereby they manipulated the objective difficulty of the to-be-remembered stimuli across lists (Experiment 2). Moulin et al. (2000a) proposed that through exposure to study and test trials, AD patients would become more accurate in their global predictions. They manipulated the difficulty and relatedness of the lists to see if AD patients were sensitive to these list differences. Pre-study and post-study predictions were collected to determine any change in their predictions relative to the difficulty of the list studied. Lists consisted of 10 items in each. The authors concluded that AD patients benefited from repeated trials, whereby AD patients became more accurate in their predictions from lists one to four. In addition, AD patients were seen to revise their predictions from their initial pre-study predictions to their post-study predictions. However, unlike the control participants tested, AD patients were not sensitive to the objective difficulty of the lists in terms of both recall performance and post-study predictions. Although this lack of sensitivity when making post-study predictions would normally be indicative of a failure to monitor the difficulty of the lists, Moulin et al. argue this is not the case in their experiment. Moulin et al. suggest that AD patients were correct in not changing their predictions depending on the qualities of the lists, as their recall performance was also insensitive to changes in list difficulty. Similar to their post-study predictions, AD patients' recall performance did not significantly differ across the four list types. Therefore the relationship between judgement and recall performance was considered appropriate. Moulin et al.'s findings illustrate that AD patients presented with intact memory monitoring as their pre-study predictions became more accurate across trials

and their post-study predictions were revised from their initial pre-study predictions on the lists.

Based on the findings from Howard et al. (in press), and the relative neurological similarity between AD patients and TLE patients, it is possible that TLE patients would also show a degree of metamemory sensitivity when tested. Experiment 2 adopted the procedure by Moulin et al. to determine whether TLE patients were sensitive to the objective differences in lists and whether they were able to revise their global predictions accordingly. Howard et al. examined global JOLs after study but not prior to study. As in the procedure implemented by Connor et al. and Moulin et al., Experiment 2 included pre-study and post-study predictions for each list to allow for metamemory monitoring at encoding to be examined.

Howard et al. (in press) manipulated the semantic relatedness of the list and concluded that recall performance was higher for the semantically related word pairs than for the unrelated words pairs in both groups. However, one possible shortfall in the stimuli chosen was that the level of difficulty of each item within each list (semantically related and unrelated) was not assessed. Experiment 2 however, aimed at improving on this by including item difficulty as another characteristic of the to-be-remembered stimuli. Furthermore, Howard et al. measured both item-by-item and global JOLs at encoding. It is possible that including item-by-item JOLs could have potentially increased the accuracy of global JOLs for the entire list, as global JOLs were made after all 60 item-by-item JOLs had been recorded. Experiment 2 removed this potential confound by only measuring global JOLs before and after study. Excluding item-by-item JOLs in this way allowed for judgements to be reflective of participants' cognitive processes at encoding and not potentially inflated by ratings reflective of online monitoring. Finally, Experiment 2 examined metacognitive control processes by assessing how much study-time was allocated to each list. Although metacognitive

control processes were not included in the study by Moulin et al., Experiment 2 included study-time as another measure of metacognitive sensitivity, to see whether TLE patients awarded appropriate amounts of study-time dependent upon the objective difficulty of the lists. Non-directional discrepancy scores were used as a direct measure of participants' accuracy in predicting their future recall on a list (Hertzog et al., 1994). Employing such a measure allowed for inferences to be made about memory monitoring processes that occurred at encoding in TLE patients that were not confounded by the previously observed episodic memory deficit (see Chapter 2).

3.1.1 Experiment 2

In Experiment 2 four lists varying in objective difficulty were presented to 15 patients with TLE and 15 matched healthy controls. To establish to what extent TLE patients accurately predicted their memory abilities on the four lists, pre- and post-study predictions were taken on each list. A memory questionnaire (EMQ, Sunderland, Harris & Gleave, 1984) was also administered to evaluate individuals' subjective perception of everyday memory performance. Furthermore, anxiety and depression were assessed to control for the possible effects of these variables on metamemory performance. Finally, executive function measures were included to detect any executive dysfunction in groups.

3.1.2 Predictions

Based on the results from Experiment 1 (Howard et al., in press) and previous studies in ageing (Connor et al., 1997) and AD (Moulin et al., 2000a), it was predicted that TLE patients would present with a deficit in episodic memory across the four lists compared with controls. Moreover, since normal metamemory was observed in these populations when using the sensitivity approach and also in a sample of TLE patients

when using a different procedure in Experiment 1 (Howard et al., in press), it was predicted also that metacognitive monitoring and control would be preserved in TLE patients. More specifically, TLE patients would revise their predictions which were reflective of the objective factors of the lists.

3.1.3 Method

Participants

Fifteen TLE patients (M = 41.13 years; SD = 12.98; range 18-64) and 15 controls (M = 32.40 years; SD = 16.01; range 18-60) participated in this study, of which six control participants and ten TLE patients also previously took part in Experiment 1. TLE patients were recruited from Derriford Hospital's (Plymouth Hospitals NHS Trust) neurology out-patients clinic, whereas control participants were recruited from the University of Plymouth's School of Psychology undergraduate and volunteers group. TLE patients and non-student controls from the Paid Supporters Group received a small remuneration to cover any travel or parking expenses. Undergraduate participants received participation points as part of their course credit.

TLE patients were considered suitable for investigation based on the research criteria outlined in Chapter 2. Nineteen TLE patients were initially screened from which 15 suitable patients were selected. Patients were excluded due to various underlying neurological factors and psychiatric disorders that were discovered after the experiment, when clinical records were thoroughly reviewed.

Demographic characteristics

Demographic characteristics of both groups and epilepsy features of the TLE patients can be found in Table 3.1. Control participants and TLE patients did not significantly differ in terms of age [F (1, 28) = 2.68, MSE = 213.26, p = .11, η^2_p = .09],

years of formal education [F (1, 28) = 2.46, MSE = 3.92, p = .13, η^2_p = .08], gender [F (1, 28) = 1.26, MSE = .24, p = .27, η^2_p = .04] and predicted full scale IQ (FSIQ) [F (1, 28) = .60, MSE = 37.75, p = .45, η^2_p = .02]. Nine (60 %) of the TLE patients were diagnosed as having complex partial seizures, five (33 %) patients experienced complex partial seizures with secondary generalisation and one (7 %) patient was classified as having both complex partial and simple partial seizures. Six (40 %) patients were seizure free[6] at the time of testing. Seven (47 %) were on monotherapy and eight (53 %) were on polytherapy (maximum combination of 3 AEDs).

[6] The six seizure free patients reported not having experienced a seizure for at least ten months at the time of testing (ranging from ten months to five years). Patients were advised by their medical team to keep their own seizure diary, which enabled the experimenter to consult the frequency of the seizures, although it should be noted that Experiment 2 cannot completely rule out the possibility that patients experienced seizures that were not recorded.

Table 3.1

Demographic characteristics and epilepsy features for TLE and control groups (standard deviations are in parentheses).

	TLE *n* = 15 *M*	Controls *n* = 15 *M*
Age	41.13 (12.98)	32.40 (16.01)
Gender (female/male)	8 / 7	11 / 4
Education (yrs)	14.87 (2.42)	16.00 (1.41)
NART (FSIQ)	117.60 (5.94)	119.33 (6.34)
Age of onset	29.50 (14.03)	—
Seizure Frequency (# per month)	2.00 (3.84)	—
Duration (years)	11.83 (10.54)	—
Laterality (right/left) * bilaterally	5 / 8 * 2	—
Evidence provided by only an abnormal EEG[1], MRI[2] or combination of both[3]	[1] 10 [2] 1 [3] 4	—

Neuropsychological evaluation

A neuropsychological test battery (see Table 3.2 for a summary of the individual tests) was completed by all participants. The battery was split into two sessions. A description of the tests administered can be found in Chapter 2.

Stimuli/Materials

Four lists of 20 words were generated in which the level of relatedness and difficulty of recall differed. Following the procedure adopted by Moulin et al. (2000a), four lists of words comprising of the following conditions; 'Easy-Related' (E-R), 'Easy-Unrelated' (E-U), 'Difficult-Related' (D-R) and 'Difficult-Unrelated' (D-U) were

constructed (see Appendix C). The two related lists (E-R, D-R) comprised of words taken from the same semantic categories (Battig & Montague, 1969). For instance, the E-R list were types of fruits (e.g. strawberry, peach, orange), whereas the D-R list consisted of different colour names (e.g. magenta, lavender, rose). The level of difficulty for these two lists were manipulated by using more frequent exemplars from the different types of fruits category for the E-R list and using less frequent colour names for the D-R list. The unrelated lists (E-U, D-U) were selected from Rubin & Friendly's (1986) free recall norms. The level of difficulty for these two lists were manipulated by selecting words of a high probability of free recall for the E-U list (e.g. boy (.84), elephant (.71) grandmother (.80)) and words of a low recall probability for the D-U list (e.g. causality (.29), figment (.19), sulphur (.29)), as implemented by Moulin et al. The four lists were programmed into Microsoft Office PowerPoint 2003 and run on a Toshiba Tablet laptop computer. Words were presented to participants one at a time in the centre of the screen in Arial font size 44 in black on a white background. Presentation time (study-time) of all word pairs was self-paced (recall readiness). To test the effect of list position on the pre-study predictions and assess whether participants improved the accuracy of their predictions over trials, the four lists were given in a set order with the starting position moving + 1 for each participant. For example, the list position for participant 1 was set as EU, DU, ER, DR. For participant 2 the starting position moved +1 (i.e. DU, ER, DR, EU). The starting position was continually rotated in this manner across all participants, as also implemented by Moulin et al. The laptop computer measured the amount of time each participant spent studying each word to calculate overall study-time allocation for all four lists between groups.

Procedure

All participants were individually tested in a quiet room at either the University of Plymouth, School of Psychology, or in one of the neurology clinic rooms at Derriford Hospital. All participants gave written consent prior to taking part in the study. The protocol was approved by the Cornwall and Plymouth Research Ethics Committee (NHS REC) and also by the University of Plymouth, Faculty of Science Human Ethics Committee.

Participants were instructed that they were going to be given four short memory tests consisting of 20 words in each. Participants were informed that the aim of the study was to try and remember as many of the words as possible and verbally recall these words in any order at the end of each presentation. Before being presented with the first list participants were asked to give an estimate as to how many words they thought they would recall as a figure out of 20 (pre-study prediction). Participants were not informed of the nature of this list when giving their pre-study prediction. They were then presented with 20 words from the first list. Words were individually presented on screen. Participants were instructed that the words would not be presented for a fixed time but that they were to determine how long they would study each word. However, they were instructed that they should try to be as productive as possible when studying the words spending the necessary amount of time they thought they needed to learn a word and no longer. After presentation of the first list and before recall, participants were instructed to give a second prediction (as a figure out of 20) as to how many of the words from the list studied they thought they would recall (post-study prediction). Participants were asked not to count up the number of words they could recall prior to giving this prediction. They were then asked to verbally recall as many of the words they could remember from the list, in any order, indicating to the experimenter when they could remember no more. The experimenter recorded responses for all four lists.

At no stage was feedback given to participants about their recall performance on a list. This procedure was repeated for the three remaining lists.

Everyday Memory Questionnaire

The Everyday Memory Questionnaire (EMQ, Sunderland et al., 1984) was included as a method of collecting individuals' perception of everyday memory functioning. The 28-item revised version of the EMQ was administered. Each statement described an everyday activity in which the participant might experience a degree of forgetting. Participants were asked to rate the frequency with which they experienced each event. Ratings were made on a 9-point scale from zero (not at all in the last three months) to eight (more than once a day). The EMQ was chosen over the MFQ which was used in the previous experiment, due to the MFQs potential limitations (see Chapter 2). The 28-item EMQ is quickly administered and it is easily applied to everyday scenarios which participants can easily relate to. Furthermore, the factor structure of the 28-item EMQ has been previously examined from which five factors emerged; retrieval, task monitoring, conversational monitoring, spatial memory and memory for activities (Cornish, 2000). Versions of the EMQ have also been frequently used in clinical populations such as the elderly, stroke patients and those recovering from brain injury (see Cornish, 2000 for review) including epilepsy research (Corcoran & Thompson, 1993).

3.1.4 Results

All statistical comparisons were conducted using SPSS 16.0. Effect sizes and the level of the p-value are reported for each analysis. Statistical assumptions were checked and corrected to take account of any violations, where necessary.

Neuropsychological test battery

The results from the neuropsychological test battery are presented in Table 3.2. The neuropsychological tests which yielded a significant difference between TLE patients and control participants included conditions one (filled dots only) [F (1, 28) = 6.71, MSE = 7.55, $p < .05$, $\eta^2_p = .19$] and two (inhibition) [F (1, 28) = 6.29, MSE = 5.42, $p < .05$, $\eta^2_p = .18$] of the D-KEFS Design Fluency Test and conditions one (colour naming) [F (1, 28) = 7.69, MSE = 5.01, $p < .01$, $\eta^2_p = .22$] and four (inhibition/switching) [F (1, 28) = 5.85, MSE = 11.03, $p < .05$, $\eta^2_p = .17$] of the D-KEFS Color-Word Interference Test, the subtest Comprehension [F (1, 28) = 8.27, MSE = 5.82, $p < .01$, $\eta^2_p = .23$] from the WAIS-III, and the subtests Logical Memory I [F (1, 28) = 7.79, MSE = 6.51, $p < .01$, $\eta^2_p = .22$] Logical Memory II [F (1, 28) = 13.59, MSE = 7.69, $p < .001$, $\eta^2_p = .33$] and Faces I [F (1, 28) = 6.91, MSE = 7.72, $p < .01$, $\eta^2_p = .20$] from the WMS-III. The overall scaled score of the Hayling Sentence Completion Test also yielded significant differences between groups [F (1, 28) = 7.76, MSE = 1.72, $p < .01$, $\eta^2_p = .22$]. Furthermore, the direction of these differences indicated that the TLE patients performed more poorly than the controls. The findings from the subtests of the WMS-III provide an indication of a memory deficit in the TLE patients for both immediate and delayed recall.

No significant differences were obtained on the NART predicted FSIQ scores [F (1, 28) = .60, MSE = 37.75, $p = .45$, $\eta^2_p = .02$], predicted verbal IQ scores [(1, 28) = .71, MSE = 31.76, $p = .41$, $\eta^2_p = .03$] and predicted performance IQ scores [F (1, 28) = .71, MSE = 29.36, $p = .41$, $\eta^2_p = .03$] or number of years of education [F (1, 28) = 2.46, MSE = 3.92, $p = .13$, $\eta^2_p = .08$]. In addition, no significant differences were obtained on the anxiety [F (1, 28) = 1.74, MSE = 16.10, $p = .20$, $\eta^2_p = .06$] and depression scores F (1, 28) = .75, MSE = 6.40, $p = .39$ $\eta^2_p = .03$] from the HADS.

Table 3.2

Summary of the neuropsychological test battery and EMQ results. (standard deviations are in parentheses).

Test	TLE $n = 15$ *M*	Controls $n = 15$ *M*	*F* statistic	*p* value
Harris Test of Lateral Dominance (Handedness)	1.00 (0.00)	1.00 (0.00)	—	—
HADS				
Anxiety	6.93 (4.06)	8.87 (3.96)	1.74	.20
Depression	4.33 (2.44)	3.53 (2.62)	.75	.39
D-KEFS Design Fluency				
Condition 1*	8.87 (2.64)	11.47 (2.85)	6.71	.02
Condition 2*	8.93 (2.84)	11.07 (1.67)	6.29	.02
Condition 3*	10.73 (3.31)	12.00 (1.89)	1.66	.21
D-KEFS Color- Word Interference				
Condition 1*	8.67 (2.77)	10.93 (1.53)	7.69	.01
Condition 2*	9.47 (2.85)	10.67 (1.68)	1.98	.17
Condition 3*	9.67 (3.54)	11.07 (1.91)	1.82	.19
Condition 4*	7.40 (3.74)	10.33 (2.85)	5.85	.02
Hayling Sentence Completion Test	5.47 (1.25)	6.80 (1.37)	7.76	01
WAIS-III				
Similarities*	9.67 (2.02)	11.13 (2.39)	3.30	.08
Arithmetic*	10.40 (2.80)	11.33 (2.85)	.82	.37
Comprehension*	10.33 (2.61)	12.87 (2.20)	8.27	.01
WMS-III				
Logical Memory I*	9.33 (2.55)	11.93 (2.55)	7.79	.01
Faces I*	9.20 (2.60)	11.87 (2.95)	6.91	.01
Logical Memory II*	9.07 (3.11)	12.80 (2.40)	13.59	.001
Digit Span*	11.33 (2.55)	12.07 (2.69)	.59	.45
NART				
Predictive FSIQ	117.60 (5.94)	119.33 (6.34)	.60	.45
Predictive Verbal IQ	115.40 (5.42)	117.13 (5.84)	.71	.41
Predictive Performance IQ	116.20 (5.17)	117.87 (5.66)	.71	.41
EMQ				
Total Score	76.40 (46.86)	62.07 (35.98)	.88	.36

Abbreviations: HADS = Hospital Anxiety and Depression Scale, D-KEFS = Delis-Kaplan Executive Function System, WAIS-III = Wechsler Adult Intelligence Scale 3rd Edition, WMS-III = Wechsler Memory Scale 3rd Edition, NART = National Adult Reading Test, EMQ = Everyday Memory Questionnaire. * Age-Adjusted Scaled Scores.

Given the significant differences in the D-KEFS Color-Word Interference Test, D-KEFS Design Fluency and Hayling Sentence Completion Test scaled scores, further analyses of the components within these tests were carried out. The number of uncorrected and self-corrected errors produced in each of the four conditions of the D-KEFS Color-Word Interference Test were rare (see Table 3.3), and were consequently not analysed. Latency times for the four conditions (see Table 3.3) were analysed using a 2 (group) x 4 (condition) repeated measures ANOVA. The results showed a main effect of group [F (1, 28) = 5.19, MSE = 464.90, $p < .05$, $\eta^2_p = .16$], condition [F (1.49, 41.70) = 115.54, MSE = 257.11, $p < .001$, $\eta^2_p = .81$] and an interaction between condition and group [F (1.49, 41.70) = 3.92, MSE = 257.11, $p < .05$, $\eta^2_p = .12$]. The analysis of the interaction showed that the greatest difference between the TLE patients and controls was revealed in the colour naming [t (28) = -2.55, $p < .05$] and inhibition/switching conditions [t (28) = -2.41, $p < .05$], but not in the inhibition condition [t (28) = -1.36, $p = .19$]. Moreover, the interference (inhibition – colour naming) and switching cost (inhibition/switching – colour naming) effects were also analysed and showed equivalent interference effects in the two groups [t (28) = -.55, $p = .59$] and an indication of a trend of a greater switching cost [t (28) = -1.97, $p = .06$] in the TLE patients than in the control participants.

Table 3.3

Number of errors (Mean and SD) in the four conditions of the D-KEFS Color-Word Interference Test for TLE and control groups. Cor = self corrected; Non Cor = uncorrected. Mean (SD) latencies to complete each of the four tasks are also included.

Group	Colour Naming	Word Reading	Inhibition	Inhibition / Switching
TLE – Cor Errors	0.07 (0.26)	0.00 (0.00)	0.20 (0.41)	0.87 (1.69)
Controls – Cor Errors	0.00 (0.00)	0.20 (0.56)	0.47 (0.64)	0.60 (1.30)
TLE – Non Cor Errors	0.13 (0.35)	0.00 (0.00)	0.67 (1.54)	2.00 (1.89)
Controls – Non Cor Errors	0.00 (0.00)	0.00 (0.00)	0.80 (1.52)	0.60 (0.91)
TLE Latency times	31.73 (7.01)	23.87 (6.19)	58.27 (19.06)	80.67 (28.11)
Controls Latency times	26.53 (3.64)	21.53 (3.16)	50.73 (9.98)	59.87 (18.22)

The number of errors and repetitions produced in each of the three conditions of the D-KEFS Design Fluency Test were also rare (see Table 3.4), and were consequently not analysed.

Table 3.4

Number of errors and repetitions committed for filled dots only, inhibition and inhibition/switching conditions in the D-KEFS Design Fluency Test for TLE and control groups.
(standard deviations are in parentheses)

Group	Filled Dots Only *M*	Inhibition *M*	Inhibition/Switching *M*
TLE – Errors	0.60 (1.24)	0.27 (0.59)	1.60 (1.72)
Controls – Errors	0.60 (1.06)	0.20 (0.56)	0.60 (1.24)
TLE – Repetitions	0.60 (0.74)	1.87 (1.41)	0.67 (1.05)
Controls – Repetitions	0.53 (1.23)	1.67 (1.72)	0.53 (0.64)

The number of correctly produced designs within 60 seconds for each of the three conditions was analysed using a 2 (group) x 3 (condition) repeated measures ANOVA (see Table 3.5). The results showed a main effect of group [F (1, 28) = 7.32, MSE = 16.42, $p < .01$, $\eta^2_p = .21$], whereby the control participants produced the most amount of correct designs across the three conditions. There was a main effect of condition [F (1.55, 43.32] = 5.23, MSE = 5.66, $p < .05$, $\eta^2_p = .16$], revealing that the most amount of correctly produced designs were generated in the inhibition condition (condition 2) for both groups. However, there was no evidence of an interaction between condition and group [F (1.55, 43.32) = .77, MSE = 5.66, $p = .44$, $\eta^2_p = .03$]. Moreover, the interference (inhibition – filled dots only) and switching cost (inhibition/switching - filled dots only) effects were also analysed and revealed equivalent interference [t (28) = -.64, $p = .53$] and switching cost [t (28) = -1.00, $p = .32$] effects in the two groups.

Table 3.5

Mean number of correctly produced designs in each of the three conditions in the D-KEFS Design Fluency Test for the TLE and control groups. (standard deviations are in parentheses).

Group	Filled Dots Only *M*	Inhibition *M*	Inhibition/Switching *M*
TLE	8.33 (3.20)	9.27 (3.41)	7.93 (3.37)
Controls	11.27 (2.94)	11.67 (1.99)	9.53 (2.13)

The Hayling Sentence Completion Test was also analysed further in terms of the time spent completing both sections of the task (Section 1: sensible completion, Section 2: unconnected completion) and the type of category errors made on section 2 of the task (Category error A: connected, Category error B: somewhat connected).

A 2 (group) x 2 (error type) repeated measures ANOVA revealed no main effect of group [F (1, 28) = .47, MSE = 2.26, p = .50, η^2_p = .02]. A main effect of error type was revealed [F (1, 28) = 4.75, MSE = 2.37, p < .05, η^2_p = .15] indicating that more errors were made in category error B: somewhat connected than from category error A: connected. There was no evidence of an interaction between group and error type [F (1, 28) = .11, MSE = 2.37, p = .74, η^2_p = .00].

The time taken to complete sections 1 (sensible completion) and 2 (unconnected completion) of the test were also analysed. A 2 (group) x 2 (latency) repeated measures ANOVA revealed a main effect of group [F (1, 28) = 4.65, MSE = 814.83, p < .05, η^2_p = .14] and condition [F (1, 28) = 25.51, MSE = 702.52, p < .001, η^2_p = .48], indicating that TLE patients spent longer overall responding than compared with controls and as expected both groups spent more time completing section 2 (unconnected completion) than section 1 (sensible completion). However, there was no evidence of an interaction between group and condition [F (1, 28) = 2.18, MSE = 702.52, p = .15, η^2_p = .07].

The 28 items from the subjective memory questionnaire (EMQ) were rated on a 9-point scale from zero (not at all in the last three months) to eight (more than once a day). Participants' total scores on the questionnaire were summed over the 28 items. Control participants total scores ranged from 7 to 150 (M = 62.07, SD = 35.98), whereas TLE patients total scores ranged from 28 to 174 (M = 76.40, SD = 46.86) (maximum score = 224, which would indicate that all 28 items occurred more than once a day). Control participants and TLE patients did not significantly differ in terms of their cumulative total scores on the EMQ, [F (1, 28) = .88, MSE = 1745.23, p = .36, η^2_p = .03]. Item 1 (*'Forgetting where you have put something. Losing things around the house'*) generated the greatest mean frequency of forgetting rating for the control participants, whereas item 13 generated the greatest mean frequency of forgetting rating for the TLE patients (*'Finding that a word is "on the tip of your tongue". You know*

what it is but cannot quite find it'). Item 2 from the EMQ was the only item to yield a significant difference between groups (*'Failing to recognise places that you are told you have often been to before'*). A one-way ANOVA revealed that TLE patients rated this item significantly more frequently than control participants [F (1, 28) = 6.70, MSE = 2.87, $p < .05$, $\eta^2_p = .19$]. Due to the large number of comparisons a Bonferroni correction was applied ($p < .001$) to prevent spurious relationships from being drawn upon. After adjusting for this correction, item 2 was no longer found to meet the critical value for significance.

Recall performance across objective difficulty of lists

Figure 3.1 shows the mean predictions (pre-study and post-study) and actual recall performance for the four list types. A 2 (group) x 2 (difficulty) x 2 (relatedness) repeated measures ANOVA was performed on the items recalled. A main effect of group, [F (1, 28) = 14.24, MSE = 24.83, $p < .001$, $\eta^2_p = .34$] revealed that control participants globally outperformed TLE patients on all four lists. A main effect of level of difficulty was revealed, [F (1, 28) = 47.32, MSE = 4.29, $p < .001$, $\eta^2_p = .63$] establishing that more words overall were recalled from the easy lists compared with the difficult lists. There was no group by level of difficulty interaction, [F (1, 28) = 3.43, MSE = 4.29, $p = .08$, $\eta^2_p = .11$] suggesting that both groups were able to differentiate between the objective difficulty of the lists to the same extent, performing overall better on the objectively 'easy' lists than the 'difficult' lists. There was also a main effect of relatedness, [F (1, 28) = 111.16, MSE = 4.39, $p < .001$, $\eta^2_p = .80$] with both groups recalling more items from the related lists than the unrelated lists, but no group by relatedness interaction, [F (1, 28) = 1.94, MSE = 4.39, $p = .17$, $\eta^2_p = .07$]. There was a difficulty by relatedness interaction, [F (1, 28) = 31.16, MSE = 3.98, $p < .001$, $\eta^2_p = .53$]

and a three-way interaction between group, difficulty and relatedness, [F (1, 28) = 7.54, MSE = 3.98, $p < .01$, $\eta^2_p = .21$].

The interaction between difficulty and relatedness was explored using paired-samples t-tests to determine differences between overall recall performance in terms of objective difficulty and semantic relatedness. Post-hoc t-tests revealed that the superiority of easy vs. difficult items in recall performance was only for unrelated items, [t (29) = -8.10, $p < .001$], but not for related items, [t (29) = -1.02, $p = .32$].

The three-way interaction was examined using paired-sample t-tests. Paired-samples t-tests revealed that there was a relatedness effect in both easy, [t (14) = 3.59, $p < .01$], and difficult lists, [t (14) = 12.29, $p < .001$], in patients, whereas in controls this effect was only present in the difficult lists, [t (14) = 9.89, $p < .001$], and not in the easy ones, [t (14) = .59, $p = .56$].

Given significant differences in the subtest Comprehension from the WAIS-III ($p < .01$) between groups, this measure was entered in separately as a covariate into the above analysis and re-run as an ANCOVA to control for possible effects of crystallised intelligence on recall performance. The analysis revealed that Comprehension failed to reach significance [F (1, 27) = .03, MSE = 25.72, $p = .86$, $\eta^2_p = .00$] and had no influence on recall performance.

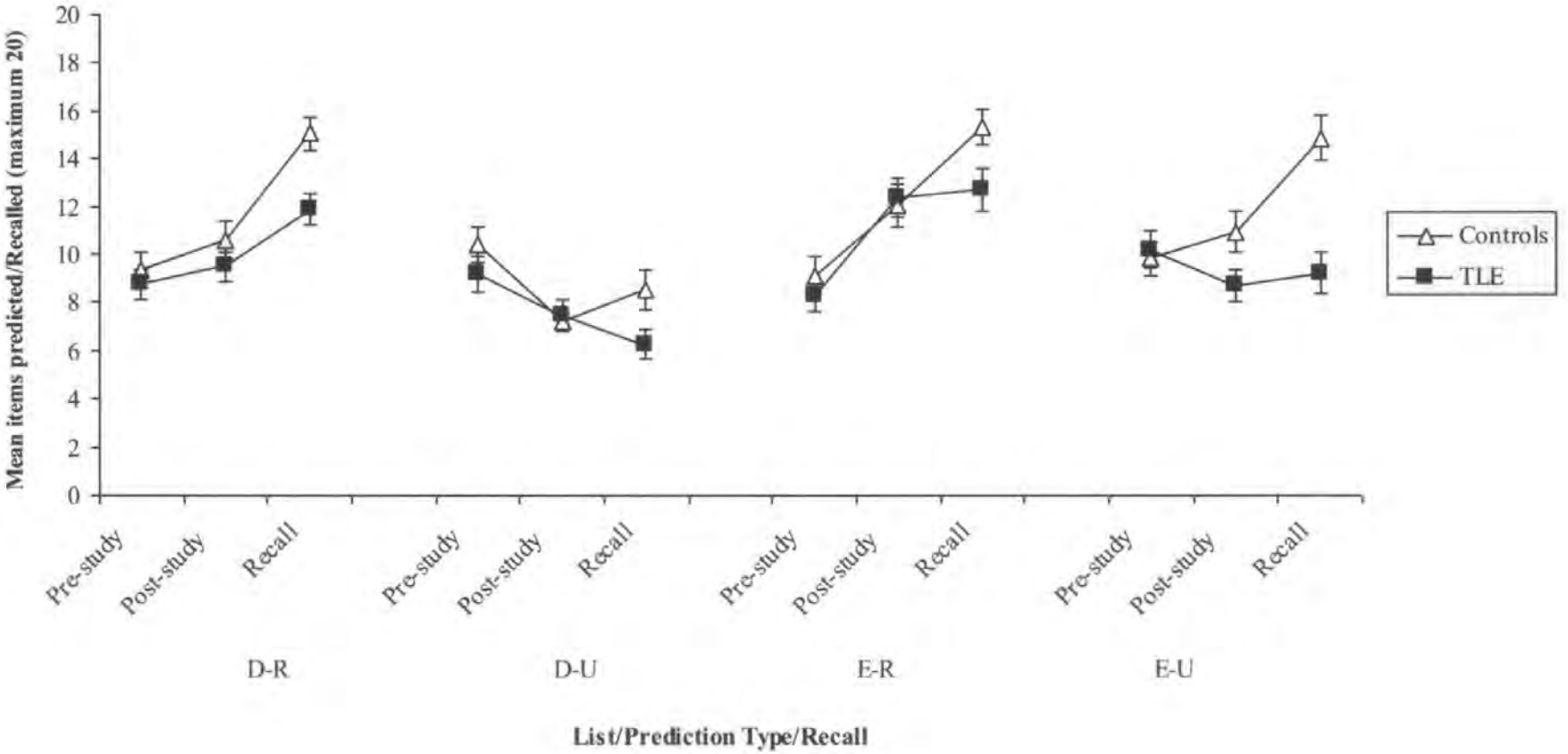


Figure 3.1. Mean pre-study and post-study predictions and actual recall performance in TLE patients and control participants across list type. Error bars relate to standard error.

Recall performance and laterality

Kruskal-Wallis (non-parametric) tests were computed to determine whether there were any differences between all four lists, dependent upon the laterality of the epileptic focus (right, left, bilateral) in the TLE patients (n = 15). This analysis revealed that lateralisation of the seizure focus did not have a significant effect on recall performance across the four lists in the TLE patients; D-U [H (2) = 2.09, p = .35]; D-R [H (2) = 1.83, p = .40]; E-U [H (2) = 5.53, p = .06]; E-R [H (2) = 1.10, p = .58]. Recall for the E-U list indicated a trend between recall performance for this list and laterality [H (2) = 5.53, p = .06]. Mann –Whitney U tests were used to follow up this finding. A Bonferroni correction was applied and so all effects are reported at a $p < .05$ level of significance. It appeared that recall for the E-U list was no different when patients with either a left and right focus performance were compared, [U = 14, r = -.25, p = .38]. However, when patients with a left and bilateral focus were compared, recall was significantly lower [U = .00, r = -.67, $p < .05$] and also when patients with a right and bilateral focus were compared [U = .00, r = -.74, $p < .05$]. This indicated that patients with a bilateral focus tended to perform less well than patients with either a right or left focus on the E-U list. However, it is important to note that there were only 2 TLE patients with a bilateral focus and therefore, this result should be interpreted with caution.

Recall by list position

A 2 (group) x 4 (list position) repeated measures ANOVA revealed that recall did not vary depending on the serial position of the lists. There was a main effect of group [F (1, 28) = 14.24, MSE = 24.83, $p < .001$, η^2_p = .34], no main effect of list position [F (3, 84) = .92, MSE = 13.38, p = .43, η^2_p = .03] and no evidence of an

interaction [F (3, 84) = 1.54, MSE = 13.38, p = .21, η^2_p = .05]. The above analysis indicates no evidence of order or practise effects.

Initial prediction on List 1

A one-way ANOVA performed on the pre-study predictions on List 1 revealed no significant differences between TLE patients (M = 10.87, SD = 2.75) and control participants (M = 9.67, SD = 2.99), [F (1, 28) = .1.31, MSE = 8.25, p = .26, η^2_p = .05]. Observation of the means indicates that the mean prediction for both groups was near to 10, representing half of the list to be recalled.

Sensitivity of post-study predictions

An important feature of this study was to examine whether participants were sensitive to the objective difficulty of a list and as a result alter their post-study predictions accordingly. A 2 (group) x 2 (difficulty) x 2 (relatedness) repeated measures ANOVA was carried out on both groups' post-study predictions. No main effect of group was apparent, [F (1, 28) = .62, MSE = 23.74, p = .44, η^2_p = .02] indicating that the two groups did not predict different levels of performance overall. A main effect of difficulty, [F (1, 28) = 64.84, MSE = 2.52, p < .001, η^2_p = .70] was revealed suggesting that both groups were able to discriminate between easy and difficult lists when making their post-study predictions. There was no group by difficulty interaction, [F (1, 28) = .85, MSE = 2.52, p = .37, η^2_p = .03]. A main effect of relatedness was revealed, [F (1, 28) = 48.26, MSE = 4.10, p < .001, η^2_p = .63] indicating as expected that both groups predicted higher recall on semantically related lists. There was no group by relatedness interaction [F (1, 28) = .66, MSE = 4.10, p = .42, η^2_p = .02], demonstrating no difference between groups when making post-study predictions based on the level of semantic relatedness of the lists. Similarly there was no difficulty by relatedness interaction, [F

(1, 28) = .27, MSE = 1.95, p = .61, η^2_p = .01]. However, a three-way interaction was revealed, [F (1, 28) = 15.42, MSE = 1.95, p < .001, η^2_p = .36].

Follow-up analysis using paired-samples t-tests revealed that the effect of relatedness was present in TLE patients in both easy [t (14) = 4.56, p < .001] and difficult lists [t (14) = 3.42, p < .01], whereas in controls this effect was highly significant in the difficult lists [t (14) = 6.28, p < .001], but not in the easy ones [t (14) = 2.06, p = .06].

Given significant differences in the subtest Comprehension from the WAIS-III (p < .01) between groups, this measure was entered in separately as a covariate into the above analysis and re-run as an ANCOVA to control for possible effects on differences in post-study predictions. The analysis revealed that Comprehension [F (1, 27) = .10, MSE = 24.53, p = .76, η^2_p =.00] failed to reach significance and had no influence on the post-study predictions.

Accuracy change across judgement type and list position

As well as determining whether participants' post-study predictions were sensitive to list type, it was also necessary to determine whether participants' predictions accurately changed across judgement type (pre-study, post-study) and across trials (position). A 2 (group) x 4 (list position) x 2 (judgement type) repeated measures ANOVA was carried out on the non-directional discrepancy scores[10]. Non-directional discrepancies (absolute) were calculated by subtracting the pre-study prediction from actual recall for each participant in each group. Similarly the non-directional discrepancies for the post-study predictions were calculated by subtracting the post-study prediction from actual recall (see Table 3.6). This analysis revealed a main effect

[10] Non-directional discrepancy scores were used where by the modulus of difference between pre-study / post-study (predictions) and actual recall was calculated for controls and TLE patients. This measure was used to determine accuracy of predictions against actual recall performance between groups (see Chapter 1 and Howard et al., in press, for the rationale for using this method).

of group [F (1, 28) = 6.74, MSE = 15.06, $p < .05$, $\eta^2_p = .19$] with the control group actually being more discrepant in their predictions than the TLE patients, due to a tendency to under-estimate recall in both their predictions. There was a main effect of judgement type [F (1, 28) = 25.16, MSE = 4.03, $p < .001$, $\eta^2_p = .47$] with participants being more accurate in their post-study predictions than their pre-study predictions indicating the ability to revise their predictions, based upon the objective difficulty of the lists after study. There was no group by judgement type interaction, [F (1, 28) = 1.06, MSE = 4.03, $p = .31$, $\eta^2_p = .04$]. Similarly, there was no main effect of list position [F (3, 84) = 2.15, MSE = 8.53, $p = .10$, $\eta^2_p = .07$], or a group by list position interaction [F (3, 84) = 1.03, MSE = 8.53, $p = .38$, $\eta^2_p = .04$]. There was no evidence of a list position by judgement type interaction [F (3, 84) = 1.01, MSE = 2.32, $p = .40$, $\eta^2_p = .04$] or a three-way interaction between group, judgement type and list position [F (3, 84) = .34, MSE = 2.32, $p = .79$, $\eta^2_p = .01$]. This analysis demonstrates that both groups were able to revise their post-study predictions from their pre-study predictions after studying the lists, therefore becoming more accurate at predicting their performance, suggesting intact metamemory in both TLE patients and control participants. Interestingly, the lack of an effect for list position shows that neither group significantly benefited from experiencing four trials to increase their accuracy with practise. This would suggest that both groups were able to adjust their predictions accordingly from the onset at List 1.

Table 3.6

Accuracy of participants' predictions before and after list presentation – non- directional discrepancy scores.
(standard deviations are in parentheses).

	Controls				TLE			
	Pre-study		Post-study		Pre-study		Post-study	
	M		*M*		*M*		*M*	
List 1	5.67	(2.94)	3.47	(2.03)	4.47	(3.23)	3.20	(2.04)
List 2	5.33	(3.48)	4.27	(3.06)	3.60	(2.17)	2.67	(1.45)
List 3	6.20	(2.46)	4.20	(2.51)	3.53	(2.67)	2.47	(2.62)
List 4	3.80	(2.24)	2.80	(2.01)	3.13	(3.11)	2.27	(1.62)

Recall readiness/study-time allocation

Metamemory control was measured as the overall study-time allocated to each list. The overall mean study-time (in seconds) for each list was calculated for both groups (see Table 3.7). To determine whether there was a difference in the groups' ability to adjust the time spent studying the words dependent on the objective difficulty of the lists, a 2 (group) x 2 (difficulty) x 2 (relatedness) repeated measures ANOVA was carried out on study-time allocation. It was anticipated that the more difficult the list, the longer participants would spend studying it. In such a case the D-U lists would therefore require the most amount of study-time. The results showed no main effect of group, [F (1, 28) = .16, MSE = .88, p = .70, η^2_p = .01] indicating that both control participants and TLE patients spent similar amounts of time on the four lists. There was a main effect of difficulty [F (1, 28) = 9.39, MSE = .05, p < .01, η^2_p =.25] revealing that the most amount of time overall was spent studying the difficult than the easy lists. There was no evidence of an interaction between difficulty and groups [F (1, 28) = .13, MSE = .05, p = .72, η^2_p = .01]. There was a main effect of relatedness on study-time [F (1, 28) = 20.76, MSE = .11, p < .001, η^2_p = .43], revealing that the least amount of time

was spent on the related than the unrelated lists. There was no evidence of an interaction between relatedness and group [F (1, 28) = .61, MSE = .11, p = .44, η^2_p =.02]. There was no interaction between difficulty and relatedness [F (1, 28) = 4.01, MSE = .04, p = .06, η^2_p = .13]. The three-way interaction did not reach significance [F (1, 28) = 4.01, MSE = .04, p = .06, η^2_p = .13], indicating that both groups were able to control successfully appropriate amounts of study-time dependent upon the objective difficulty of the lists.

Table 3.7

Participants mean study-time allocation for each list. (standard deviations are in parentheses).

List	Controls *M*	TLE *M*
D-R	87.80 (29.36)	93.00 (61.25)
D-U	114.33 (45.51)	154.40 (112.23)
E-R	83.07 (48.57)	89.13 (42.90)
E-U	99.40 (31.12)	117.60 (89.06)

Intrusions

False memories (words incorrectly recalled in a list) were recorded by totalling the number of intrusions made in all four lists for each group. The number of false memories recorded in each list were rare and consequently not analysed (see Table 3.8).

Table 3.8

Participants mean number of intrusions made on each list. (standard deviations are in parentheses).

List	Controls *M*	TLE *M*
D-R	0.20 (0.56)	0.53 (0.92)
D-U	0.60 (1.55)	1.53 (1.36)
E-R	0.07 (0.26)	0.40 (0.74)
E-U	0.07 (0.26)	0.80 (1.15)

Correlation analysis of the EMQ total scores with recall performance

In order to determine whether there was a relationship between subjective ratings of memory forgetting measured by the EMQ and actual recall performance, Pearson's correlation coefficients (r) were computed between the 28 items on the EMQ and recall performance on the four lists. Three possible relationships emerged from this analysis from the control participants and six from the TLE patients, however due to the large correlation matrices a number of these may have occurred by chance. To prevent such spurious relationships from being drawn upon, a Bonferroni correction was used ($p < .001$). After adjusting for this correction, all of the previous correlations were no longer significant ($p > .001$). As a result, no relationships were found between the 28 items on the EMQ and recall performance on the four lists in either group.

Correlation analysis of epilepsy variables and recall performance

In order to determine whether there were any specific epilepsy variables (laterality, seizure type, age of onset, duration, frequency of seizures and number of AEDs) which had an influence on recall performance, Pearson's correlation coefficients (r) were computed and revealed lists D-U [$r = -.59$, $p < .05$] and D-R [$r = -.60$, $p < .05$]

negatively correlated with age of onset. After applying Bonferroni's correction analysis to the correlation matrices, none of the epilepsy variables significantly correlated with recall performance on the four lists ($p > .01$).

Pearson's correlation coefficients (r) were also computed between all epilepsy variables and standardised subtests of the WMS-III ($n = 15$) and revealed the subtest digit span [$r = -.59$, $p < .05$] negatively correlated with duration of epilepsy. After applying Bonferroni's correction analysis to prevent erroneous relationships from occurring, none of the WMS-III subtests correlated with the epilepsy variables ($p > .01$).

Correlation analysis of executive function measures and metamemory accuracy

The relationship between executive function measures (Design Fluency Test number of correctly produced designs in the inhibition and inhibition/switching conditions, interference and switching costs, Color-Word Interference Test latency times in inhibition and inhibition/switching conditions, interference and switching costs and latency times in Hayling B (inhibition section)) and metamemory accuracy measures (non-directional discrepancy scores, pre-and post-study global JOLs) were computed into a correlation matrix. Six possible relationships emerged from this analysis from the control participants and one from the TLE patients, however due to the large correlation matrices a number of these may have occurred by chance. Bonferroni's correction analysis was applied for multiple comparisons ($p < .001$). After applying Bonferroni's correction none of the executive function measures significantly correlated with the metamemory measures in either controls or TLE patients ($p > .001$) (or both groups together) ($p > .001$).

3.1.5 Discussion

The aim of Experiment 2 was to investigate the sensitivity approach, employed by Connor et al. (1997) and Moulin et al. (2000a), in TLE patients. There were two main objectives of this experiment. First, to examine global predictions before and after presentation of a list to determine whether there was a shift in predictions reflective of the intrinsic qualities of the to-be-remembered material. Requesting pre-study and post-study predictions on a particular list allowed for inferences to be made about memory monitoring processes occurring at encoding in TLE patients. Second, to examine metamemory control processes across lists. As the intrinsic qualities of the four lists were known, it was possible to predict how participants should behave if metamemory monitoring and control processes were intact. For instance, more time would be allocated overall to difficult lists and less time to easier lists (Howard et al., in press; Mazzoni & Cornoldi, 1993). Likewise, in terms of metamemory monitoring, higher predictions would be expected in lists containing easier items and lower predictions in lists deemed more difficult (Moulin et al., 2000a).

Overall, the findings from Experiment 2 showed that control participants outperformed TLE patients in recall on all four lists, indicating evidence of a clear episodic memory deficit in this sample. However, both groups were able to discriminate between the objective qualities of the lists to the same extent. The results are now discussed separately in more detail.

Memory performance

As established earlier in Chapter 2 (see Howard et al., in press), this experiment also revealed a clear episodic memory deficit in the TLE patients when compared with matched controls. As expected, both groups recalled more items from the related than the unrelated lists and more items from the easy than the difficult lists. Of particular

interest was whether the TLE patients would be able to differentiate between the objective difficulties of the lists, as this was not a feature previously measured by Howard et al. (see Experiment 1). The results revealed that both controls and TLE patients were able to differentiate, performing overall better on the easy lists than the difficult lists.

Also as in Howard et al. (in press) episodic memory performance was measured by the subtests of the WMS-III (Logical Memory I and Faces I), revealing a significant memory deficit in the TLE patients. As well as objectively testing memory performance in TLE patients this experiment also administered a questionnaire to evaluate participants' subjective perception of everyday memory performance. In terms of their overall cumulative scores, groups did not significantly differ, although TLE patients' cumulative scores were higher suggesting a greater degree of perceived forgetting. Item 2 was the only item to yield a significant difference between groups (*'Failing to recognise places that you are told you have often been to before'*) with TLE patients significantly rating this statement more frequently than controls. According to Cornish (2000), item 2 relates to task monitoring (Factor 2). However, this significant difference was removed after applying a Bonferroni correction for multiple comparisons.

Finally, it is important to note that the differences between TLE patients and control participants in memory performance observed in the current experiment could not be explained by lower levels of crystallised intelligence (performance on the Comprehension subtest of the WAIS-III) as this was ruled out by controlling for this variable (see ANCOVA). Furthermore, mood disturbances did not play a role either in the clear episodic memory deficit observed in the TLE patients in this experiment.

Metacognitive monitoring and control (metamemory)

Post-study predictions on the 'E-U' list were the only significant difference observed between groups. Control participants gave a significantly higher post-study prediction on the 'E-U' list compared with TLE patients. However, no other differences were found in groups' accuracy or magnitude for future recall in their pre-study or post-study predictions for any of the other lists. Groups did not significantly differ in terms of their initial prediction on the first list presented, anchoring their predictions around the mid-point. This finding supports the midpoint anchoring hypothesis suggested by Connor et al. (1997). The only information available to participants when making their initial pre-study prediction on List 1 was list length (i.e. 20 items) from which to base their judgements. Both controls and TLE patients predicted that they would recall around half of the list prior to studying the words, which would suggest midpoint anchoring occurring on the first list. Midpoint anchoring would seem a plausible explanation by which the participants in this current experiment made their initial prediction, particularly as both groups then revised their post-study prediction on List 1 after study. Furthermore, previous research examining different populations have also found midpoint anchoring to be present (Connor et al., 1997; Moulin et al., 2000a), therefore indicating that generally participants tend to 'anchor' their initial prediction on a memory task around the midpoint, regardless of whether they display any memory impairment or not.

This is the first study to date examining global JOLs in TLE patients at different phases in the same task (pre-study, post-study predictions). Both groups were able to successfully monitor the difficulty of the lists and alter their post-study predictions accordingly. Of particular importance was that both groups were more accurate in their post-study global JOLs than in their pre-study global JOLs, indicating the ability to revise their predictions, based upon the objective difficulty of the lists after study.

Groups were equivalent when making their post-study predictions based on the level of semantically relatedness of the lists. However, sensitivity of post-study predictions (measured by non-directional discrepancy scores) indicated that the control groups were actually more discrepant in their predictions than the TLE patients, due to a tendency to under-estimate. One possible explanation for this finding refers to participants' self-efficacy of their memory capabilities. Self-efficacy in short refers to the belief one holds in mastering certain goals (see Bandura, 1989 for review). The subjective beliefs that one has about their memory performance has an influence on future goal setting behaviour. Self-efficacy of memory functioning would therefore seem an important component of metamemory (Bandura, 1989). It would seem appropriate to consider that participants' judgements about their memory abilities are influenced by both past experiences of memory performance and also consideration for certain aspects of the current task (i.e. number of words to be recalled). In the current experiment, TLE patients appeared to be more on target than controls when making their global judgements. One possibility is that TLE patients who experience more memory problems are perhaps better aware of their skills as a consequence of greater exposure to memory tests and everyday memory problems than control participants. As a result, TLE patients are perhaps better able at giving a general prediction of their future memory performance. However, controls with less memory-related experiences have reservations about their capabilities on such tests and lower their expectations to ensure that goals are achieved. Despite TLE patients being less discrepant than controls on their global JOLs, both groups were more accurate in their post-study predictions than in their pre-study predictions, indicating the ability to revise their predictions, based upon the objective difficulty of the lists after study.

The results from the current experiment suggest that TLE patients presented with a memory deficit across all four lists when compared with controls, yet displayed

intact memory monitoring processes at encoding. Similar to Moulin et al.'s (2000a) findings, TLE patients were able to shift their predictions from their pre-study to their post-study to become more accurate. The initial prediction on List 1 was consistent with Connor et al.'s hypothesis of midpoint anchoring and also Moulin et al.'s findings on AD patients. Unlike, Moulin et al.'s findings, TLE patients were sensitive to the different qualities of semantic relatedness across the lists by revising their post-study predictions. However, control participants and TLE patients did not become more accurate in their pre-study predictions across lists one to four. AD is clearly marked by a greater memory deficit than TLE patients and therefore floor effects were not an issue in Experiment 2. The current results extend the sensitivity approach examining the shift in predictions in another neurological population. Connor et al.'s findings on ageing and Moulin et al.'s on AD patients demonstrated a shift in predictions before and after encoding, and the current results are in keeping with this finding.

Examining metacognitive control processes across the four lists was also a feature of the current experiment. Since the difficulty of the to-be-remembered material was manipulated across lists it was expected that different amounts of study-time would be allocated, with overall more time allocated to more difficult lists. Overall study-time was measured across the four lists and revealed that no differences in metacognitive control processes existed between groups. Overall more time was systematically devoted to studying the difficult lists than the easy lists. Whereas, the least amount of time was spent studying the related than the unrelated lists. No evidence of interactions between groups indicated that both controls and TLE patients were able to successfully allocate appropriate amounts of study-time dependent upon the objective difficulty of the lists. These results confirm Howard et al.'s (in press) findings, which also showed intact control processes in another sample of TLE patients. Despite allocating similar

amounts of study-time to lists, patients recalled fewer items than controls on each list, an effect that suggests encoding problems more than monitoring and control problems.

To conclude, the current findings indicate that TLE patients demonstrated a level of metacognitive sensitivity similar to that of controls. Both groups were able to revise their post-study predictions after study to be more representative of their actual recall, using feedback from memory monitoring processes. In actual fact, TLE patients tended to be more accurate than controls when making their global JOLs. Both groups spent similar amounts of time studying the lists and in particular efficiently allocating more time to the difficult lists and less time to the easier lists.

Executive functions

The age-adjusted scaled scores for some of the conditions in the Design Fluency and Color-Word Interference tests from the Delis-Kaplan Executive Function System yielded significant differences between groups and were therefore examined further. Omitted errors were rare in both the Design Fluency and Color-Word Interference tests and were consequently not analysed. Latency times were further analysed in the Color-Word Interference test and revealed that TLE patients overall spent significantly longer than controls on this task. However, equivalent effects were found between groups in the interference effects and only an indication of a trend between switching costs and groups [p = .06] on the Color-Word Interference test. The number of correctly produced designs from the Design Fluency task revealed that controls overall produced a significantly greater amount of designs than TLE patients. However, similarly to the Color-Word Interference test, equivalent interference and switching cost effects were found between groups in the Design Fluency task. The Hayling Sentence Completion test was analysed further in terms of number of errors and latency times between groups. This further analysis revealed that the number of errors did not significantly

differ between groups and in terms of latency times TLE patients spent significantly longer overall completing this task.

These executive function measures indicate that although TLE patients were slower to complete the Color-Word Interference test and produced fewer designs in the Design Fluency test, when interference and switching costs effects were considered groups performed equivalently. The Hayling Sentence Completion test revealed TLE patients spent longer overall completing the task but lack of an interaction did not indicate a clear executive deficit. As a consequence, these measures show a reduction in general speed of processing, but do not provide specific evidence of an executive deficit in this cohort of TLE patients.

In summary, Experiment 2 revealed a clear episodic memory deficit in the TLE patients compared with matched controls. Metamemory monitoring and control processes were intact in TLE patients. TLE patients were sensitive to the objective qualities of the four lists, indicating that they were receptive to the intrinsic cues of the lists similar to control participants. Furthermore, TLE patients were actually less discrepant when making their global JOL predictions compared to control participants. Experiment 2 confirms the dissociation between memory impairment and intact metamemory abilities in TLE patients previously observed by Howard et al. (in press). The ability to revise post-study predictions from their pre-study predictions indicated that both TLE patients and control participants demonstrated a level of metacognitive sensitivity during encoding.

Chapter 4: Metamemory in TLE – Sensitivity to Item-by-Item Repetition

4.1 Introduction

Chapter 3 (Experiment 2) aimed at addressing whether TLE patients were sensitive to intrinsic factors at encoding, when making global predictions on the future likelihood of recalling lists of varying objective difficulty. Chapter 3 revealed that TLE patients along with controls were sensitive to differences in the objective difficulty of the lists and were able to revise their post-study predictions accordingly. Similarly, both groups were able to allocate appropriate amounts of study-time to a list dependent upon its objective difficulty. Overall, these findings indicate that TLE patients demonstrated a level of metacognitive sensitivity when making post-study predictions and systematically allocated appropriate amounts of study-time to a list. Furthermore, Chapter 3 also revealed a clear episodic memory deficit in the TLE patients. As such, a dissociation between memory impairment and intact metamemory was observed, a result which is in keeping with Experiment 1 (also see Janowsky et al., 1989). The primary aim of Chapter 3 was to determine whether TLE patients revised their global post-study predictions from their pre-study predictions after studying a list. The present experiment was also undertaken within the sensitivity approach adopted by Moulin, Perfect and Jones (2000b). The purpose of this experiment was to determine whether the level of metacognitive sensitivity previously observed in global JOLs, could also be established when making item-by-item JOLs. Specifically, the current experiment aimed at examining the effect of online monitoring when repetition was a factor at encoding.

Experiment 3 adopted the procedure employed by Moulin et al. (2000b) to investigate online monitoring at encoding in TLE patients. Moulin et al. conducted an

experiment in which the effects of repetition on JOLs and study-time in AD patients were investigated. In this study, a total of 12 items were presented to participants for future recall and recognition. Of the 12 items, four were presented once, four twice and four three times. Participants were requested to self-pace their study-time and make item-by-item JOLs when studying the to-be-remembered list. The purpose of this design was to see whether AD patients would be sensitive to the repetition of items during study and, as a consequence, regulate their JOL ratings and decrease study-time with increased repetition of an item. Moulin et al. showed that AD patients spent less time studying repeated items but did not increase their JOLs accordingly, despite explicit memory performance being affected. They concluded that AD patients were sensitive to item repetition in terms of their study-time but not when making item-by-item JOLs.

As described in previous chapters, Judgements-of-Learning (JOLs) are perceived ratings of how well an item has been learnt after study. JOLs are therefore predictions concerning the future likelihood of recalling the item at test. Study-time allocation allows participants to self-pace the amount of time spent studying a particular item in order to have the best chance of recalling it at test.

Mazzoni and Nelson (1995) observed the relationship between monitoring and control in normal populations to reveal that JOLs were affected by processes at encoding which were independent of recall performance, a finding which is contrary to the notion that individuals' JOLs are assumed to be based solely on the likelihood of future recall. Whereas Experiment 2 focused on examining global judgements that were made following study, Experiment 3 aimed at concentrating efforts to explore item-by-item JOLs and study-time in TLE patients during encoding.

4.1.1 Experiment 3

In Experiment 3, thirty-nine word pairs were presented in a cued recall task. There were three levels of word pair repetition (one, two, and three presentations) of which 13 word pairs were assigned to each level. To establish whether there was an effect of repetition at encoding, item-by-item JOLs and the amount of study-time allocated to each word pair was recorded in both groups. A memory questionnaire (EMQ, Sunderland et al., 1984) was also administered in order to evaluate participants' subjective perception of everyday memory performance. Furthermore, anxiety and depression were assessed to control for the possible effect of these variables on metamemory performance. Finally, executive function measures were included to detect any executive dysfunction in these groups.

4.1.2 Predictions

Based on the results from the previous two experiments (1 & 2), it was predicted that TLE patients would again present with a deficit in episodic memory when compared with controls. In view of the fact that Experiments 1 and 2 found efficient metamemory monitoring and control in the samples of TLE patients, it was predicted here also that metacognitive monitoring and control processes would be preserved. More specifically, metacognitive sensitivity would be intact in TLE patients, an increase in item repetition would increase item-by-item JOLs and decrease the amount of study-time allocated. Furthermore, it was predicted that repetition would have an effect on recall. As a consequence, repeated items would be more likely to be recalled than those presented less frequently.

4.1.3 Method

Participants

Fifteen TLE patients (M = 41.20 years; SD = 13.05; range 18-65) and 15 controls (M = 37.93 years; SD = 15.40; range 19-61) participated in this study, of which eight control participants and 12 TLE patients previously took part in Experiment 1 and/or 2. TLE patients were recruited from Derriford Hospital's (Plymouth Hospitals NHS Trust) neurology out-patients clinic, whereas control participants were recruited from the University of Plymouth's School of Psychology undergraduate and volunteers group. TLE patients and non-student controls from the Paid Supporters Group received a small remuneration to cover any travel or parking expenses. Undergraduate participants received participation points as part of their course credit.

TLE patients were considered suitable for investigation based on the research criteria described in Chapter 2. Twenty-one TLE patients were initially screened from which 15 suitable patients were selected. Patients were excluded due to various underlying neurological factors and psychiatric disorders that were discovered after the experiment, when clinical records were thoroughly reviewed.

Demographic characteristics

Demographic characteristics of both groups and epilepsy features of the TLE patients can be found in Table 4.1. Control participants and TLE patients did not significantly differ in terms of age [F (1, 28) = .39, MSE = 203.76, p = .54, η^2_p = .01], years of formal education [F (1, 28) = .37, MSE = 3.21, p = .55, η^2_p = .01], gender [F (1, 28) = 1.19, MSE = .25, p = .29, η^2_p = .04] and predicted full scale IQ (FSIQ) [F (1, 28) = 2.95, MSE = 27.17, p = .10, η^2_p = .10]. Nine (60 %) of the TLE patients were diagnosed as having complex partial seizures, five (33 %) patients experienced complex partial seizures with secondary generalisation and one (7 %) other patient was classified as

having both complex partial and simple partial seizures. Five (33 %) patients were seizure free[11] at the time of testing. Ten (67 %) were on monotherapy and five (33 %) were on polytherapy (maximum combination of 3 AEDs).

Table 4.1

Demographic characteristics and epilepsy features for TLE and control groups (standard deviations are in parentheses).

	TLE *n* = 15 *M*	Controls *n* = 15 *M*
Age	41.20 (13.05)	37.93 (15.40)
Gender (female/male)	7 / 8	10 / 5
Education (yrs)	15.20 (1.97)	15.60 (1.60)
NART (FSIQ)	118.27 (5.88)	121.53 (4.44)
Age of onset	28.47 (13.53)	—
Seizure Frequency (# per month)	1.00 (1.07)	—
Duration (years)	12.73 (11.00)	—
Laterality (right/left) * bilaterally	6 / 7 * 2	—
Evidence provided by only an abnormal EEG[1], MRI[2] or combination of both[3]	[1] 10 [2] 1 [3] 4	—

[11] The five seizure free patients reported not having experienced a seizure for at least four months at the time of testing (four for over a year and one for four months). Patients were advised by their medical team to keep their own seizure diary, which enabled the experimenter to consult the frequency of the seizures, although it should be noted that Experiment 3 cannot completely rule out the possibility that patients experienced seizures that were not recorded.

Neuropsychological evaluation

A neuropsychological test battery (see Table 4.2 for a summary of the individual tests) was completed by all participants. The battery was split into two sessions. A description of the tests administered can be found in Chapter 2.

Stimuli/Materials

As apposed to Moulin et al.'s (2000b) study, where only 12 words were presented, the word list consisted of 39 semantically unrelated word pairs (memory difficulties are less severe in TLE patients than in AD patients). Word pairs were chosen over word items to increase difficulty. All words were selected from Rubin & Friendly's (1986) recall norms. All 39 cue and target words were matched for recallability according to recall norms, with a mean recallability proportion of 0.60 (range 0.53 to 0.67). There were three levels of word pair repetition (one, two, and three presentations) of which 13 word pairs were assigned to each level. The list was constructed so that word pair repetition was distributed randomly throughout the list, ensuring that repeated word pairs did not follow in succession, but repetition was evenly spread throughout the list. The 39 word pairs with three levels of repetition made a total of 78 trials (13 x 1 + 13 x 2 + 13 x 3). The word pairs and levels of repetition are listed in Appendix D. The word pairs were programmed into Microsoft Office PowerPoint 2003 and run on a Toshiba Tablet laptop computer. Word pairs were presented to participants one at a time in the centre of the screen in Arial font size 44 in black on a white background. Presentation time (study-time) of all word pairs was self-paced in order to measure study-time allocation in seconds.

Procedure

All participants were individually tested in a quiet room at either the University of Plymouth, School of Psychology, or in one of the neurology clinic rooms at Derriford Hospital. All participants gave written consent prior to taking part in the study. The protocol was approved by the Cornwall and Plymouth Research Ethics Committee (NHS REC) and also by the University of Plymouth, Faculty of Science Human Ethics Committee.

JOL task

Participants were instructed that they were going to be presented with a series of 39 different word pairs on a computer screen, some of which would be repeated during the study phase. They were asked to study the word pairs and try to remember as many as possible. Participants were instructed that following study they would be presented with the first part of all the word pairs (cue word) and asked to recall the second part to the word pairs (target word) if known. Participants were instructed that they could study each word pair for as long as necessary to increase their chances of recalling the word pairs. If they came across a word pair previously studied they were to use this as another opportunity to study the word pair and not rely on specific word pairs being repeated throughout the study phase.

The computer measured how long each participant spent studying every word pair in order to calculate study-time allocation between groups. Each word pair was presented one at a time and participants used the spacebar to declare recall readiness and proceed onto the next word pair. A practise block consisting of four word pairs were given before test to ensure that participants understood the task procedure and the words could be clearly read. Practise word pairs were not included in the recall phase.

Immediately after studying a word pair, participants were asked to rate how certain they felt they would recall the second part of that particular word pair, if presented with only the first word as a cue after study (Judgement-of-Learning, JOLs). Item-by-item JOLs were requested on a 6-point scale set at 20% intervals (0% = definitely will not recall, 20% = 20% sure, 40% = 40% sure, 60% = 60% sure, 80% = 80% sure, 100% = definitely will recall; Kelemen & Weaver, 1997). Once participants had finished studying a particular word pair, a screen followed which included the JOL ratings to prompt the participant to rate the word pair they had just studied. Participants verbally responded to give their rating on a particular word pair and the experimenter recorded their responses on a record sheet. At the time of making a JOL the word pair was no longer visible to the participant.

Following the study phase, participants were given a cued recall test in which the first part of the word pairs (e.g. alligator - ?) were presented one at a time for five seconds. Whilst the first part of the word pair was visible on screen, participants were instructed to respond verbally if they knew the corresponding target word. In the cued recall phase all 39 word pairs were tested and responses were recorded by the experimenter.

FOK task

As apposed to Moulin et al.'s (2000b) study where a yes/no recognition test followed the recall phase, presenting all 12 target words with 12 distracters, Experiment 3 employed a FOK task only for the non recalled or incorrectly recalled word pairs. Following the cued recall phase, participants were given an opportunity to correctly recognise the target words for all non recalled or incorrectly recalled word pairs. Participants were informed that they would be presented with the first part of the word pair as in the cued recall phase (e.g. alligator - ?) but at the same time also be presented

with four words, one of which would be the target word. Distracters were target words to other word pairs from the list. Prior to the recognition phase, participants were asked to give a FOK judgement for every non recalled or incorrectly recalled word pair. FOK judgements were made on the same 6-point scale described for JOLs (from 0% to 100% at 20% intervals) as to whether they would be able to recognise the second part of the word pair when the first part was presented along with four possible alternatives, one of which was the target word. The recognition task was presented after the FOK judgements had been completed. It was emphasised to participants not to guess at a particular word but to only respond if they thought it was the correct word. Participants were given eight seconds in which to read the four alternatives and choose the answer. Responses were recorded by the experimenter on a record sheet.

To summarise, the experiment comprised of four phases; study, cued recall, FOK judgements and recognition. In the study phase, metamemory control was measured by the overall study-time allocated to each level of item repetition and metamemory monitoring was measured by participants' individual JOLs at each level of item repetition. The effects of word pair repetition on study-time, JOLs and retrieval were examined in this experiment.

Everyday Memory Questionnaire

The 28-item revised version of the Everyday Memory Questionnaire (EMQ, Sunderland et al., 1984) was included as a method of collecting individuals' perception of everyday memory functioning. Each statement described an everyday activity in which the participant might experience a degree of forgetting. Participants were asked to rate the frequency with which they experienced each event.

4.1.4 Results

All statistical comparisons were conducted using SPSS 16.0. Effect sizes and the level of the p-value are reported for each analysis. Statistical assumptions were checked and corrected to take account of violations, where necessary.

Neuropsychological test battery

The results from the neuropsychological test battery are presented in Table 4.2. The neuropsychological tests which yielded a significant difference between TLE patients and control participants included the subtests Faces I [F (1, 28) = 4.59, MSE = 6.98, $p < .05$, $\eta^2_p = .14$] and Logical Memory II [F (1, 28) = 6.36, MSE = 9.25, $p < .05$, $\eta^2_p = .19$] from the WMS-III. In both these measures, control participants outperformed TLE patients, indicating evidence of an immediate and delayed memory deficit.

No significant differences were obtained on the NART predicted FSIQ scores [F (1, 28) = 2.95, MSE = 27.17, $p = .10$, $\eta^2_p = .10$], predicted verbal IQ scores [(1, 28) = 2.91, MSE = 23.21, $p = .10$, $\eta^2_p = .09$] and predicted performance IQ scores [F (1, 28) = 2.63, MSE = 21.33, $p = .12$, $\eta^2_p = .09$] or number of years of education [F (1, 28) = .37, MSE = 3.21, $p = .55$, $\eta^2_p = .01$], indicating that both groups were properly matched. In addition, no significant differences were obtained on the anxiety [F (1, 28) = 1.07, MSE = 11.22, $p = .31$, $\eta^2_p = .04$] and depression scores [F (1, 28) = .46, MSE = 5.87, $p = .50$, $\eta^2_p = .02$] from the HADS.

Table 4.2

Summary of the neuropsychological test battery and EMQ results. (standard deviations are in parentheses).

Test	TLE $n = 15$ M	Controls $n = 15$ M	F statistic	p value
Harris Test of Lateral Dominance (Handedness)	1.00 (0.00)	1.13 (0.35)	2.15	.15
HADS				
Anxiety	6.20 (3.63)	7.47 (3.04)	1.07	.31
Depression	3.33 (2.87)	2.73 (1.87)	.46	.50
D-KEFS Design Fluency				
Condition 1*	9.20 (2.57)	10.13 (3.14)	.80	.38
Condition 2*	9.00 (2.80)	10.07 (2.15)	1.37	.25
Condition 3*	10.60 (3.04)	11.60 (2.20)	1.07	.31
D-KEFS Color- Word Interference				
Condition 1*	8.67 (2.44)	9.73 (2.15)	1.61	.22
Condition 2*	9.93 (1.71)	10.27 (1.87)	.26	.61
Condition 3*	10.13 (2.48)	11.13 (1.60)	1.73	.20
Condition 4*	8.73 (3.31)	10.20 (2.65)	1.80	.19
Hayling Sentence Completion Test	5.93 (1.10)	6.33 (0.90)	1.19	.29
WAIS-III				
Similarities*	10.27 (2.37)	10.87 (2.03)	.55	.46
Arithmetic*	10.47 (2.70)	11.40 (3.00)	.81	.38
Comprehension*	10.60 (2.56)	11.47 (2.80)	.78	.38
WMS-III				
Logical Memory I*	10.13 (3.09)	11.80 (2.37)	2.75	.11
Faces I*	9.73 (2.58)	11.80 (2.70)	4.59	.04
Logical Memory II*	9.67 (3.56)	12.47 (2.42)	6.36	.02
Digit Span*	11.20 (2.73)	12.27 (3.52)	.86	.36
NART				
Predictive FSIQ	118.27 (5.89)	121.53 (4.44)	2.95	.10
Predictive Verbal IQ	116.00 (5.35)	119.00 (4.23)	2.91	.10
Predictive Performance IQ	116.87 (5.21)	119.60 (3.94)	2.63	.12
EMQ				
Total score	96.53 (42.43)	92.93 (32.44)	.07	.80

Abbreviations: HADS = Hospital Anxiety and Depression Scale, D-KEFS = Delis-Kaplan Executive Function System, WAIS-III = Wechsler Adult Intelligence Scale 3rd Edition, WMS-III = Wechsler Memory Scale 3rd Edition, NART = National Adult Reading Test, EMQ = Everyday Memory Questionnaire. * Age-Adjusted Scaled Scores.

The 28 items from the subjective memory questionnaire (EMQ) were rated on a 9-point scale from zero (not at all in the last three months) to eight (more than once a day). Participants' total scores on the questionnaire were summed over the 28 items. Control participants' total scores ranged from 2 to 105 (M = 65.00, SD = 32.49), whereas TLE patients' total scores ranged from 32 to 174 (M = 68.67, SD = 42.54) (maximum score = 224, which would indicate that all 28 items occurred more than once a day). Control participants and TLE patients did not significantly differ in terms of their cumulative total scores, [F (1, 28) = .07, MSE = 1432.91, p = .80, η^2_p = .00]. Item 1 (*'Forgetting where you have put something. Losing things around the house'*) had the greatest mean rated frequency of forgetting score for the control participants, whereas item 13 had the greatest mean rated frequency of forgetting for the TLE patients (*'Finding that a word is "on the tip of your tongue". You know what it is but cannot quite find it'*). None of the items from the EMQ yielded significantly different rating scores between groups.

Memory performance

Recall performance for each level of repetition between groups is illustrated in Figure 4.1. Cued recall performance between groups across the three levels of repetition was analysed first. The respective mean items recalled across the three levels of presentation between groups can be found in Table 4.3. A 2 (group) x 3 (word pair repetition) repeated measures ANOVA revealed a main effect of group [F (1, 28) = 5.59, MSE = 25.83, $p < .05$, η^2_p = .17], indicating that control participants outperformed TLE patients. There was a main effect of item repetition [F (2, 56) = 47.34, MSE = 3.15, $p < .001$, η^2_p = .63], revealing that recall increased with repetition. The analysis failed to find an interaction between group and item repetition [F (2, 56) = .79, MSE = 3.15, p = .46, η^2_p = .03], suggesting that both groups behaved similarly in terms of their recall

performance across the different levels of repetition. Both groups benefited from repetition of the to-be-remembered word pairs.

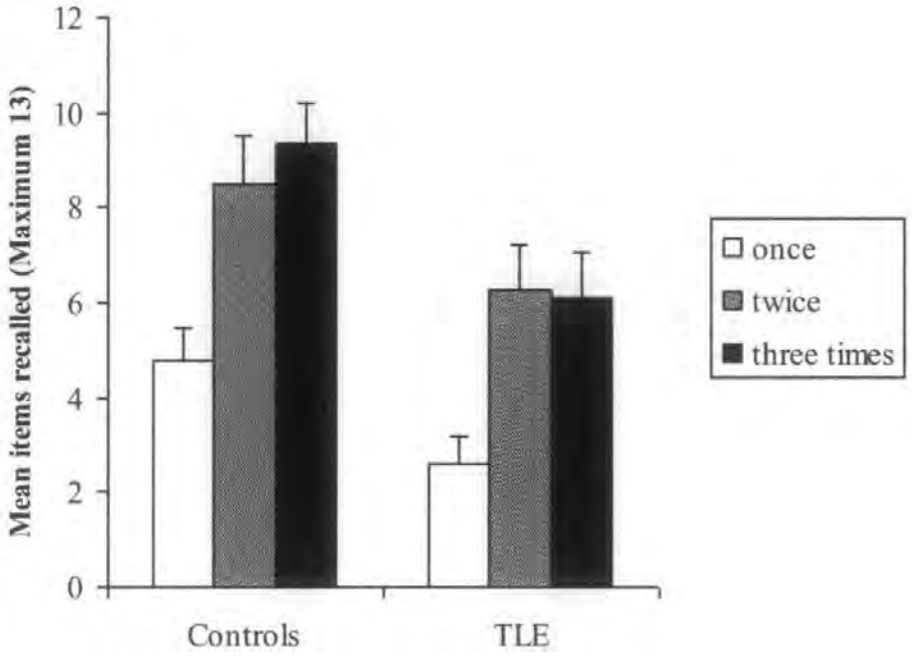


Figure 4.1. Mean recall performance for the three levels of repetition between groups. Error bars relate to standard error.

Table 4.3

Mean items recalled for word pairs presented once, twice and three times for both groups.
(standard deviations are in parentheses).

	TLE	Controls
	M	*M*
Once	2.60 (2.23)	4.80 (2.51)
Twice	6.27 (3.67)	8.47 (3.98)
Three times	6.13 (3.54)	9.33 (3.33)

Recall performance and laterality

Kruskal-Wallis (non-parametric) tests were computed to determine whether there were any differences between overall recall performance, dependent upon the

laterality of the epileptic focus (right, left, bilateral) in the TLE patients (n = 15). This analysis revealed that lateralisation of the seizure focus did not have a significant effect on overall recall performance [H (2) = 4.63, p = .10].

Analysis of metamemory monitoring and control

The amount of study-time allocated for each word pair (recall readiness) and the item-by-item JOL data could be analysed in two ways. Firstly, the means at each level of item repetition for all word pairs (i.e. 1st presentation of each word pair compared with 2nd presentation compared with 3rd presentation) could be examined. Secondly, the effects of repetition for the 13 word pairs which were presented for all three repetition levels could also be conducted.

However, it is important to outline that the first approach, using the frequency of presentation (means at each level of item repetition), had the potential to confound the results as all 39 items were presented once, but 26 were presented only twice and 13 only once. For that reason, the analysis of the raw data was conducted using both methods. The means at each level of repetition for all 39 items was analysed, as well as the 13 items presented at all three levels of repetition to show consistency of the results.

Metamemory control – Allocation of study-time/recall readiness

Figure 4.2. shows the amount of time allocated to studying word pairs in seconds across the three presentation levels (mean for all items) and across the stimulus set for each level of repetition (once, twice, three times). The study-time allocated in seconds for the 13 word pairs presented three times in all was analysed using a 2 (group) x 3 (repetition level) repeated measures ANOVA and revealed a main effect of group [F (1, 28) = 11.57, MSE = 32.86, $p < .01$, η^2_p = .29] with TLE patients spending significantly longer studying the word pairs compared with controls. A main of effect of

repetition was revealed [F (1.25, 35.01) = 11.13, MSE = 7.15, $p < .001$, $\eta^2_p = .28$], indicating that study-time decreased with increased repetition. The interaction did not reach significance [F (1.25, 35.01) = 1.68, MSE = 7.15, $p = .21$, $\eta^2_p = .06$], revealing that groups behaved similarly in allocating study-time across the three levels of repetition. As a result, both controls and TLE patients were seen to be sensitive to item repetition and, as a consequence, controlled their study-time accordingly; spending less time studying word-pairs with increased repetition.

To ensure transparency of the results, the means for all word pairs seen once, twice and three times across presentation trials were also analysed to confirm the findings. A 2 (group) x 3 (means across presentation trials) repeated measures ANOVA revealed a main effect of group [F (1, 28) = 10.24, MSE = 32.10, $p < .01$, $\eta^2_p = .27$] with TLE patients spending significantly longer than control participants, a main effect of means across presentation trials [F (1.30, 36.51) = 16.39, MSE = 3.65, $p < .001$, η^2_p = .37], indicating that groups spent less time with increased repetition. The interaction did not approach significance [F (1.30, 36.51) = 2.39, MSE = 3.65, $p = .12$, $\eta^2_p = .08$] confirming that both control participants and TLE patients were sensitive to the effects of repetition on study-time and behaved similarly in allocating their study-time. Of particular importance here is that the results for the 13 word pairs presented three times in all and also for the means at each level of item repetition for all word pairs were consistent, indicating that, on this occasion, unequal frequencies of item presentation did not confound the analysis.

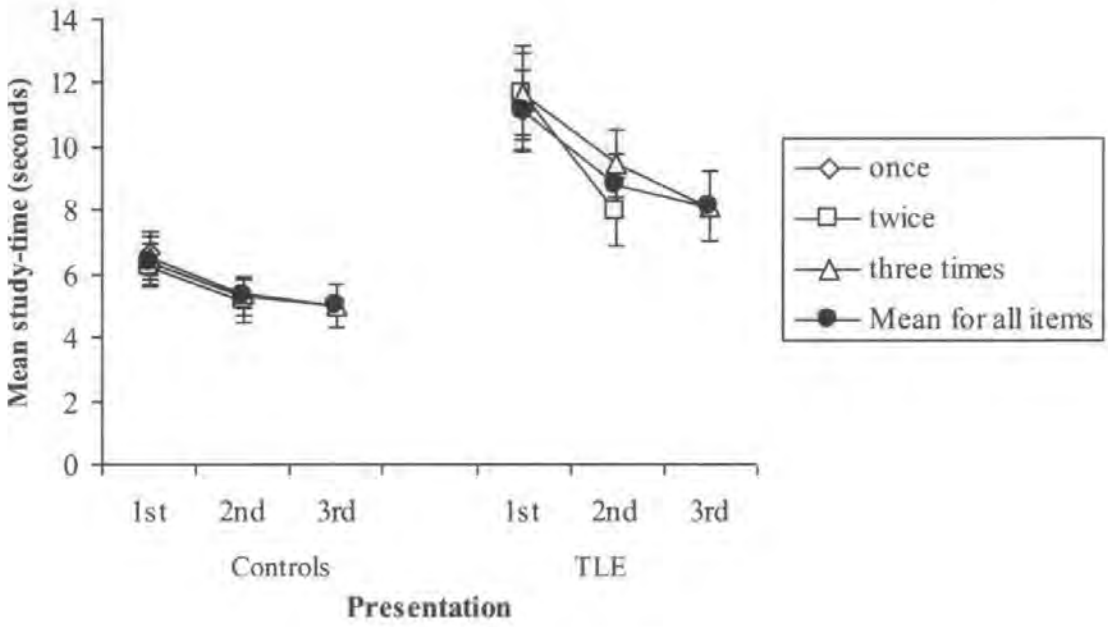


Figure 4.2. Mean study-time allocation by stimulus set and presentation between groups. Error bars relate to standard error.

Metamemory monitoring – Judgements-of-Learning (JOLs)

Figure 4.3. shows the JOL ratings across the three presentation levels (mean for all items) and across the stimulus set for each level of repetition (once, twice, three times). As with the study-time data, the item-by-item JOLs was first analysed for the 13 word pairs presented at each level of repetition. A 2 (group) x 3 (repetition level) repeated measures ANOVA revealed no main effect of group [F (1, 28) = .31, MSE = 975.22, p = .58, η^2_p =.01], indicating that both groups made similar JOLs overall and a main effect of JOLs across repetition [F (1.42, 39.78) = 6.68, MSE = 92.74, $p < .01$, η^2_p = .19], indicating that word pairs that were seen more times were rated as easier to recall. The interaction did not approach significance [F (1.42, 39.78) = 2.71, MSE = 92.74, p = .10, η^2_p = .09], revealing that both groups were equivalent in their JOL ratings across repetition, that is to say that both control participants and TLE patients were sensitive to repetition and rated word pairs as more likely to recall as the number of repetitions increased.

As with the study-time data, it was necessary to analyse the means at each level of item repetition for all word pairs (items seen once, twice and three times, across presentation trials) for the JOLs to confirm that findings were consistent with the above analysis. A 2 (group) x 3 (means across presentation trials) repeated measures ANOVA revealed no main effect of group [F (1, 28) = .46, MSE = 1002.77, p = .50, η^2_p = .02], indicating that groups gave similar JOL ratings overall, a main effect of means across presentation trials [F (1.31, 36.53) = 19.11, MSE = 65.75, p < .001, η^2_p = .41], revealing that as repetition increased for word-pairs, participants JOL ratings also increased rating them as easier to recall. As in the above analysis, the interaction failed to reach significance [F (1.31, 36.53) = 2.55, MSE = 65.75, p = .11, η^2_p = .08], revealing that both groups gave similar JOL ratings overall, increasing their ratings with repetition. Analysing the data using both methods confirmed the findings were consistent.

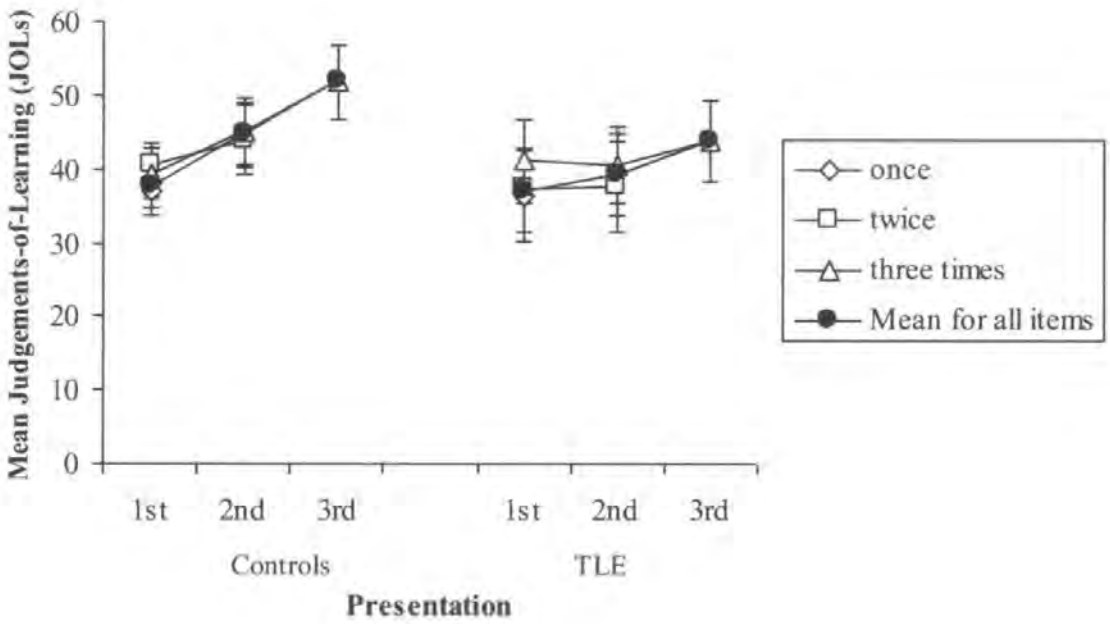


Figure 4.3. Mean Judgement-of-Learning ratings by stimulus set and presentation between groups. Error bars relate to standard error.

It can therefore be concluded for both the study-time and JOL results, that analysing the data by the 13 word pairs presented over the three repetition levels or by the means across presentation trials, gave consistent findings throughout.

In order to test whether the two groups used the ratings for JOLs differently, a 2 (group) x 6 (6-point ratings) repeated measures ANOVA was also carried out on the number of times (proportions of use) each JOL rating was used (see Figure 4.4). There was no main effect of group [F (1, 28) = .06, MSE = 8.73, p = .80, η^2_p = .00], indicating that overall use of ratings did not significantly differ between groups and a main effect of rating type [F (2.93, 81.91) = 13.45, MSE = 411.29, $p < .001$, η^2_p = .32], showing that some ratings were more frequently used than others. Finally, the interaction between group and rating type did not reach significance [F (2.93, 81.91) = .75, MSE = 411.29, p = .52, η^2_p = .03], an indication that both groups used a similar distribution of JOL ratings across the entire list.

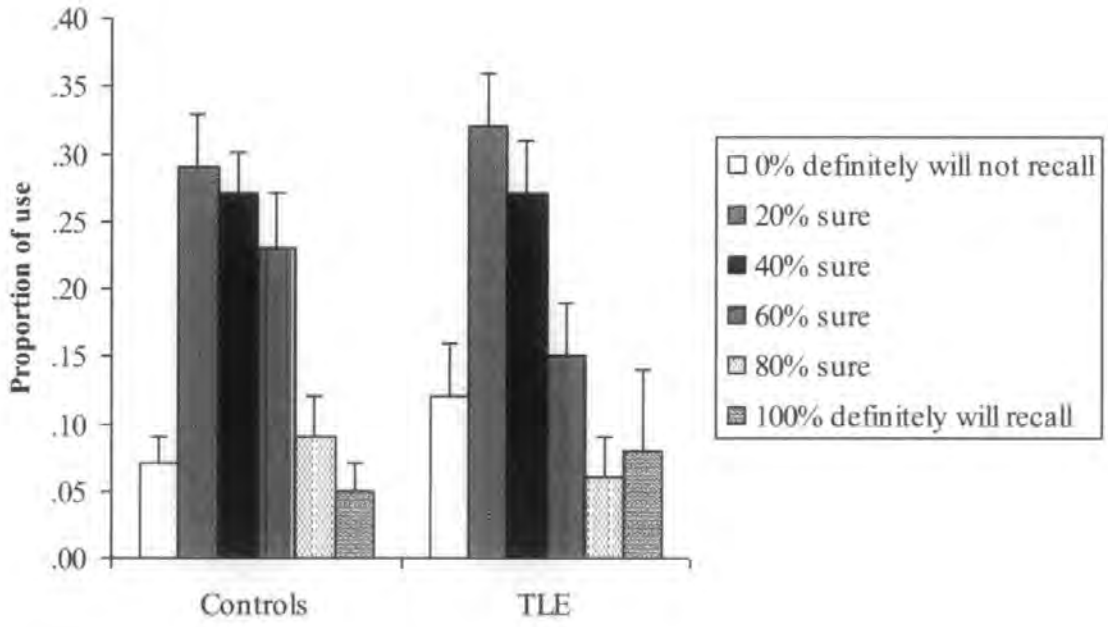


Figure 4.4. Judgement-of-Learning ratings' proportions of use in TLE patients and controls. Error bars relate to standard errors.

Metamemory accuracy – Feeling-of-Knowing (FOKs)

Goodman-Kruskal Gamma correlations between the FOK judgements and recognition performance were calculated for both groups. One-sample t-tests revealed that FOK Gamma correlations were significantly different from zero for control participants [t (14) = 2.55, $p < .05$] and TLE patients [t (14) = 2.32, $p < .05$], indicating that both groups were metacognitively competent when making their FOK judgements. Independent-samples t-tests revealed FOK Gamma correlations were not significantly different in the control participants ($M = .39$, $SD = .60$) and TLE patients ($M = .33$, $SD = .55$), t (28) = .32, $p = .76$, indicating that both groups behaved similarly in terms of their FOK ratings relating to actual recognition performance.

Recognition

An independent-samples t-test was carried out on the proportion of correctly recognised items between control participants and TLE patients. Independent-samples t-test revealed that control participants ($M = 71.22$, $SD = 20.48$) recognised a significantly greater percentage of target words than the TLE patients ($M = 48.47$, $SD = 24.82$), t (28) = 2.74, $p < .01$.

Correlation analysis of the EMQ total scores with recall performance

In order to determine whether there was a relationship between subjective ratings of memory forgetting measured by the EMQ and actual recall performance, Pearson's correlation coefficients (r) were computed between the 28 items on the EMQ and overall recall performance (maximum score = 39) on the list. Three possible relationships emerged from this analysis from the TLE patients and one from the control participants, however due to the large correlation matrices a number of these may have occurred by chance. To prevent such spurious relationships from being drawn upon, a

Bonferroni correction was applied ($p < .001$). After adjusting for this correction, all of the previous correlations were no longer significant. As a result, no relationships were found between the 28 items on the EMQ and overall recall performance on the list in either group.

Correlation analysis of epilepsy variables and recall performance

In order to determine whether there were any specific epilepsy variables (laterality, seizure type, age of onset, duration, frequency of seizures and number of AEDs) which had an influence on overall recall performance. Pearson's correlation coefficients (r) were computed and found that none of the epilepsy variables significantly correlated with overall recall performance ($p > .05$).

Pearson's correlation coefficients (r) were also computed between all epilepsy variables and standardised subtests of the WMS-III ($n = 15$). After applying Bonferroni's correction analysis ($p > .001$) to prevent erroneous relationships from occurring, none of the WMS-III subtests correlated with overall recall performance.

4.1.5 Discussion

The purpose of the present experiment was to investigate further the sensitivity approach (Connor et al., 1997; Moulin et al., 2000a,b,c), by examining the effects of repetition on online monitoring in TLE patients. The study aimed at addressing whether the level of metacognitive sensitivity previously observed in global JOLs (Experiment 2), could also be established when making item-by-item JOLs. In particular, the current study involved examining the effect of online monitoring when extrinsic cues (item repetition) were a factor at encoding.

Overall, the findings from Experiment 3 showed that control participants outperformed TLE patients on recall and recognition of the word pairs, indicating evidence of a clear episodic memory deficit in this sample as well. However, both groups were sensitive to repetition of word pairs throughout the list, revealing intact online monitoring and control processes at encoding. The results are now discussed separately in more detail.

Memory performance

Previous chapters (2 & 3) have provided evidence of a clear episodic memory deficit in TLE patients compared with control participants. The results in Experiment 3 are in keeping with this finding by showing that control participants performed better than TLE patients on all three levels of word pair repetition. Furthermore, the results indicated that both groups benefited overall from repetition. Explicit memory was affected by the repeated presentation of word pairs in both groups. Despite control participants outperforming TLE patients on recall, lack of an interaction between item repetition and group suggested that both controls and TLE patients behaved similarly in terms of their recall performance across the different levels of repetition.

Previous chapters (2 & 3) have also provided further evidence of a memory deficit in TLE patients when memory performance was measured in subtests of the WMS-III. In Experiment 3, the subtests Faces I and Logical Memory II of the WMS-III revealed that TLE patients performed significantly worse than control participants. Furthermore, control participants also outperformed TLE patients on the proportion of correctly recognised items on the FOK task.

It was an important aspect of all experiments in this thesis to assess patients' subjective views of their memory. In Experiment 3, the EMQ was administered to all participants to establish the frequency of everyday memory forgetting in both groups. In

terms of their overall cumulative scores, groups did not significantly differ, although TLE patients' cumulative scores were numerically higher. The EMQ did not detect any significant differences between the groups' perception of everyday memory functioning. However, the experimental tasks indicated that TLE patients were able to adjust their behaviour accordingly, for instance increasing their study-time compared with controls. In Experiment 4 the EMQ failed to reflect the same level of sensitivity as the experimental tasks, which raises the issue of using subjective questionnaires alongside objective measures. The use of subjective questionnaires is discussed further in Chapter 6.

Finally, as with the previous chapters, it is important to emphasise that the differences between TLE patients and control participants in memory performance observed in Experiment 3 could not be explained by lower levels of crystallised intelligence, as the subtests Similarities, Arithmetic and Comprehension from the WAIS-III were not significantly different between groups. Mood disturbances did not play a role in the episodic memory deficit observed in the TLE patients in this experiment either, as the anxiety and depression measures were again not significantly different between groups. Similarly, the executive function measures did not provide evidence of an executive deficit in this cohort of TLE patients.

Metacognitive monitoring and control (metamemory)

The fundamental element of this experiment was to assess metacognitive sensitivity for extrinsic cues at encoding. Primarily, Experiment 3 examined the effect of online monitoring when repetition was a function at encoding, when making item-by-item JOLs and allocating study-time.

Metacognitive monitoring was assessed by item-by-item JOLs, which were recorded for each word pair at each level of repetition. No effect of group was observed,

which indicated that both TLE patients and controls made similar JOLs overall. The distribution of JOL ratings did not significantly differ between TLE patients and controls. The most frequently used rating ('20% sure') was the same in both groups. TLE patients used '80% sure', and control participants '100% definitely will recall' the least. The extrinsic factor (repetition) of the to-be-remembered list did have an effect on JOL ratings, whereby the more frequently an item was presented, the higher the JOL rating. Of particular importance here is that groups were equivalent in their JOL ratings across repetition. This finding provides evidence that metamemory monitoring, measured by item-by-item JOLs, were intact in TLE patients. Moreover, TLE patients and control participants were sensitive to repetition at encoding, rating word pairs as more likely to be recalled as the number of presentations increased.

Metacognitive control was measured by the amount of study-time allocated to word pairs across the three levels of repetition. It was predicted that the amount of study-time allocated would be dependent upon the extrinsic cues of the to-be-remembered material. If intact metacognitive control processes were to be observed, a decrease in study-time would be detected with increased presentation of items. Nelson and Narens' (1990) theoretical framework implies that feedback from monitoring of the to-be-remembered material feedbacks back to control processes. Online monitoring and control processes should therefore act as a self regulatory system to achieve the optimal memory performance.

The amount of study-time allocated across the three levels of repetition revealed that TLE patients spent significantly longer studying the word pairs compared with controls. However, as in control participants, repetition had an effect on study-time, whereby study-time decreased with further repetitions. Of particular importance here, is that both groups behaved similarly in allocating time across the three levels of repetition. As a consequence, both controls and TLE patients were sensitive to the

extrinsic cues (repetition) demonstrated by controlling their study-time accordingly; spending less time studying word-pairs with increased repetition.

The evaluation of these metacognitive results indicates that TLE patients demonstrated a level of metacognitive sensitivity similar to that of control participants. Online monitoring and control processes were intact, measured by item-by-item JOLs and study-time allocation. Despite preserved metamemory monitoring and control processes, TLE patients demonstrated a clear memory impairment at recall. Finally, significant differences were detected between the amount of study-time allocated between groups; with TLE patients spending significantly longer studying the word pairs than controls. This finding is indicative of a vulnerability of general speed of processing which is common amongst clinical populations (see DeLuca & Kalmar, 2007). Furthermore, this finding also parallels results in previous chapters which revealed TLE patients to be slower at responding to some of the executive function measures (Experiments 1 & 2).

In summary, Experiment 3 once again revealed an episodic memory deficit in the sample of TLE patients tested compared with a group of matched controls, whereas their online metamemory monitoring and control processes were intact. Both groups benefited from repetition at encoding, with repeated items being recalled more frequently. In addition, both groups allocated less time to repeated items and increased their JOLs with increased repetition. Thus, both groups' explicit memory performance, study-time and item-by-item JOLs were affected by repetition. The results indicated that TLE patients and controls were sensitive to repetition at encoding. In keeping with the previous experiments in this thesis, Experiment 3 indicates a dissociation between memory performance and metamemory abilities in TLE patients (also see Janowsky et al., 1989). The experiments reported so far in this thesis (1, 2 & 3) have provided

evidence that monitoring and control processes at encoding are intact in TLE patients, suggesting that metamemory difficulties cannot explain the memory impairment observed in the TLE patients tested.

Chapter 5: Material-Specific Lateralisation in Unilateral TLE

5.1 Introduction

Previous experiments in this thesis have provided converging evidence that TLE patients presented with an episodic memory deficit when compared with matched controls. Furthermore, metamemory monitoring and control processes were intact at both the item-by-item and global levels. Moreover, in some circumstances, TLE patients tended to be more accurate than controls in assessing their metamemory (see Chapter 2). TLE patients were also seen to be sensitive to manipulations in the to-be-remembered material when making their predictions regarding their future performance (see Chapters 3 & 4). The experiments discussed in the previous chapters indicate a dissociation between memory and metamemory in TLE patients, whereby memory performance was impaired but metamemory abilities were intact.

It was the purpose of Experiment 4 to examine the material-specific hypothesis in unilateral TLE, utilising the 'Remember-Know' paradigm. The material-specific hypothesis suggests that the two hemispheres of the brain are independent and support different cognitive functions. The left hemisphere is associated with the functioning of verbal information, whereas the right hemisphere is associated with processing of non verbal information. This model was first established by Milner and colleagues (see Saling, 2009 for review), who demonstrated an association between memory material (verbal vs. non verbal) and laterality in surgical resections (L-TLE vs. R-TLE). The material-specific hypothesis is a unique approach to assessing memory performance in neurologically impaired populations and suggests that damage to one of these hemispheres will lead to a deficit in the associated memory function. As such, the material-specific lateralisation of TLE patients has been of particular interest (Baxendale et al., 1998; Moscovitch & McAndrews, 2002; Saling, 2009; Wagner,

Sziklas, Garver & Jones-Gotman, 2009), and also in epilepsy surgery candidates (Barr et al., 1997). Studies have set out to examine the relationship between lateralisation of the seizure focus and memory performance for the corresponding hemisphere. Unilateral damage to the left temporal lobe has been found to impair the learning and retention of verbal material, whereas right temporal lobe damage has been associated with memory deficits in non verbal information. It was the primary purpose of this final experiment to examine whether the material-specific hypothesis could be applied to unilateral TLE patients, when assessing memory and metamemory, whilst employing the 'Remember-Know' (R-K) paradigm.

The R-K paradigm was first introduced by Tulving (1985) and later further explored by Gardiner and colleagues (Gardiner, 1988; Gardiner & Java, 1990, 1991; Gardiner & Parkin, 1990). The R-K paradigm explores the familiarity and recollection of retrieved items in a recognition task. Instead of providing a simple 'yes/no' response to whether an item had been previously studied, the R-K paradigm requires that participants differentiate between recollection and familiarity of an item. For instance, if the participant can remember the original presentation of the item, a '*Remember*' (recollection) response would be given. However, when a participant recognises the item as being presented previously, but cannot recollect its original presentation, then a '*Know*' (familiarity) response would be given. Recognition for an item is thus discriminated by whether there is conscious recollection of the item or whether there is a sense of familiarity without the recollective experience.

To the author's knowledge, there are only three studies which have investigated hemispheric differences of R-K responses in TLE (Bengner & Malina, 2008; Blaxton & Theodore, 1997; Moscovitch & McAndrews, 2002). In Experiment 1, Blaxton and Theodore (1997) presented a series of abstract visuospatial designs for study. At recognition, controls and left TLE (L-TLE) patients assigned significantly more 'know'

than 'remember' responses, whereas the right TLE (R-TLE) showed the opposite pattern of responses. Blaxton and Theodore suggest that the higher frequency of 'know' responses given to the abstract (non verbal) designs by controls and L-TLE patients reflect perceptual rather than a distinctiveness processing. Since R-TLE patients may have a deficit in recognising the abstract designs, then a different pattern of responses would be expected. Experiment 1 found that R-TLE patients did in fact show an opposite pattern of responses to that of controls and L-TLE patients. Blaxton and Theodore suggest that this finding may be a result of information processing impairments. A follow-up study (Experiment 1a) including pre- and post surgery L-TLE and R-TLE patients found a similar pattern of responses, demonstrating a dissociation between left and right TLE patients. Moreover, the results indicated that the side of the lesion was responsible for the differing pattern of responses and not the patient's surgical status (pre or postoperative). In a second experiment, in which encoding conditions were manipulated to represent either perceptual fluency or distinctiveness, the control participants gave, as expected, a higher frequency of 'know' responses for counting the number of lines in each design (perceptual) and a greater frequency of 'remember' responses for judging the appropriateness of category labels for each design (distinctiveness). However, the two patient groups showed the same pattern of responses as in experiments 1 and 1a regardless of the encoding conditions. Blaxton and Theodore proposed that the different pattern of responses in the R-K paradigm in left and right TLE patients were reflective of impairments in information processing. L-TLE patients assigned a greater number of 'know' responses due to an inability to distinctively recognise stimuli, whereas, R-TLE patients produced a greater number of 'remember' responses due to impaired processing of perceptual fluency. Blaxton and Theodore's findings are interpreted within a theoretical framework, suggestive of a

"modes of processing" approach of laterality in which the left hemisphere mediates 'remember' responses, whereas the right hemisphere mediates 'know' responses.

Moscovitch and McAndrews (2002) aimed at exploring further whether the "modes of processing" view could be observed in both verbal and non verbal material in unilateral TLE patients using faces and word stimuli. Moscovitch and McAndrews manipulated the way in which the verbal and non verbal materials were encoded to enhance either a perceptual or conceptual (distinctiveness) level of processing. Moscovitch and McAndrews' findings do not confirm Blaxton and Theodore's "modes of processing" view (i.e. left hemisphere dominates remembering and the right dominates knowing). Remembering for stimuli following conceptual processing did not show enhancement in unilateral TLE patients for material that was related to the side of the damaged hemisphere. For instance, L-TLE patients did not reveal an increase in "remember" responses for words conceptually processed but did for faces. Similarly, R-TLE patients showed a marginal benefit from conceptually encoding faces, whereas for words this was clearly evident. Instead, Moscovitch and McAndrews' findings supported a material-specific view of laterality, in that processing impairments were only apparent in verbal stimuli in the L-TLE patients and non verbal stimuli in the R-TLE patients. The material-specific view of laterality implies that the left temporal lobe is associated with the retention of verbal information, whilst the right temporal lobe is linked with the retention of non verbal information.

Blaxton and Theodore's (1997) and Moscovitch and McAndrews' (2002) studies used TLE patients with either hippocampal sclerosis or anterior temporal resection and therefore conclusions could not be made upon the role of the hippocampus in recollection and familiarity. Furthermore, differences in methodologies prevented direct comparisons being made between the two studies. Bengner and Malina (2008) aimed at resolving one of these potential issues by recruiting left and right TLE patients with and

without hippocampal sclerosis whilst employing the R-K paradigm on a face recognition task. Bengner and Malina's results suggested that the hippocampus plays a role in familiarity as patients without hippocampal sclerosis made more 'know' responses than those with hippocampal sclerosis. Furthermore, their findings add some support for the material-specific view of laterality as suggested by Moscovitch and McAndrews. Benger and Malina's findings revealed that R-TLE patients gave fewer 'remember' responses than L-TLE patients on the face recognition task, indicating a dominance of the right temporal lobe in facilitating face recognition.

Moscovitch and McAndrews' findings indicate that TLE patients with focal seizures originating from the left hemisphere typically demonstrate a deficit in recognising verbal material, whereas TLE patients with seizures originating in the right temporal lobe tend to show a deficit in the recollection of non verbal stimuli (Benger & Malina, 2008). The implications of these findings suggest that focal seizures originating from the temporal lobe and the underlying pathology have a marked effect on the learning and retention of information for the corresponding hemisphere.

More recently, Wagner, Sziklas, Garver and Jones-Gotman (2009) examined the role of working memory in medial temporal lobe epilepsy patients. Wagner et al. (2009) employed matched verbal and visuospatial supraspan tasks. Findings from this study indicate that medial temporal lobe damage resulted in deficits in the verbal and visuospatial tasks irrespective of the side of damage. However, lateralisation of damage was revealed to have an effect on working memory capacity. R-TLE patients were revealed to have a lowered visuospatial working memory capacity, whereas L-TLE patients made a greater number of verbal intrusions. Wagner et al. suggest that their results extend the material-specific hypothesis to working memory in medial temporal lobe patients.

Some previous studies (Baxendale et al., 1998; Barr et al., 1997) did not include a group of matched control participants for comparison, and therefore inferences concerning material-specific effects were made by directly comparing L-TLE patients to R-TLE. However, in order to fully examine the results in terms of the material-specific hypothesis, Experiment 4 deemed it necessary, as in the previous experiments, to compare the two patient groups to a control group to measure any deviations from the 'norm'. Therefore, if verbal performance was found to be significantly impaired in L-TLE compared with control participants and not significantly different between R-TLE and controls and/or non verbal performance found to be significantly impaired in R-TLE patients compared with controls and not significantly different between L-TLE patients and controls, then the findings would go some way to support the material-specific view of laterality. Furthermore, if L-TLE patients significantly differed from R-TLE patients and both groups significantly differed from the control group, then this finding would also go some way to support the material-specific hypothesis.

To the author's knowledge, no previous studies have investigated the role of laterality on metamemory in TLE using a combination of item-by-item JOLs and the 'Remember-Know' paradigm. Therefore, the aim of the current experiment was firstly to examine whether the lateralisation of the seizure focus had an effect on performance on either a verbal or non verbal task, which was representative of the material-specific hypothesis and secondly, to establish whether item-by-item JOLs were reflective of accurate online monitoring.

5.1.1 Experiment 4

Experiment 4 aimed at exploring the material-specific hypothesis (unilateral damage to the left temporal lobe has been found to impair the learning and retention of verbal material, whereas right temporal lobe damage results in memory deficits for non-

verbal information). Using the 'R-K' paradigm, recognition for verbal and non verbal material was examined in unilateral left and right TLE patients. In addition, Judgements-of-Learning (JOLs) were recorded at study to examine accuracy of online monitoring in both the verbal and non verbal material and reveal any differences in TLE patients dependent upon the laterality of their seizure focus. As in previous experiments (2 & 3) the Everyday Memory Questionnaire (EMQ, Sunderland et al., 1984) was administered in order to evaluate participants' subjective perception of everyday memory performance. Furthermore, anxiety and depression were assessed to control for the possible effect of these variables on metamemory performance. Finally, executive function measures were included to detect any executive dysfunction in these groups.

5.1.2 Predictions

In line with findings from the previous experiments featured in this thesis, it was predicted that controls would outperform TLE patients in the recognition tasks and that metamemory monitoring would be preserved in both the verbal and non verbal tasks. In terms of the material-specific hypothesis and the R-K paradigm, it was predicted that controls, R-TLE patients and L-TLE patients pattern of responses to the R-K task would differ from each other and also from the type of material presented (i.e. verbal, non verbal), with L-TLE patients performing less well on verbal task and R-TLE patients on the non verbal task.

5.1.3 Method

Participants

Fourteen control participants (M = 39.29 years; SD = 15.03; range 18-61) and 14 TLE patients (7 left hemisphere and 7 right hemisphere TLE; TLE-L, TLE-R respectively) (TLE-L: M = 38.71 years; SD = 12.24, range 19-52; TLE-R: M = 42.86

years; *SD* = 15.13, range 18-65) participated in this study. All 14 control participants and 13 of the TLE patients previously took part in Experiment 3. TLE patients were recruited from Derriford Hospital's (Plymouth Hospitals NHS Trust) neurology out-patients clinic, whereas control participants were recruited from the University of Plymouth's School of Psychology undergraduate and volunteers group. TLE patients and non-student controls from the Paid Supporters Group received a small remuneration to cover any travel or parking expenses. Undergraduate participants received participation points as part of their course credit.

TLE patients were considered suitable for investigation based on the research criteria described in Chapter 2. In addition to this, only those TLE patients who had unilateral seizures in either the left or right temporal lobe were recruited into this experiment. Patients with unilateral left or right TLE were distinguished through either their EEG recordings, MRI or a combination of both (see Table 5.1). None of the patients were newly diagnosed and therefore normally had more than one EGG recording or MRI to confirm their epileptic focus.

Demographic characteristics

Demographic characteristics of both groups and epilepsy features of the TLE patients can be found in Table 5.1. Control participants, TLE-L and TLE-R patients did not significantly differ in terms of age [F (2, 25) = .18, MSE = 208.37, p = .84, η^2_p = .01], years of formal education [F (2, 25) = .15, MSE = 3.27, p = .86, η^2_p = .01], gender [F (2, 25) = 2.68, MSE = .22, p = .09, η^2_p = .18] and predicted full scale IQ (FSIQ) [F (2, 25) = 2.55, MSE = 27.22, p = .10, η^2_p = .17]. Eight (57 %) of the TLE patients were diagnosed as having complex partial seizures, five (36 %) patients experienced complex partial seizures with secondary generalisation and one (7 %) other patient was classified as having both complex partial and simple partial seizures. Five (36 %) patients were

seizure free[9] at the time of testing. Nine (64 %) were on monotherapy and five (36 %) were on polytherapy (maximum combination of 3 AEDs). Twenty TLE patients were initially screened from which 14 suitable patients were selected. Patients were excluded due to various underlying neurological factors and psychiatric disorders that were discovered after the experiment, when clinical records were thoroughly reviewed.

Table 5.1

Demographic characteristics and epilepsy features for L-TLE, R-TLE and control groups (standard deviations are in parentheses).

	L-TLE *n* = 7 *M*	R-TLE n =7 *M*	Controls *n* = 14 *M*
Age	38.71 (12.24)	42.86 (15.13)	39.29 (15.03)
Gender (female/male)	2 / 5	6 / 1	9 / 5
Education (yrs)	15.14 (1.35)	15.29 (2.43)	15.57 (1.65)
NART (FSIQ)	116.86 (6.94)	118.57 (5.19)	122.00 (4.21)
Age of onset	25.29 (12.11)	32.00 (14.74)	—
Seizure Frequency (# per month)	1.43 (1.27)	0.57 (0.79)	—
Duration (years)	13.43 (11.77)	10.86 (7.36)	—
Evidence provided by only an abnormal EEG[1], MRI[2] or combination of both[3]	[1] 4 [2] 1 [3] 2	[1]5 [2]0 [3]2	—

[9] The five seizure free patients reported not having experienced a seizure for at least four months at the time of testing (four for over a year and one for four months). Patients were advised by their medical team to keep their own seizure diary, which enabled the experimenter to consult the frequency of the seizures, although it should be noted that Experiment 4 cannot completely rule out the possibility that patients experienced seizures that were not recorded.

Neuropsychological evaluation

A neuropsychological test battery (see Table 5.2 for a summary of the individual tests) was completed by all participants. The battery was split into two sessions. A description of the tests administered can be found in Chapter 2.

Pilot study

Memory performance for non verbal (visual) material is typically lower than memory performance on verbal material, as verbal information is more readily recalled than non verbal information (see Moye, 1997 for a review of construct validity and clinical utility of a number of figural memory measures). Moye (1997) suggests that in particular, using a recognition memory test and also a large number of designs maximises the specific measurement of non verbal memory and test validity. To reduce verbalisation effects in a non verbal task, abstract designs are often used to assess non verbal learning and memory performance (e.g. Blaxton & Theodore, 1997). Furthermore, to try and equate verbal and non verbal tasks in terms of their level of difficulty, it is typically necessary to present a greater number of items in the verbal task during the study phase than in the non verbal task (e.g. Moscovitch & McAndrews, 2002).

A pilot study (n = 14) testing control participants was initially conducted on the verbal and non verbal tasks to manipulate the number of words and abstract designs needed to construct two tasks with similar levels of difficulty. The objective of this pilot study was to equate the verbal and non verbal tasks as far as possible in their level of difficulty, so that comparisons could be made between groups and also memory performance based on the task material. The number of items, either words or abstract designs, were manipulated so that there were a greater number of words and fewer abstract designs presented to participants.

In addition to the number of to-be-remembered stimuli, the presentation time was also a factor which the pilot study explored, allowing a longer presentation time for the abstract designs to compensate for the level of difficulty. Furthermore, any abstract designs that could be clearly given a verbal label to assist encoding were omitted and replaced. Fourteen control participants (M = 20.57 years; SD = 6.50; range 18 to 43) participated in the pilot study. All participants were presented with both the verbal and non verbal tasks, the order of which was counterbalanced. Participants were presented with 120 words and 80 abstract designs, half of which were presented for study and the remaining half as distracters at the recognition test. To construct a series of abstract designs for the non verbal task, this experiment adopted the procedure used by Blaxton and Theodore (1997) in which a series of line drawings were generated that were difficult to name. All abstract designs were black. The abstract designs were constructed within a 3 x 3 dot matrix in which each dot was assigned a number from one to nine. A series of random numbers were generated from which five lines were connected on the dot matrix to form an abstract design. After construction, the dots were removed to leave the abstract design. The proportion of correctly recognised words and abstract designs were recorded. Paired-samples t-tests revealed that the proportion of correctly recognised stimuli from the verbal (M = 73.93, SD = 6.77) and non verbal tasks (M = 66.43, SD = 11.57) used in the pilot study was marginally not significantly different [t (13) = 2.03, p = .06]. As a consequence of conducting the pilot study, the number of words for the verbal task was increased and a delay introduced between study and recognition, by adding in a digit span distracter task. The number of abstract designs for the non verbal task remained the same as in the pilot study.

Stimuli/Materials

The materials used for the verbal and non verbal tasks were programmed into Microsoft Office PowerPoint 2003 and run on a Toshiba Tablet laptop computer. Words used for the verbal task were presented to participants one at a time in the centre of the screen in Arial font size 44 in black on a white background. The 80 target and 80 distracter words were taken from Rubin & Friendly's (1986) recall norms (see Appendix E1). Target and distracter words had a mean recallability rating of 0.51 (range 0.41 to 0.62).

The abstract designs were also presented one at a time in the centre of the screen on a white background. Eighty abstract designs (see Appendix E2 for examples) were generated, 40 of which were assigned to the study phase and the remaining half to act as distracters in the recognition task. Care was taken in constructing the designs to ensure that designs were not repeated or rotated to act as new designs. Although not initially implemented into the pilot study, the current experiment requested participants to continually repeat A-B-A-B to prevent verbalising any of the abstract designs and ensure that the task was polarised as non verbal as possible. The order in which participants completed the verbal and non-verbal task was counterbalanced to prevent possible order effects.

Procedure

All participants were individually tested in a quiet room at either the University of Plymouth, School of Psychology, or in one of the neurology clinic rooms at Derriford Hospital. All participants gave written consent prior to taking part in the study. The protocol was approved by the Cornwall and Plymouth Research Ethics Committee (NHS REC) and also by the University of Plymouth, Faculty of Science Human Ethics Committee.

Verbal task

Participants were told that they were going to see 80 words presented one at a time on the laptop screen and that each word would be shown for three seconds. Participants were told that they would later be given a recognition test. After studying a word, participants were asked to rate how certain they felt they would recognise that particular item, if presented with all 80 items studied and 80 new items (Judgement-of-Learning, JOLs). Item-by-item JOLs were requested on a 6-point scale set at 20% intervals (0% = definitely will not recognise, 20% = 20% sure, 40% = 40% sure, 60% = 60% sure, 80% = 80% sure, 100% = definitely will recognise; Kelemen & Weaver, 1997). Once participants had declared recall readiness, a screen followed which included the JOL ratings to prompt the participant to rate the word they had just studied. Participants verbally responded to give their rating on a particular word and the experimenter recorded their responses on a record sheet. At the time of making a JOL, the word they had studied was no longer visible to the participant. Immediately following the study phase, participants were given a digit span distracter task. The recognition test then followed, whereby the previously studied 80 words were presented along with 80 new words. The order in which the previously studied words were presented was randomised. Participants were informed that half of the words on the recognition test had been presented earlier and the other half were new. Participants were then informed that they could give one of three possible responses to a word, either "No", "Know" or "Remember". Participants were told that a "No" response should be given when they thought the word had not been previously presented, a "Know" response when the item was familiar, they believed the item had been previously presented, but they could not consciously recollect studying it and "Remember" when they could recall the original presentation of the item from the study phase. Three A4 laminated cards were given to the participant with the following

responses '*No – I do not recall studying the item*', '*Know – The item is familiar. I am sure the item was previously presented, but cannot consciously recollect studying it*' and '*Remember – I can recall the original presentation of the item from the study phase*', and were asked to point at a card when giving a response to a particular word. The experimenter made sure the participant clearly understood the difference between the three responses before proceeding onto the recognition task. Participants completed the recognition task at their own pace. The verbal task took approximately 20 minutes to complete.

Non verbal task

Participants were informed that they were going to be presented with 40 abstract designs presented one at a time on the laptop screen and that each design would be shown for five seconds. Participants were instructed to continually repeat A-B-A-B aloud whilst studying a design to suppress verbalising any of the abstract designs, to ensure the task remained non verbal throughout. As with the verbal task, participants were required to give item-by-item JOLs after studying each design. Participants were told that after the study phase they would immediately be given a recognition test. The recognition test also followed the same procedure as the verbal task described above. In the recognition test, the 40 previously presented abstract designs were presented along with 40 new designs. Participants gave one of the three responses ("No", "Know" and "Remember") to each abstract design. The recognition test was self-paced. The non verbal task lasted approximately 20 minutes.

Everyday Memory Questionnaire

The Everyday Memory Questionnaire (EMQ, Sunderland et al., 1984) was included as a method of collecting individuals' perception of everyday memory

functioning. The 28-item revised version of the EMQ was administered. Each statement described an everyday activity in which the participant might experience a degree of forgetting. Participants were asked to rate the frequency with which they experienced each event. Ratings were made on a 9-point scale from zero (not at all in the last three months) to eight (more than once a day).

5.1.4 Results

All statistical comparisons were conducted using SPSS 16.0. Effect sizes and the level of the p-value are reported for each analysis. Statistical assumptions were checked and corrected to take account of violations, where necessary.

Neuropsychological test battery

The results from the neuropsychological test battery are presented in Table 5.2. The only neuropsychological tests which yielded a significant difference between groups included the subtest Logical Memory II [F (2, 25) = 4.25, MSE = 8.88, $p < .05$, $\eta^2_p = .25$] from the WMS-III. Independent-samples t-tests confirmed that this difference was due to control participants significantly outperforming L-TLE patients [t (19) = 3.01, $p < .01$], and not due to any difference between R-TLE patients and control participants [t (19) = 1.36, $p = .19$], therefore providing the first indication of partial support for the material-specific hypothesis. L-TLE patients did not significantly differ from R-TLE patients on this measure [t (12) = -1.22, $p = .25$].

No significant differences were obtained in the NART predicted FSIQ scores [F (2, 25) = 2.55, MSE = 27.22, $p = .10$, $\eta^2_p = .17$], predicted verbal IQ scores [F (2, 25) = 2.44, MSE = 23.46, $p = .11$ $\eta^2_p = .16$] and predicted performance IQ scores [F (2, 25) = 2.32, MSE = 21.49, $p = .12$, $\eta^2_p = .16$] or number of years of education [F (2, 25) = .15, MSE = 3.27, $p = .86$, $\eta^2_p = .01$]. In addition, no significant differences were obtained on

the anxiety [F (2, 25) = 2.32, MSE = 13.95, p = .12, η^2_p = .16] and depression scores [F (2, 25) = 1.04, MSE = 6.06, p = .37, η^2_p = .08] from the HADS.

Table 5.2

Summary of the neuropsychological test battery and EMQ results. (standard deviations are in parentheses).

Test	L-TLE $n = 7$ *M*	R-TLE $n = 7$ *M*	Controls $n = 14$ *M*	*F* statistic	*p* value
Harris Test of Lateral Dominance (Handedness)	1.00 (0.00)	1.00 (0.00)	1.14 (0.36)	1.04	.37
HADS					
Anxiety	5.00 (2.71)	9.29 (5.44)	7.36 (3.13)	2.32	.12
Depression	3.29 (2.63)	4.43 (3.21)	2.79 (1.93)	1.04	.37
D-KEFS Design Fluency					
Condition 1*	9.14 (3.49)	8.57 (1.99)	10.00 (3.21)	.56	.58
Condition 2*	9.43 (3.87)	9.00 (1.29)	9.93 (2.17)	.33	.72
Condition 3*	11.00 (4.24)	10.57 (2.37)	11.43 (2.17)	.22	.81
D-KEFS Color- Word Interference					
Condition 1*	9.14 (1.35)	8.86 (3.49)	9.93 (2.09)	.56	.58
Condition 2*	9.57 (1.62)	10.71 (1.80)	10.43 (1.83)	.82	.45
Condition 3*	10.00 (2.83)	10.86 (2.85)	11.00 (1.57)	.47	.63
Condition 4*	7.71 (3.99)	9.29 (2.50)	10.21 (2.75)	1.58	.23
Hayling Sentence Completion Test	5.71 (1.38)	6.29 (0.76)	6.36 (0.93)	.98	.39
WAIS-III					
Similarities*	10.43 (2.51)	10.29 (2.50)	10.93 (2.09)	.22	.80
Arithmetic*	11.43 (2.57)	9.71 (2.87)	11.36 (3.10)	.85	.44
Comprehension*	11.43 (2.76)	10.29 (2.43)	11.50 (2.90)	.49	.62
WMS-III					
Logical Memory I*	9.57 (3.26)	10.43 (3.10)	11.57 (2.28)	1.31	.29
Faces I*	9.57 (1.72)	10.43 (3.55)	11.50 (2.53)	1.29	.29
Logical Memory II*	8.29 (3.68)	10.57 (3.31)	12.29 (2.40)	4.25	.03
Digit Span*	11.57 (2.15)	10.57 (2.37)	12.07 (3.56)	.58	.57
NART					
Predictive FSIQ	116.86 (6.94)	118.57 (5.19)	122.00 (4.21)	2.55	.10
Predictive Verbal IQ	114.71 (6.18)	116.43 (4.93)	119.43 (4.03)	2.44	.11
Predictive Performance IQ	115.57 (6.02)	117.29 (4.75)	120.00 (3.76)	2.32	.12
EMQ					
Total Score	71.14 (57.87)	66.83 (32.17)	64.57 (33.63)	.06	.94

Abbreviations: HADS = Hospital Anxiety and Depression Scale, D-KEFS = Delis-Kaplan Executive Function System, WAIS-III = Wechsler Adult Intelligence Scale 3rd Edition, WMS-III = Wechsler Memory Scale 3rd Edition, NART = National Adult Reading Test, EMQ = Everyday Memory Questionnaire. * Age-Adjusted Scaled Scores.

Participants' total scores on the subjective memory questionnaire (EMQ) were summed over the 28 items. Control participants total scores ranged from 2 to 105 (M = 64.57, SD = 33.63), TLE-L patients total scores ranged from 32 to 174 (M = 71.14, SD = 57.87) and TLE-R patients total scores ranged from 33 to 113 (M = 66.83, SD = 32.17) (maximum score = 224, which would indicate that all 28 items occurred more than once a day). Control participants and TLE patients (L-TLE, R-TLE) did not significantly differ in terms of their cumulative total scores on the EMQ, [F (2, 25) = .08, MSE = 1612.17, p = .93, η^2_p = .01]. Item 1 (*'Forgetting where you have put something. Losing things around the house'*) had the greatest mean frequency of forgetting score for the control participants, whereas item 13 had the greatest frequency of forgetting for the L-TLE patients (*'Finding that a word is "on the tip of your tongue". You know what it is but cannot quite find it'*) and item 5 (*'Having to go back and check whether you have done something that you meant to do'*) for the R-TLE patients. The only item of the EMQ to yield a significantly different rating score between groups was item 19 (*'Forgetting important details about yourself, e.g. your birth date or where you live'*). A one-way ANOVA revealed that L-TLE patients rated this item significantly more frequently than control participants and R-TLE patients [F (2, 25) = 4.69, MSE = .56, $p < .05$, η^2_p = .27], suggesting greater perceived memory difficulties on this item. However due to the large number of comparisons a Bonferroni correction was applied ($p < .001$), to prevent spurious relationships from being drawn upon. After adjusting for this correction, item 2 was found to no longer meet the critical value for significance.

Experimental tasks

It was the aim of this experiment to equate the verbal and non verbal tasks so that direct comparisons could be made between lateralisation of seizure focus and

performance on the two tasks. Despite every effort to match the two tasks in terms of their level of difficulty, by first testing materials in a pilot study and second increasing the difficulty of the verbal task, it was apparent that the verbal and non verbal stimuli were still not sufficiently equated in the actual experiment. Overall performance for the non verbal stimuli was significantly poorer than performance on the verbal task in all three groups. To prevent potential confounds from occurring from directly comparing the two tasks, analysis was carried out separately on the verbal and non verbal data and compared between groups (controls, L-TLE, R-TLE).

Corrected recognition performance scores for the verbal and non verbal tasks were calculated by the proportion of hits minus the number of false alarms as a function of response type ('Remember', 'Know') for each participant (Remember = hits $_{remember}$ minus false alarms $_{remember}$; Know = hits $_{know}$ minus false alarms $_{know}$).

Item-by-item JOLs were recorded for all studied items and were used to calculate the relationship between item-by-item JOLs and actual recognition performance. For the purpose of calculating Goodman-Kruskal Gamma correlations, 'Remember' and 'Know' responses were collapsed together.

Verbal recognition task

Corrected recognition performance scores (hits minus false alarms) for the verbal task are presented in Figure 5.1. A 3 (group) x 2 (response type) repeated measures ANOVA was carried out on the proportion of corrected recognition scores in all three groups (controls, L-TLE, R-TLE). There was a main effect of group [F (2, 25) = 5.76, MSE = 69.43, $p < .01$, $\eta^2_p = .32$]. This main effect was explored through independent-samples t-tests, revealing that L-TLE patients did not significantly differ from R-TLE patients [t (9) = -1.30, $p = .29$]. However, control participants (M = 86.88, SD = 10.86) significantly outperformed L-TLE patients (M = 68.93, SD = 8.02) by

recognising a significantly greater proportion of words at test [t (19) = 3.86, $p < .001$]. Furthermore, R-TLE patients (M = 76.61, SD = 16.08) did not significantly differ from control participants [t (19) = 1.74, p = .10]. A main effect of response type ('Remember', 'Know') was established [F (1, 25) = 523.90, MSE = 133.25, $p < .001$, η^2_p = .95], indicating that a significantly greater proportion of 'Remember' responses were provided at test. The interaction between group and response type failed to reach significance [F (2, 25) = 2.78, MSE = 133.25, p = .08, η^2_p = .18] revealing that all three groups gave a similar distribution of responses, with a greater proportion of responses being given to the 'Remember' category than the 'Know' category.

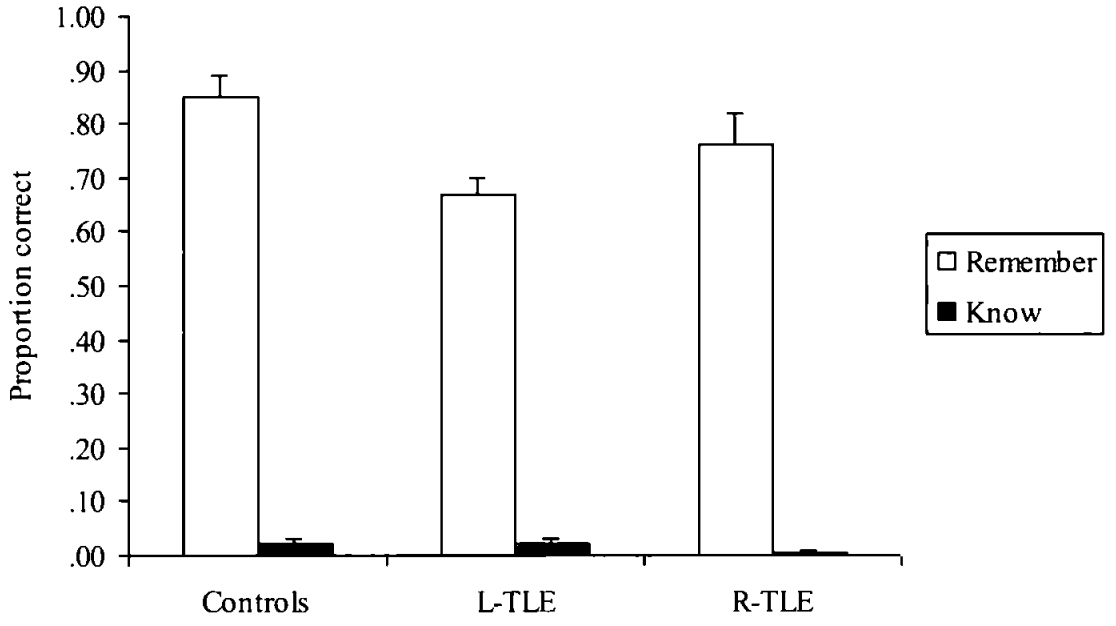


Figure 5.1. Corrected recognition (hits minus false alarms) as a function of group and response type. Error bars relate to standard error.

False alarm data for the remember/know recognition test are presented in Table 5.3. A 3 (group) x 2 (response type) repeated measures ANOVA was carried out on the proportion of false alarm rates in all three groups (controls, L-TLE, R-TLE). There was no main effect of group [F (2, 25) = .35, MSE = 59.96, p = .71, η^2_p = .03], indicating that

the rate of false alarms was equivalent in all three groups. There was a main effect of judgement type [F (1, 25) = 10.87, MSE = 44.87, $p < .01$, $\eta^2_p = .30$], revealing that participants were more likely to respond 'Know' than 'Remember' for words not presented at study but judged as items recognised. The interaction between group and judgement type did not reach significance [F (2, 25) = .20, MSE = 44.87, $p = .82$, $\eta^2_p = .02$], indicating that all groups gave a similar distribution of false alarms.

Table 5.3

Proportion of false alarms produced between groups as a function of judgement type. (Standard deviations are in parentheses).

	Remember *M*	Know *M*
Controls	.05 (.07)	.11 (.08)
L-TLE	.08 (.05)	.12 (.07)
R-TLE	.05 (.06)	.13 (.09)

Metamemory accuracy: Judgement-of-Learning paradigm

Item-by-item JOLs were collected for both the verbal and non verbal tasks. The Goodman-Kruskal's Gamma correlation (which ranges from +1 to -1) was used to calculate the relationship between item-by-item JOL predictions and actual recognition performance for all 80 word pairs and 40 abstract designs studied (see Tables 5.4 and 5.6 for Gamma correlations). A score nearer +1 indicates a high relationship between the item-by-item JOLs and recognition. 'Remember' and 'Know' responses were collapsed together for the purpose of this analysis.

One-sample t-tests revealed that control participants' [t (8) = .99, p = .35], L-TLE [t (6) = .15, p = .89] and R-TLE patients' [t (5) = -.88, p = .42] JOL Gamma correlations were not significantly different from zero for the verbal task, indicating a possibility that the three groups item-by-item JOLs were made by chance and not due to

a metacognitive response. A one-way ANOVA revealed that there was no significant difference between groups JOL Gamma correlations [F (2, 19) = .94, MSE = .23, p = .41, η^2_p = .09] when considering all 80 studied words in the verbal task (see Table 5.4).

Table 5.4

JOL Gamma correlations for control, L-TLE and R-TLE groups. (standard deviations are in parentheses).

	γ
Controls	+.17 (.51)
L-TLE	+.02 (.41)
R-TLE	-.18 (.49)

Note: Controls n = 9, L-TLE n = 7, R-TLE n = 6,

In order to test whether the three groups used the ratings for JOLs differently, a 3 (group) x 6 (6-point ratings) repeated measures ANOVA was also carried out on the number of times (proportions of use) each JOL rating was used (see Figure 5.2). There was no main effect of group [F (2, 25) = 1.71, MSE = .72, p = .20, η^2_p = .12], indicating that overall use of ratings did not significantly differ between groups. There was however a main effect of rating type [F (2.38, 59.38) = 9.72, MSE = 4.28, p < .001, η^2_p = .28], showing that some ratings were more frequently used than others. Finally, the interaction between group and rating type did not reach significance [F (4.75, 59.38) = .73, MSE = 4.28, p = .60, η^2_p = .06], an indication that the three groups used a similar distribution of JOL ratings across the entire list.

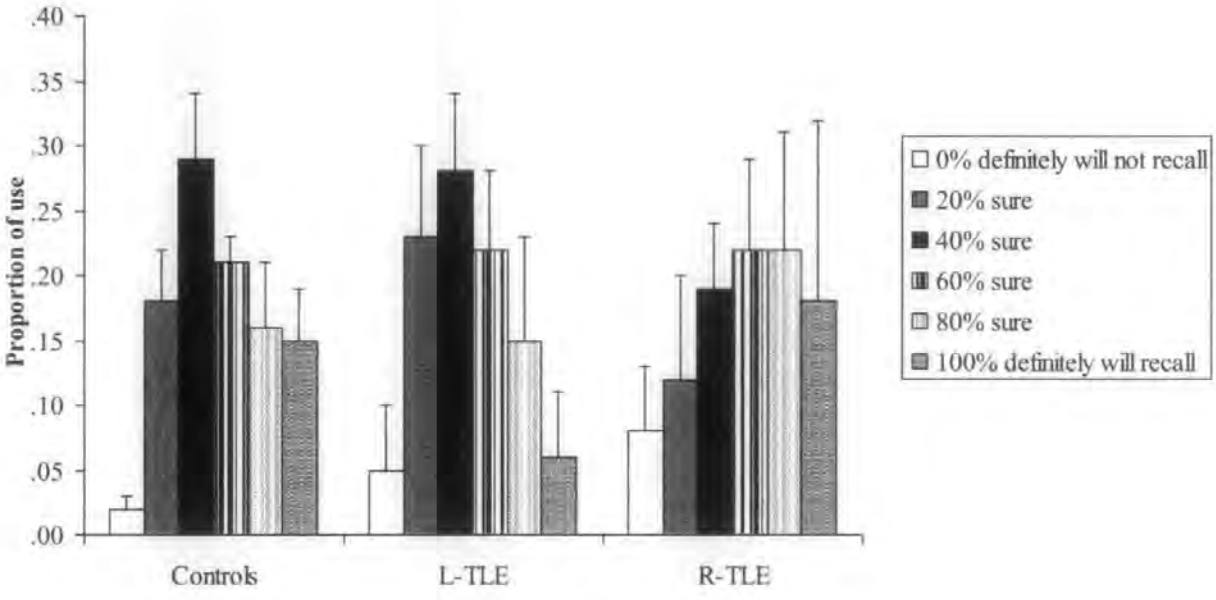


Figure 5.2. Judgement-of-Learning ratings' proportions of use in TLE patients and controls. Error bars refer to standard error.

Non verbal recognition task

Corrected recognition performance scores (hits minus false alarms) for the non verbal task are presented in Figure 5.3. A 3 (group) x 2 (response type) repeated measures ANOVA was carried out on the proportion of corrected recognition scores in all three groups (controls, L-TLE, R-TLE). There was no main effect of group [F (2, 25) = .34, MSE = 95.87, p = .72, η^2_p = .03], indicating that the proportion of correctly recognised abstract designs was equivalent between groups (Controls: M = 38.75, SD = 15.18; L-TLE: M = 33.57, SD = 9.88; R-TLE: M = 36.07, SD = 14.21). A main effect of response type ('Remember', 'Know') [F (1, 25) = 68.40, MSE = 154.80, p < .001, η^2_p = .73] revealed that a significantly greater proportion of 'Remember' responses were provided at test. The interaction between group and response type failed to reach significance [F (2, 25) = 1.50, MSE = 154.80, p = .24, η^2_p = .11], revealing that all three groups gave a similar distribution of responses, with a greater proportion of responses being given to the 'Remember' category than the 'Know' category.

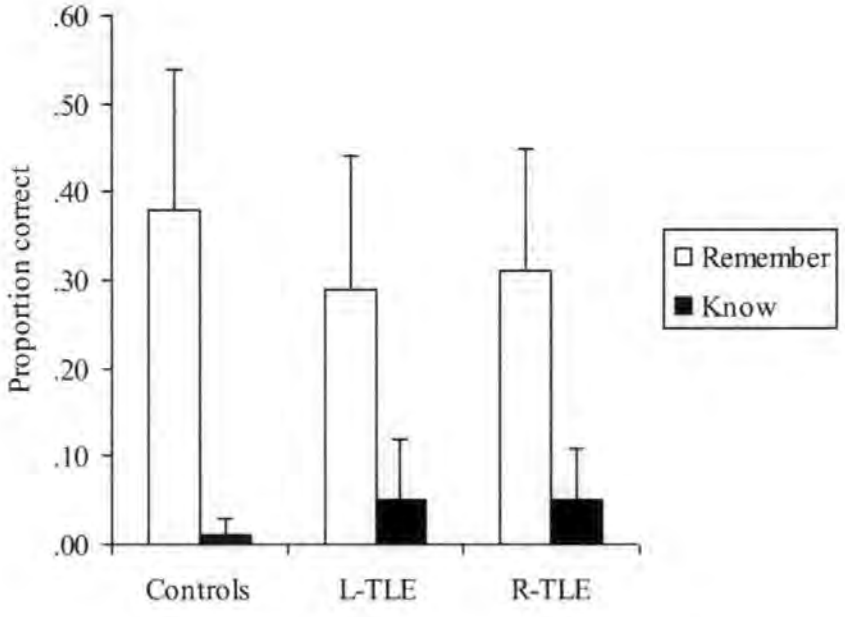


Figure 5.3. Corrected recognition (hits minus false alarms) as a function of group and response type. Error bars relate to standard error.

False alarm data for the remember/know recognition test are presented in Table 5.5. A 3 (group) x 2 (response type) repeated measures ANOVA was carried out on the proportion of false alarms rates in all three groups (controls, L-TLE, R-TLE). There was no main effect of group [F (2, 25) = .17, MSE = 147.57, p = .84, η^2_p = .01] indicating that rate of false alarms was equivalent in all three groups. There was no evidence of a main effect of judgement type [F (1, 25) = .61, MSE = 128.75, p = .44, η^2_p = .02] revealing that the distribution of false alarms was equivalent across 'Remember' and 'Know' responses. The interaction between group and judgement type failed to reach significance [F (2, 25) = 2.07, MSE = 128.75, p = .15, η^2_p = .14], indicating that all groups gave a similar distribution of false alarms.

Table 5.5

Proportion of false alarms produced between groups as a function of judgement type. (Standard deviations are in parentheses).

	Remember *M*	Know *M*
Controls	.16 (.13)	.24 (.11)
L-TLE	.25 (.13)	.18 (.13)
R-TLE	.16 (.09)	.21 (.11)

Metamemory accuracy: Judgement-of-Learning paradigm

One-sample t-tests revealed that control participants' [t (13) = 5.17, $p < .001$], L-TLE [t (6) = 5.15, $p < .01$] and R-TLE patients' [t (6) = 2.45, $p < .05$] JOL Gamma correlations were significantly different from zero for the non verbal task, indicating that all three groups demonstrated a level of metacognitive ability and that their item-by-item JOLs were not made by chance. A one-way ANOVA revealed that there was no significant difference between groups JOL Gamma correlations [F (2, 25) = .54, MSE = .08, p = .59, η^2_p = .04] when considering all 40 abstract designs studied in the non verbal task (see Table 5.6).

Table 5.6

JOL Gamma correlations for control, L-TLE and R-TLE groups. (standard deviations are in parentheses).

	γ
Controls	+.38 (.27)
L-TLE	+.47 (.24)
R-TLE	+.31 (.33)

In order to test whether the three groups used the ratings for JOLs differently, a 3 (group) x 6 (6-point ratings) repeated measures ANOVA was also carried out on the number of times (proportions of use) each JOL rating was used (see Figure 5.4). There

was no main effect of group [F (2, 25) = .36, MSE = .70, p = .70, η^2_p = .03], indicating that overall use of ratings did not significantly differ between groups. There was however a main effect of rating type [F (1.83, 45.81) = 13.25, MSE = 4.98, $p < .001$, η^2_p = .35], showing that some ratings were more frequently used than others. Finally, the interaction between group and rating type did not reach significance [F (3.66, 45.81) = .47, MSE = 4.98, p = .74, η^2_p = .04], an indication that the three groups used a similar distribution of JOL ratings across the entire list.

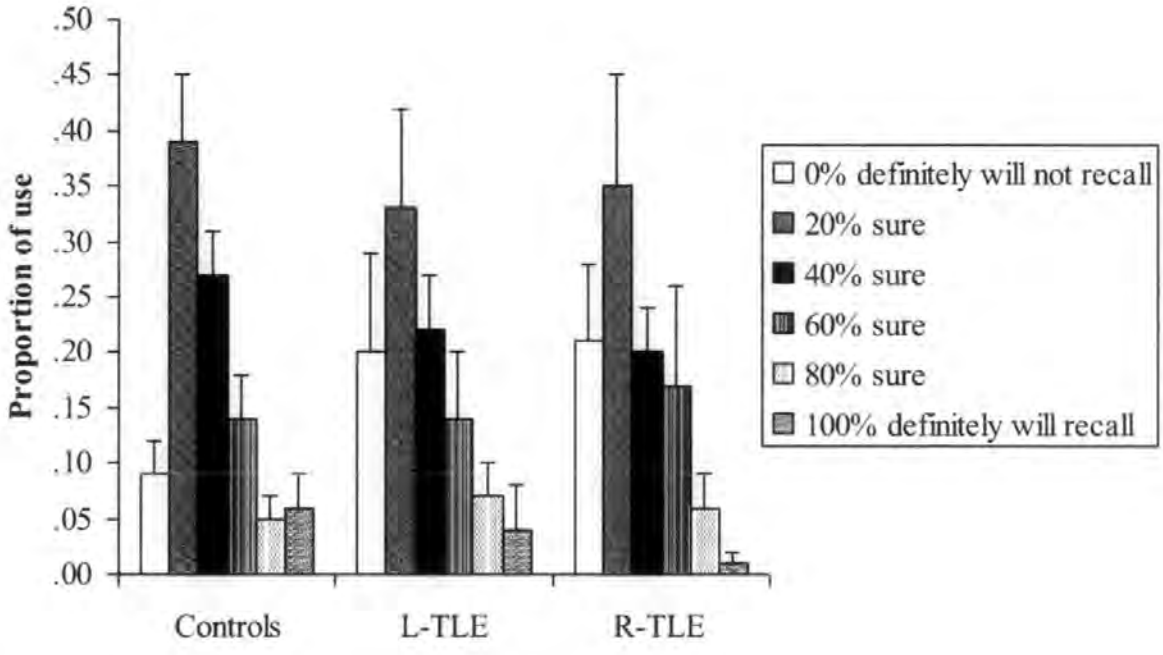


Figure 5.4. Judgement-of-Learning ratings' proportions of use in TLE patients and controls. Error bars refer to standard error.

Correlation analysis of the EMQ total scores with recall performance

In order to determine whether there was a relationship between subjective ratings of perceived memory forgetting measured by the EMQ and actual recognition performance on the verbal and non verbal tasks, Pearson's correlation coefficients (r) were computed between the 28 items on the EMQ and overall recognition performance (Overall = hits $_{remember\ +\ know}$ minus false alarms $_{remember\ +\ know}$) on the verbal and non verbal tasks.

None of the 28 items from the EMQ correlated with overall recognition performance on the verbal or non verbal tasks in the control participants. Ten possible relationships emerged from the analysis with the L-TLE patients overall recognition performance on the non verbal task and one from the R-TLE patients performance on the verbal task. However due to the large correlation matrices a number of these may have occurred by chance. To prevent such spurious relationships from being drawn upon, a Bonferroni correction was applied ($p < .001$). After adjusting for this correction, all of the previous correlations were no longer significant. As a result no relationships were found between the 28 items on the EMQ and overall recognition performance on both verbal and non verbal tasks in any of the groups.

Correlation analysis of epilepsy variables and recall performance

In order to determine whether there were any specific epilepsy variables (laterality, seizure type, age of onset, duration, frequency of seizures and number of AEDs) which had an influence on overall recognition performance on either the verbal or non verbal tasks and patient groups (L-TLE, R-TLE) Pearson's correlation coefficients (r) were computed. After applying Bonferroni's correction analysis ($p > .001$) none of the epilepsy variables significantly correlated with overall recognition performance for either patient group (L-TLE, R-TLE).

Pearson's correlation coefficients (r) were also computed between all epilepsy variables and standardised subtests of the WMS-III (L-TLE $n = 7$; R-TLE $n = 7$). After applying Bonferroni's correction analysis ($p > .001$) to prevent erroneous relationships from occurring, the only correlations that remained were between Logical Memory I and age of onset [$r = .99, p < .001$] and Digit Span and duration of epilepsy [$r = -.97, p < .001$] in the R-TLE patients. Indicating that age of onset appeared to be positively correlated with Logical Memory I accounting for 98% of the variance, whereas duration

of epilepsy appeared to be negatively correlated with Digit Span accounting for 94% of the variance in the R-TLE patients. None of the WMS-III subtests and epilepsy variables correlated in the L-TLE group.

5.1.5 Discussion

It was the aim of Experiment 4 to examine the material-specific hypothesis in unilateral TLE, whilst utilising the 'Remember-Know' paradigm. Previous experiments featured in this thesis have focused on the use of verbal episodic memory tasks (Experiments 1, 2 & 3). These experiments established a clear episodic memory deficit in patients with TLE when compared to a group of matched controls. Despite attempts to control for task difficulty on the verbal and non verbal stimuli by way of conducting a pilot study, it was apparent at test that the two tasks were not adequately equated, as the proportion of non verbal material recognised by all groups was substantially lower than the proportion of verbal material recognised. To prevent potential confounds from occurring by directly comparing the verbal task to the non verbal task, the two data sets were treated as separate. Moreover, conducting this study highlighted some potential issues when trying to compare hemispheric differences using material-specific stimuli, which are discussed further in Chapter 6. Lastly, this final experiment set to explore metamemory monitoring accuracy by way of item-by-item JOLs and their relationship to actual recognition performance.

Overall, the findings from Experiment 4 revealed that L-TLE patients showed a significant impairment in their verbal recognition performance compared with controls. No significant differences on the non verbal task between groups were apparent. Groups did not significantly differ in the distribution of 'Remember' and 'Know' responses on either the verbal or non verbal task. Groups also did not significantly differ in their JOL Gamma correlations on either task. Furthermore, all three groups demonstrated intact

metamemory monitoring on the non verbal task. The results are now discussed separately in more detail.

Memory performance

Verbal recognition task

The results from the verbal task revealed that the two patient groups did not significantly differ from one another. However, control participants significantly outperformed L-TLE patients on the proportion of correctly recognised words, and yet R-TLE patients did not significantly differ from control participants. Such a finding provided partial support for the material-specific hypothesis, i.e., patients with potential damage to the left hemisphere performed less well with the presentation of the verbal stimuli. The findings from the verbal task also demonstrated that a significantly greater proportion of 'Remember' responses were given at test. However, the interaction between groups and response type failed to reach significance which indicated that controls, L-TLE and R-TLE patients gave a similar distribution of responses. The significantly greater proportion of 'Remember' responses at test reflected the high success rate in correctly recollecting words previously studied. However, it is important to note that the very low frequency of 'Know' responses from all three groups created a floor effect which prevented any real test of Blaxton and Theodore's (1997) 'modes of processing' hypothesis. However despite this, the verbal recognition results partly parallel Moscovitch and McAndrews' (2002) findings in that a verbal processing impairment was only apparent in the L-TLE patients and not in the R-TLE patients.

However, it is important to note that five control participants and one R-TLE patient correctly recognised all eighty words previously studied during the recognition task. Thus, ceiling effects in these individuals were problematic in the verbal

recognition task and particularly when calculating Gamma correlations. Despite this limitation, response type could still be examined in all participants.

The false alarm data for the verbal recognition task revealed that the distribution of false alarms was equivalent across groups. A substantial 'Remember' response bias in the verbal recognition task should have led to more false positives in the 'Remember' than in the 'Know' responses. However, participants were more likely to respond 'Know' than 'Remember' for words not previously presented at study but judged as items recognised.

In the WMS-III, the only subtest to yield a significant result was Logical Memory II ($p < .05$). As a reminder, the Logical Memory II subtest measures delayed story recall and is therefore considered a verbal task. In this measure, the two patient groups did not significantly differ from one another. However, the control participants significantly outperformed L-TLE patients, but R-TLE patients did not differ from controls, providing further partial support for the material-specific hypothesis.

Finally, it is worth mentioning that differences detected between TLE patients and control participants in the verbal recognition task could not be explained by differences in mood (anxiety, depression scores from the HADS) or differing levels of crystallised intelligence (performance on the Similarities, Arithmetic and Comprehension subtests of the WAIS-III) as these measures were not significantly different between groups.

Non verbal recognition task

The findings from the non verbal recognition task revealed that the proportion of correctly recognised abstract designs were equivalent in all three groups, although numerically controls recognised a greater proportion than TLE patients. It is important to note that despite no significant difference between groups on the proportion of

correctly recognised abstract designs, recognition performance was below 50% for all three groups. Although reduced levels of performance would be expected in the non verbal task compared to the verbal task, such low levels of recognition in the control participants and TLE patients raise concerns about the validity of this task. One potential reason for this may have been as a consequence of asking participants to continually repeat A-B-A-B whilst studying the non verbal designs to prevent verbalisation effects, which was not initially implemented in the pilot study. Implementing this additional instruction was aimed at ensuring that the designs were not encoded in a verbal manner. However, in doing so, this may have substantially increased the difficultly of the task. The low levels of performance in Experiment 4 are also reflective of the findings in Blaxton and Theodore's (1997) study in which all three groups performed below 50%. The implications of such low levels of performance are discussed further in Chapter 6. The findings for the non verbal task demonstrated that a significantly greater proportion of 'Remember' responses were given at test. The interaction between groups and response type failed to reach significance which indicated that controls, L-TLE and R-TLE patients gave a similar distribution of responses for all the abstract designs presented at test. Again, low frequency of 'Know' responses from all three groups did not permit any real test of Blaxton and Theodore's 'modes of processing' hypothesis. Furthermore, the results from the non verbal task did not follow Moscovitch and McAndrews' (2002) findings, in which a non verbal processing impairment was detected and only apparent in the R-TLE patients.

The false alarm data for the non verbal recognition task revealed that the distribution of false alarms were equivalent across the three groups and across the two judgement types, with a similar number of false alarms being rated as 'Remember' as 'Know'.

From a theoretical view point, the low frequency of 'Know' responses in both the verbal and non verbal tasks posed a problem for any real test of Blaxton and Theodore's (1997) 'modes of processing' theory. Instead the current findings are partly in accordance with the material-specific hypothesis, that damage to the left hemisphere impairs the learning and retention of verbal stimuli (Moscovitch & McAndrews, 2002).

The EMQ was administered as a subjective questionnaire consisting of 28 items describing everyday activities in which a participant might experience a degree of forgetting. Participants were asked to rate the frequency with which they experienced each event. In terms of their overall cumulative scores control participants and TLE patients did not significantly differ. Item 19 was the only item to yield a significant difference between groups (*'Forgetting important details about yourself, e.g. your birth date or where you live'*). L-TLE patients significantly rated forgetting this item more than the other two groups. In fact control participants and R-TLE patients mean rating for this item was zero, indicating that overall these groups had not experienced this type of memory problem in the last three months. Despite this difference, Bonferroni correction was applied and revealed that this difference was no longer significant.

Metacognitive monitoring (metamemory)

Verbal recognition task

Metacognitive monitoring was assessed by item-by-item JOLs. Groups did not significantly differ between their overall Gamma correlations in the verbal task. However, groups' JOL Gamma correlations were not significantly different from zero suggesting the possibility that groups' item-by-item JOL ratings may have been made by chance and not related to any metacognitive ability. However, it is important to note that five control participants and one R-TLE patient (21%) were not included in this analysis as Gamma correlations could not be calculated for these participants due to

correctly recognising all words previously studied, and so the interpretation of this result should be treated with caution. Such ceiling effects in individuals are problematic when calculating Gamma correlations as tied pairs cannot be included. Furthermore, it is likely that the finding that groups Gamma correlations were not significantly different from zero was due to extreme variability between individual Gamma values within groups (Controls: -.42 to +1.00; L-TLE: -.64 to +.45; R-TLE -1.00 to +.34).

Non verbal recognition task

Groups Gamma correlations were found to be significantly different from zero, revealing that the three groups demonstrated a level of metacognitive ability when making their item-by-item JOLs when studying the abstract designs. Overall Gamma correlations did not significantly differ between groups. Furthermore, groups used a similar distribution of JOL ratings across the entire list.

Executive functions

Unlike Experiment 1, where deficits in executive function measures were detected, Experiment 4, similar to Experiments 2 and 3, did not reveal any significant differences between groups. This finding further suggests that executive dysfunction is not always a constant feature of TLE.

In summary, Experiment 4 revealed a deficit in the L-TLE compared with control participants on the verbal recognition task. This finding, together with significant differences from the subtest Logical Memory II in which L-TLE patients performed significantly less well than controls and R-TLE patients did not significantly differ from either group, provided partial support for the material-specific hypothesis, which suggests that damage to the left temporal lobe impairs the learning and retention

of verbal material. No evidence emerged to support a material-specific lateralisation effect in unilateral R-TLE patients. Metamemory monitoring processes were intact in all groups on the non verbal task, indicating that both L-TLE and R-TLE patients were aware of their online monitoring processes on this task. In terms of the 'R-K' paradigm, groups did not significantly differ in the distribution of responses at test on either task. The material-specific hypothesis is a central approach to understanding memory functioning in patients with unilateral TLE, especially concerning post-operative impairment. However, L-TLE and R-TLE patients share epilepsy related characteristics (e.g. frequency of seizures, seizure type, duration of epilepsy, type of AEDs) which adds to the complexity of examining the relationship between lateralisation of the seizure focus and memory function in unilateral TLE patients. It is important to highlight that conducting Experiment 4 raised some potential issues with examining material-specific memory deficits in unilateral TLE patients, which are discussed in detail in Chapter 6.

Chapter 6: General Discussion

6.1 Overview of the thesis

The purpose of this research was to establish whether inadequate metamemory monitoring and/or control processes might be responsible for the memory problems commonly affecting patients with TLE (see Bell & Giovagnoli, 2007; Leritz et al., 2006 for reviews). A limited amount of previous research has attempted to investigate metamemory abilities in TLE patients, but despite such efforts, the findings were mixed and unclear (Prevey et al., 1988; Prevey et al., 1991). The experiments presented in this thesis explored whether memory and metamemory processes were disrupted in TLE patients by applying Nelson and Narens' (1990) theoretical framework. To the author's knowledge, this is the first attempt to investigate the existence of a metamemory deficit in TLE patients using verbal episodic memory tasks, to examine whether the memory impairment typically observed in TLE patients (Bell & Giovagnoli, 2007; Leritz et al., 2006) might be due to it. Furthermore, a number of the concepts explored in this thesis (i.e. study-time allocation, item-by-item JOLs, metacognitive sensitivity) have not been previously explored in TLE patients and therefore the experiments in this thesis are considered the first contribution into this area of research.

This thesis comprises four experiments investigating memory and metamemory performance in TLE patients and a group of matched controls. The experiments examine verbal episodic memory, online metamemory abilities at encoding, global metamemory predictions, the sensitivity approach examining global predictions across trials, the effects of repetition on online monitoring and control processes and finally, the material-specific hypothesis in unilateral TLE, utilising the 'R-K' paradigm. Based on the results from previous studies (see Bell & Giovagnoli, 2007; Leritz et al., 2006 for reviews), it was predicted that TLE patients would present with a deficit in episodic

memory. In addition, similarities between metacognition and executive control processes suggested in previous literature (Fernandez-Duque et al., 2000; Shimamura, 2000; Souchay et al., 2000), supported the prediction that there would also be the potential for a degree of executive dysfunction in TLE patients. Finally, based on the methodological problems in previous studies (Prevey et al., 1988, 1991) and the mixed results obtained in the literature, the research aimed at exploring further metamemory abilities in TLE patients. The key findings will now be summarised in terms of memory performance and metamemory abilities.

6.2 Summary of key findings

6.2.1 Evidence of impaired memory performance

The experiments featured in this thesis provide converging evidence of clear verbal episodic memory impairment in TLE patients when directly compared with a group of matched control participants. In Experiment 1 (Howard et al., in press), TLE patients performed significantly worse than controls when recalling word pairs at Time 1 (30 minutes after encoding). Interestingly, recall performance at Time 2 (4 weeks after encoding) did not significantly differ between groups and the rate of forgetting over the four weeks was equivalent for TLE patients and controls, suggesting further evidence that AF was not a feature in this TLE sample. Recognition for incorrectly and non recalled items at test revealed that controls also significantly outperformed TLE patients at both Time 1 (30 minutes) and Time 2 (four weeks). These findings were the first indication to support the notion that TLE patients possibly experience difficulties at the encoding stage, a finding which is typically observed in patients with damage to the temporal lobes (Shimamura et al., 1991). Having found no evidence to support a metamemory deficit in TLE in this initial experiment, the focus for the proceeding

experiments was to examine further memory performance in a variety of different tasks, whilst integrating metamemory measures of monitoring and control.

Experiment 2 provided further support for a memory impairment in TLE patients by way of measuring recall on four lists of varying difficulty. Control participants performed significantly better than TLE patients on all four lists, with both groups recalling a greater amount of words from the easy than from the difficult lists. TLE patients performed significantly worse than controls on all three levels of word pair repetition in Experiment 3 as well. Finally, Experiment 4 revealed that controls significantly outperformed L-TLE patients on the proportion of words recognised at test in the verbal task. Therefore, the results from the four experiments provide clear and consistent evidence of a verbal episodic memory impairment in TLE patients, which is also consistent with the findings in other neurological populations (Moulin et al., 2000a,b,c; Janowsky et al., 1986; Shimamura & Squire, 1986).

It is important to note that the presence of mood disturbances (notably anxiety and depression), have previously been suggested as a possible explanation for TLE patients underestimating their memory performance (Baños et al., 2004; Elixhauser, et al., 1999; Giovagnoli et al., 1997; Vermeulen et al., 1993). It was therefore important to measure anxiety and depression levels in all experiments to examine whether mood had an affect on memory performance. Only Experiment 1 detected a significant difference between groups' depressions scores, which revealed TLE patients to have higher depression levels than control participants. However, the differences between TLE patients and control participants in memory performance observed in Experiment 1 could not be explained by greater levels of depression, as this was ruled out when its role was tested in an ANCOVA. It can therefore be concluded that mood disturbances were not responsible for TLE patients perceived or actual memory performance in this thesis.

6.2.2 Memory performance and clinical variables

A number of the experiments identified that the epilepsy variables laterality, age of onset, duration and AEDs had an affect on either recall performance in the experimental tasks or on subtests of the WMS-III. This confirmed that these characteristics were important in predicting the extent to which TLE patients are likely to experience memory difficulties. A number of contributing factors have been previously suggested which may be responsible for the observed memory deficits in TLE patients affecting the consolidation process, including the occurrence of seizures (see Butler & Zeman, 2008 for review). However, Blake et al. (2000) did not find a relationship between seizure frequency and memory performance, and the current research is also in keeping with this finding. None of the experiments featured in this thesis found seizure frequency to have an affect on recall performance. For example, Experiment 1 was able to measure whether seizure related episodes experienced during a 4-week retention interval had an affect on recall performance. Seizures experienced during the 4-week interval did not correlate with recall at Time 2. Taken together, these findings indicate that certain epilepsy related variables are important indicators in observing memory impairment in TLE patients. Future research should focus efforts to understand better the influence of these clinical variables, particularly the type and dosage of AEDs and their influence on memory behaviour. Since the prescription of AEDs is the most common treatment for epilepsy, and yet the type, combination and dosage can vary greatly between cases, it would seem particularly important that future research continues to examine the effects of existing and new AEDs on memory performance (see Kwan & Brodie, 2001 for review).

6.2.3 Evidence of intact metamemory awareness and accuracy

In a number of experiments within this thesis, online monitoring was assessed by item-by-item JOLs and item-by-item FOKs. Individual judgements for each item studied were made as to which of the items would or would not be recalled or recognised at test (Experiments 1, 3 & 4). Such online monitoring measures were calculated by using Goodman-Kruskal Gamma correlations as a measure of relative accuracy. Metamemory control processes were also assessed by the amount of study-time allocated to studying items (Experiments 1, 2 & 3). Global predictions (global JOLs) also featured in two of the experiments (Experiments 1 & 2). The degree to which global JOLs corresponded to actual memory performance was calculated by non-directional discrepancy scores, a measure of absolute accuracy.

Experiment 1 (Howard et al., in press) provided the first indication that the observed memory impairments in TLE patients could not be attributed to poor monitoring and control processes, as suggested in previous literature (Prevey et al., 1988, 1991). On the contrary, TLE patients were no different in any of the online monitoring processes compared with controls. TLE patients were seen to be able to predict with relative accuracy which items they would recall and which they would not.

In Experiment 1 no significant differences were found either in the amount of study-time allocated between groups, although more time was devoted to unrelated word pairs than to the related word pairs by both groups. It could be argued that one would expect greater study-time in the TLE patients to compensate for their perceived and actual memory problem. Therefore, the finding that study-time was statistically equivalent could be indicative of a mild metacognitive deficit, despite them clearly adapting to the difficulty of the word pairs, by spending longer on the unrelated than the related word pairs. However, it should be noted that TLE patients had a tendency to allocate overall more study-time (seconds) (M = 446.07, SD = 204.94) than controls (M

= 350.67, *SD* = 166.55). Statistically this did not reach standard levels of significance which may be reflective of a small sample size. As a consequence, given the directional trend and the fact that TLE patients allocated more study-time to unrelated than related word pairs, it was considered premature to interpret this as a possible failure in metamemory.

Furthermore, it is important to highlight again here Nelson and Leonesio's (1988) findings of the "*labor-in-vain effect*" which would suggest that in circumstances where participants are given unlimited study-time, this can yield little or no increased chance of recalling the items studied. Therefore, this would imply that TLE patients and control participants recall performance would only benefit to a certain extent from allowing them endless study-time, and therefore it is likely that the memory deficit observed in TLE patients would still be evident.

Finally, in terms of global JOLs, no difference was found between groups in either magnitude or accuracy (non-directional discrepancy scores) at either Time 1 or Time 2. All in all, findings from Experiment 1 demonstrate that TLE patients monitoring and control processes at the item-by-item and global levels were intact. It could be argued that the global JOLs were somewhat influenced by the item-by-item JOLs, since global JOLs were collected after the item-by-item JOLs. However, previous evidence suggests that item-by-item and global JOLs rely on different mechanisms (Mazzoni & Nelson, 1995).

To further explore this notion, Experiment 2 examined global JOLs in isolation and extended the results of absolute accuracy measured by global JOLs in Experiment 1. The findings demonstrate that both controls and TLE patients were able to successfully monitor the difficulty of the lists and alter their post-study (global JOLs) predictions accordingly.

In Experiment 3, metacognitive monitoring was assessed by item-by-item JOLs at each level of repetition. Controls and TLE patients did not significantly differ in their overall JOL ratings across the three levels of repetition. The results also complement those found in Experiment 1, where Gamma correlations were significantly different from zero demonstrating that both controls and TLE patients were metacognitive competent when making their JOL and FOK judgements (Time 1). Repetition had an effect on item-by-item JOLs and study-time, whereby study-time decreased and JOL ratings increased with further repetitions.

Experiment 4 focused on the accuracy of item-by-item JOLs on a verbal and non verbal task. The results revealed that there was no significant difference between groups' (controls, L-TLE, R-TLE) JOL Gamma correlations when considering all 80 words studied in the verbal task. In the non verbal task, Gamma correlations were significantly different from zero, and not significantly different between groups. Results from the non verbal task at least, add further support to the notion that TLE patients do not present with a metamemory deficit when monitoring both verbal (Experiments 1 & 3) and non verbal stimuli (Experiment 4).

The results on metamemory awareness and accuracy summarised here, indicate that TLE patients behaved similarly to control participants in terms of their monitoring and control process. TLE patients were revealed to have intact metamemory monitoring and control processes. These findings differ from the previous literature (Prevey et al., 1988, 1991) which suggested that memory impairments were attributed to poor monitoring processes. In contrast, the findings from this thesis demonstrate that monitoring and also control processes are preserved in TLE patients, and thus contribute to our understanding of the verbal episodic memory deficit in TLE. Furthermore, the finding that online monitoring and control processes are intact in TLE patients, suggest that their memory deficit is increasingly likely to be a by-product of problems at

encoding. It is encouraging to note that since metamemory processes appear to be intact in TLE patients, in terms of applying strategies to aid everyday memory activities, they should be aware of their own memory performance and thus be able to monitor and control their memory behaviour appropriately.

6.2.4 Evidence of metamemory sensitivity

Experiments 2 and 3 employed the sensitivity approach adopted by Connor et al., (1997) in normal ageing and later by Moulin et al. (2000a,b,c) in AD patients, in which predictions were taken at different stages of a memory task. The sensitivity approach was used to examine metacognitive processes at encoding that were independent from recall performance. It was clear from Experiment 1 that TLE patients presented with an episodic memory deficit, and thus by exploring metamemory sensitivity at encoding allowed for monitoring and control processes to be examined irrespective of memory performance. Therefore removing any potential confound that different levels of recall performance may have had on metamemory processes between groups. Experiments 2 and 3 revealed that controls and TLE patients demonstrated a level of metacognitive sensitivity during encoding. In Experiment 2, TLE and control participants were able to successfully monitor the difficulty of the four lists and alter their post-study predictions accordingly. Both groups were sensitive to the objective difficulty of the lists and this was confirmed by an appropriate revision from their pre-study global JOLs to their post-study global JOLs on each list. This finding was supported by the results on study-time allocation, both groups systematically devoted more study-time to the most difficult list ('D-U) and the least amount of time to the easiest list ('E-R'). The results from Experiment 2 therefore revealed that controls and TLE patients demonstrated a level of metacognitive sensitivity when making their item-by-item JOLs and also allocating sufficient study-time to each list.

Experiment 3 also supported this metacognitive sensitivity view in TLE patients. It examined the effects of repetition on item-by-item JOLs and study-time allocation. In terms of both item-by-item JOLs and study-time allocation, TLE patients and controls were deemed to be sensitive to the three levels of repetition. Both TLE patients and controls were sensitive to repetition at encoding, rating word pairs as more likely to be recalled as the number of presentations increased. Furthermore, both groups allocated less study-time to word pairs with increased repetition.

It is evident from Experiments 2 and 3 that TLE patients, similar to control participants, were explicitly aware of the benefit of repetition and also semantically related words at encoding. TLE patients were thus aware of variations in task difficulty and also differing levels of repetition at encoding, which resulted in alterations in item-by-item JOLs and study-time appropriate to the demands of the task and thus improved their chances of recalling the stimuli. Overall, these results are encouraging as they suggest that TLE patients are able to judge which items will or will not be recalled/recognised and devote appropriate amounts of study-time to allow themselves the optimal chance of recalling the to-be-remembered stimuli.

6.2.5 Evidence of partial material-specificity

It was the purpose of Experiment 4 to explore the material-specific hypothesis in a group of unilateral TLE patients compared with controls. The material-specific hypothesis suggests that damage to one of these hemispheres will lead to a deficit in the associated memory function, i.e., left damage is associated with a deficit in verbal memory stimuli and right damage is associated with a deficit in non verbal memory functioning. Experiment 4 found partial evidence to support the view of a material-specific hypothesis in unilateral TLE patients. In support of the hypothesis, Experiment 4 revealed evidence of a verbal memory impairment in L-TLE patients when compared

with control participants, but not in R-TLE patients. In addition to this, Logical Memory II from the WMS-III yielded significant differences between groups, which revealed that L-TLE patients were impaired, compared with control participants and again no significant difference was apparent in R-TLE patients. The findings from Experiment 4 suggest partial support for the material-specific hypothesis, according to which only patients with left temporal lobe damage present with deficits in verbal memory. The non verbal task did not indicate any significant differences between groups. The findings from the verbal task were consistent with previous research (Moscovitch & McAndrews, 2002), which detected impairments in L-TLE patients for verbal stimuli.

Employing the 'R-K' paradigm in both the verbal and non verbal tasks allowed for items to be discriminated by whether there was conscious recollection or a sense of familiarity for all recognised items. The results from both the verbal and non verbal tasks revealed that groups did not differ in terms of their responses. Furthermore, in both tasks a significantly greater proportion of 'Remember' than 'Know' responses were given by all three groups. However, the low frequency of 'Know' responses created a floor effect which prevented any real test of Blaxton and Theodore's (1997) "modes of processing" view.

It is important to note that performance on the non verbal task was below 50% for all three groups. This finding is similar to Blaxton and Theodore's (1997) results, in which controls, L-TLE and R-TLE patients recognised less than 50% of the abstract designs. The implications of such low levels of performance in the non verbal task in all three groups raise concerns about the validity of the task. Low levels of recognition in non verbal tasks may be a common problem, and go some way to explaining difficulties in observing material-specific effects or any other effects in non verbal material. However, the reason for such low levels of performance in Experiment 4 may have been in part due to participants continually repeating A-B-A-B whilst studying the designs.

Although this instruction was essentially aimed at reducing verbalisation effects, it could have led to the decrease in recognition levels on the actual experiment. This instruction was not implemented into the pilot study and as a result the initial high levels of performance in this task may have been due to participants encoding the designs in a verbal manner. The same number of designs were used in the experimental task, however including the verbal distracter may have been responsible for the low levels of recognition performance in the three groups. Participants may have found the task too difficult which could have resulted in them guessing, leading to the low levels of performance. A reduction in the number of designs would have perhaps reduced this problem. The low levels of performance in all three groups' throws into question the validity and robustness of this non verbal task and could also be responsible for not observing any group or lateralisation effects.

Due to difficulties recruiting unilateral TLE patients that met the research criteria for Experiment 4, the cohort of patients tested was rather limited. The sample size of left and right TLE patients was disappointing and it could be argued that lack of group differences in this experiment, and no evidence to support the material-specific effects in R-TLE patients, could have been due to low statistical power. This relatively small sample size may have reduced the probability of rejecting the null hypothesis.

However, there is evidence in the literature to suggest that finding material-specific effects in R-TLE patients using non verbal material is difficult to observe, even when the sample size is substantial. Barr et al. (1997) used the Rey-Osterrieth Complex Figure Test as a measure of non verbal memory performance in 757 TLE pre-surgical candidates and found no significant differences between L-TLE and R-TLE patients. Despite the large sample size, Barr et al. did not find any significant differences between laterality. Power analysis confirmed that the sample size was more than sufficient to detect any significant effects. Such a large sample size and no evidence of

material-specific effects, highlights potential issues regarding the relationship between the nature of non verbal memory and memory impairment in the right hemisphere.

The pattern that has emerged from the current literature suggests there is more pathology in the left hippocampus which correlates with impaired performance on verbal memory tasks, and yet very little evidence indicating involvement of the right hippocampus with deficits on non verbal memory measures. Alternatively, the problem of finding material-specific effects in unilateral TLE patients may surround the test materials themselves. Previous research has shown that verbal memory deficits in L-TLE patients are easier to detect than non verbal memory deficits in R-TLE, and this would also seem apparent from the findings in Experiment 4. It is possible discrepancies in the literature concerning material-specific effects concern a number of factors.

Firstly, verbal and non verbal materials should be carefully constructed so that they are strongly polarised as either verbal or non verbal as far possible, in particular to prevent non verbal tasks from verbalisation effects. Experiment 4 attempted to polarise the two tasks by including abstract designs that could not be clearly given a label to aid remembering the designs. Furthermore, participants were instructed to continually say out loud A-B-A-B whilst studying the designs to prevent verbalising any of the abstract designs and ensure that the task was polarised as a non verbal as far possible. Despite these attempts to polarise the two tasks, Experiment 4 cannot completely rule out the possibility that some participants did not encode the words in a 'verbal' manner and likewise encode the abstract designs in a 'non verbal' manner. Butler and Zeman (2008) draw attention to the possibility that the insensitivity of standard memory tests challenge traditional theoretical models of memory, which would seem pertinent in being able to fully support the material-specific hypothesis. Although Experiment 4 did

not use standard memory tests this is an important point to highlight for previous studies which have examined the material-specific hypothesis and also for future research.

Secondly, the methods used to classify left and right unilateral TLE vary between studies. In Experiment 4, EEG recordings, MRI neuroimaging data or a combination of both, were used to classify right and left unilateral TLE. Although the use of EEG recording is a widely used technique, its level of sensitivity is relatively low and therefore its reliability can be questionable when used as a stand alone method in the diagnosis of epilepsy (see Chapter 1). There are however a wide range of imaging parameters which are used throughout the literature to classify right and left TLE on which inferences are made about functional localisation. However, perhaps a greater emphasis should be placed on specific hippocampal volumetric measurements to determine the extent of left and right laterality in TLE patients. The current literature on material-specific effects in unilateral TLE patients is limited in that there is marked heterogeneity between studies from the imaging techniques used to select patients, neuropsychological measures and even to the approach taken to analyse the data from differences between group test scores to differences between brain regions (see Saling, 2009 for review).

To the author's knowledge, there are very few published studies which have been able to confirm the material-specific hypothesis (e.g. Delaney, Rosen, Mattson & Novelly, 1980; Helmstaedter, Pohl & Elger, 1995), and in many other studies the hypothesis has only been partially supported (e.g. Baxendale et al., 1998; Moore & Baker, 1996), whilst others have found no evidence to support the theory (e.g. Hermann, Connell, Barr & Wyler, 1995; Naugle, Chelune, Schuster, Lüders & Comair, 1994). Such discrepancies in the literature would suggest that this phenomenon is not easy to replicate.

6.2.6 Executive functioning

It was predicted at Experiment 1 that there could be the potential for a degree of executive dysfunction in TLE patients, based on the findings from previous research suggesting a relationship between metacognition and executive processes (Fernandez-Duque et al., 2000; Shimamura, 2000; Souchay et al., 2000) and also evidence which suggests that executive functions in general are sustained by a diffuse neural network rather than by only prefrontal areas (Andrés, 2003; Collette & Van der Linden, 2002). It was therefore an essential component of the research to include executive function measures in each experiment. The same executive function measures (D-KEFS Color-Word Interference Test, D-KEFS Design Fluency and the Hayling Sentence Completion Test) were administered throughout the four experiments. Experiment 1 provided some evidence of executive dysfunction in TLE patients compared with control participants. In a number of the measures, TLE patients performed significantly worse than controls or indicated a tendency for a level of executive dysfunction, particularly in the inhibitory domain. Experiments 2, 3 and 4 however, did not reveal any specific executive dysfunction in TLE patients as they either performed equivalent to control participants or significant interference and switching cost effects were not detected between groups, but did show a reduction in general speed of processing. Evaluation of the executive function results across the experiments indicate firstly, that a focal frontal lesion is not necessary to observe this type of deficit in clinical populations (Andrés, 2003; Andrés & Van der Linden, 2001). Secondly, that executive function is not always a constant hallmark of TLE but may exist in this neurological population (see Experiment 1). Finally, the presence of this relative executive dysfunction in TLE patients with intact metamemory abilities indicates that metamemory is likely to run independently at least from inhibitory mechanisms.

6.3 Can metamemory be localised?

A growing body of evidence involving different neurological populations has added support to a frontal lobe hypothesis of metamemory (see Pannu & Kaszniak, 2005 for review). In particular, studies involving populations with frontal lobe damage have indicated a strong correlation between frontal lobe functioning and impaired metamemory accuracy (Janowsky et al., 1989; Schnyer et al., 1994; Vilkki et al., 1999). Furthermore, a combination of frontal lobe dysfunction and memory impairment has been suggested as the condition under which metamemory deficits are most prevalent (Pannu & Kaszniak, 2005).

However, O'Shea, Saling & Bladin (1994) examined the neuropsychological literature available at the time on metacognition and concluded that there was no evidence to support the notion that metamemory was mediated in the frontal lobes. However, O'Shea et al. (1994) partly based their claims on Prevey et al.'s (1988, 1991) research in TLE patients, which provided unclear and mixed results about metamemory processes which cannot be substantiated due to serious methodological issues (see Chapter 2 for a review). Today, a greater volume of literature is available including evidence from neuroimaging (Kikyo et al., 2002; Maril et al., 2003) and neuropsychological (Janowsky et al., 1989; Modirrousta & Fellows, 2008; Schnyer et al., 2004; Vilkki et al., 1998; Vilkki et al., 1999) studies which has revealed a primary role of the prefrontal cortex is involved in metamemory processing. In particular, Shimamura & Squire (1986, see also Janowsky et al., 1986) tested FOK judgements in Korsakoff syndrome patients, patients prescribed electroconvulsive therapy, amnesic patients and controls, and demonstrated that only patients with Korsakoff syndrome (who present with a frontal dysfunction) were impaired in their FOK judgements. The findings from Shimamura & Squire (1986) and Janowsky et al. (1986) demonstrated that amnesic patients presented with intact metamemory functions. These studies alone

suggest that metamemory impairment is associated to some extent to frontal lobe pathology. However, as highlighted in Chapter 1, there is also a small amount of literature suggesting that the temporal lobes may play some role in metamemory processes (Kikyo & Miyashita, 2004; see also Schnyer et al., 2005).

The consistent findings from this thesis, which revealed TLE patients to have intact metamemory processes, together with the findings from the likes of Shimamura & Squire (1986) and Janowsky et al. (1989) research, would suggest that some frontal lobe damage is needed for metamemory problems to be present. The findings in this thesis provide strong evidence that memory and metamemory can be dissociated, as TLE patients presented with a clear memory deficit yet preserved metamemory processes. Above all, the results from the global JOLs in Experiment 2 indicated that TLE patients were better at predicting global performance as their judgements were more on target than controls. This finding suggests that the TLE patients seemed to be aware of their memory problems, and may actually be better at predicting global memory performance.

Moreover, the notion that metamemory and memory may be dissociated was suggested early in the metacognitive literature, *"memory and metamemory are to some degree independent variables...[potentially] dissociable at a biological level"* (Cooley & Stringer, 1991; in O'Shea et al., 1994). The current findings featured in this thesis would suggest that metamemory dysfunction is not associated with temporal lobe pathology. Furthermore, a review of the past metamemory literature, including neurological populations would suggest that metamemory dysfunction is associated with a degree of frontal lobe damage.

6.4 Methodological issues and limitations of the research

The experiments in this thesis followed Nelson and Narens' (1990) framework to investigate metamemory abilities in TLE patients. Despite following this framework and reviewing the past metacognitive literature, some methodological issues were apparent in the current research. Where such potential issues were apparent, every effort was made to control for these effects in subsequent experiments. An example of this was in Experiment 1 (Howard et al., in press), where item-by-item JOLs and global JOLs were collected together, which potentially could have lead to an increase in global JOL accuracy, as these predictions followed on from completing all item-by-item JOLs. Experiment 2 removed this potential confound by examining global JOLs in isolation.

It is also important to note, that the author was the only experimenter in the research to administer all tests to participants. Having all tests delivered by a single experimenter maintained consistency when administering the experimental tasks and neuropsychological measures, as variations in administering styles could have led to inconstancies in the results obtained.

Experiment 1 recorded the number of correctly recalled word pairs at test, with all incorrectly or non-recalled word pairs being used in the following FOK task. A potential limitation of this experiment was that errors and omissions at recall were not separately recorded and thus recall failures could not be analysed in these terms.

Experiment 4, which examined the material-specific hypothesis in unilateral TLE patients, raised the most methodological issues in this research. Every effort was made to ensure that the verbal and non verbal tasks were polarised as far as possible. This was done by instructing participants to continually repeat out loud A-B-A-B whilst studying the abstract designs to prevent participants from verbalising the non verbal task. Despite such efforts, the author cannot be certain that some of the designs were not

verbalised and although a pilot study was conducted on the task materials prior to testing, the verbal and non verbal tasks were not equated in their level of difficulty.

Furthermore, Experiment 4 used a combination of EEG and MRI evidence to determine laterality in TLE patients, however a more precise technique of MRI volumetric measurements should be used in future studies to determine laterality in TLE patients when exploring the material-specific hypothesis. MRI volumetric measurements are more precise in confirming patient laterality and thus ensuring that patients are well matched to other unilateral TLE patients in the same group.

Moye (1997) highlight certain characteristics that have been suggested to relate specifically to measuring non verbal memory associated with specificity of localisation, and which should be considered for future non verbal tasks. These include, (1) the use of a large number of perceptually similar stimuli, (2) the use of ambiguous and nonverbalisable stimuli, (3) exposure time, (4) response format i.e., recognition and (5) the use of delayed recall.

In each of the experiments in this thesis a subjective questionnaire was administered to examine TLE patients perceived memory abilities. It is important to highlight the problems encountered with using subjective memory questionnaires in a clinical setting. The fundamental problem concerns testing a memory impaired population, in that they are reliant on using their own memory to answer the questionnaire. Many of the subjective questionnaires available today were developed for research purposes and do not necessarily reflect memory situations which are applicable to the sample being examined. For instance, the MFQ was administered in Experiment 1 as a subjective measure of participants' perceived memory. Several of the items were not applicable to the participants (e.g. public speaking) and, by default, received a response indicating no memory problems for such activities. Such responses imply that these individuals do not have any memory difficulties, when in reality they actually

have not encountered the situation described to experience any problems. As a consequence, the EMQ was used in all other experiments as it was considered easier for participants to relate towards. Similar difficulties arise when asking TLE patients to record the frequency of seizures in their seizure diaries. In the four experiments, the frequency of seizures per month were recorded by each TLE patient. However, it cannot be ruled out that the TLE patients were not susceptible to forgetting or even aware that a seizure had occurred. Therefore, this may have resulted in some seizures not being recorded.

The majority of limitations in the current research are largely due to time constraints. Patient recruitment took a long time to complete. Patients were initially approached about the research through either their consultant or epilepsy specialist nurse at the time of their health check-up. Only patients that were seen in these clinical appointments were told about the research if they met the research criteria. This procedure meant that the recruitment of patients onto the experiments was a lengthy process spanning four years, and a smaller sample of TLE patients therefore took part in each of the experiments than was initially anticipated. As a consequence, a possible limitation of the research may have been the small number of participants. It could be argued that this might have lead to low statistical power. However, given that significant differences were found in both control and TLE patients on experimental and neuropsychological measures, this is likely not to be the case. It is important to note that another limiting factor of the research was that it was not possible to distinguish between MTL and LTL patients, as this information was not available at the time of testing, and therefore this variable could not be included in the analysis. Changes to the recruitment and selection process for TLE patients could be managed more effectively if time constraints were not an issue. This could aid the recruitment of patients and hopefully lead to a larger sample size to investigate.

6.5 Future research

The examination of metamemory and memory processes has been a neglected topic in the neuropsychological literature. Indeed no research has been conducted on metamemory and episodic memory in relation to TLE patients, and therefore this thesis marks the first contribution into TLE patients' verbal episodic memory and metamemory capabilities. The current findings suggest that in order to observe metamemory problems, some frontal lobe damage might be necessary. It therefore seems an important next step to consider examining memory and metamemory processes in a group of FLE patients comparing the findings with a group of TLE patients and matched controls. From the findings in this thesis, it would be predicted that FLE patients would present with a degree of metamemory dysfunction but a lesser memory impairment compared with TLE patients.

Following on from the current findings, future research could examine further a number of memory and metamemory constructs. For instance, a longitudinal study could determine whether memory declines further over time dependent on specific epilepsy variables (e.g. type of seizures, duration, laterality, AEDs, age of onset). Future studies could also focus more on clinical variables such as AED usage and seizure type and how these affect memory functioning in TLE patients (see Bell et al., 2005; Mamemiskiene et al., 2006). Advancement of neuroimaging techniques has helped further our understanding of many neuropsychological populations. It would therefore seem appropriate for future research to utilise neuroimaging techniques in conjunction with memory and metamemory measures in patients with epilepsy. Memory performance and perceptions pre- and post-operatively for temporal lobectomy have featured in past research (Janszky et al., 2005; Lah, Garyson, Lee & Miller, 2004; Lineweaver, Naugle, Cafaro, Bingaman & Lüders, 2004; McGlone, 1994; Richardson et

al., 2004). It would also be of interest to see if metamemory abilities are affected post-operatively in such patients.

There are a number of additional avenues the research on memory and metamemory in epilepsy could follow, however examining FLE would seem central to furthering our understanding of the localisation of metamemory processes.

6.6 Conclusion

In summary, the four experiments featured in this thesis examined memory and metamemory processes in TLE patients compared with a group of matched control participants. The main purpose of this research was to establish whether metamemory problems could be responsible for the often observed memory impairment in TLE patients. Nelson and Narens' (1990) theoretical framework on metamemory was used to explore these constructs. The research findings revealed clear and consistent evidence of a memory deficit in TLE patients compared with controls and yet preserved metamemory processes.

Furthermore, the results suggest that such memory difficulties are more likely to be a result of problems at encoding, due to damage within the temporal lobes, similar to the deficits observed in stronger forms of amnesia (Mayes et al., 2003; O'Connor et al., 1997), and contrasted from deficits in retrieval strategies and planning suggested to occur in patients with frontal lobe damage (Shimamura et al., 1991).

The results indicate that memory and metamemory are dissociable processes in TLE patients, whereby a clear episodic memory deficit was apparent in the patient group, whilst metamemory abilities remained intact, which is also in accordance with some research findings on AD patients (see Moulin et al., 2000a). In the absence of any metamemory problems in the TLE patients tested in this thesis, the results would suggest that some frontal lobe dysfunction might be necessary to observe metamemory

impairment in patients with epilepsy. Further research is still required to advance our understanding of memory and metamemory processes in patients with epilepsy and other neurological populations.

Appendix A

Goodman-Kruskal Gamma correlation coefficient (*G*) (Nelson, 1984) is a non-parametric measure which is based on the difference between concordant pairs (C) and discordant pairs (D). Values range from +1 to – 1. Gamma is computed as follows:

$$G = (C\text{-}D) / (C+D)$$

In several of the experiments, Goodman-Kruskal Gamma correlation coefficients were calculated between item-by-item Judgements-of-Learning (JOLs) and actual recall, and also between item-by-item Feeling-of-Knowing (FOKs) and recognition performance. Mean *G* JOL/FOK accuracy was computed for comparison between groups.

Appendix B1

Word pairs presented in the JOL task.

Related word pairs	*Unrelated word pairs*
knight – horse	vain – tin
purse – wallet	flag – uncle
shovel – spade	onion – stove
inn – hotel	snow – package
lime – lemon	rose – sock
dog – cat	drum – house
youth – child	umbrella – sweet
sketch – draw	giraffe – rock
spoon – fork	lorry – time
blouse – skirt	queen – pine
glass – cup	baby – crow
book – magazine	bank – morning
village – town	jockey – pencil
hammer – saw	hedge – oxygen
carpet – rug	ant – work
penny – money	engine – lobby
cushion – pillow	plate – horn
ale – beer	duck – cloth
garden – lawn	aerosol – film
doctor – dentist	soil – grape
jacket – coat	scissors – ear
paper – card	fence – dress
world – earth	mountain – daisy
army – navy	fairy – tractor
chair – table	beetle – spike
iron - steel	cloud – pea
couch – sofa	fossil – knife
coffee – tea	church – ship
can – jar	bat – frog
orange – banana	envelope – summer

NB. The second words in the pairs are the target words.

Appendix B2

Distracters presented for the FOK task.

First part of word pair presented at Recognition	*Distracters and target words presented at recognition*
bat	cake – toad – **frog** - hog
coffee	belt – team – **tea** - milk
fairy	**tractor** – case – farm - factor
aerosol	movie – file – **film** - harbour
inn	lodge – icicle – hook - **hotel**
drum	**house** – cottage – judge – mouse
beetle	kettle – spice – thorn – **spike**
can	bar – **jar** – bottle – desk
garden	lawyer – **lawn** – plant – industry
umbrella	ballot – sugar – **sweet** – treat
paper	gun – pen – **card** – carriage
knight	**horse** – bowl – donkey – course
church	shell – page – boat – **ship**
lime	junior – **lemon** – cherry – demon
jockey	phone – ruler – penguin – **pencil**
fossil	letter – **knife** – knee – blade
glass	mail – drink – **cup** – cube
queen	**pine** – oak – pint – bone
world	earl – racket – **earth** – round
fence	canal – gown – drain – **dress**
vain	metal – **tin** – linen – bin
jacket	map – **coat** – tie –goat
envelope	**summer** – mole – winter – sum
orange	fruit – budget – **banana** – band
army	degree – soldier – gravy – **navy**
hammer	egg – **saw** – law – tool
village	face – **town** – home – tower
carpet	**rug** – floor – cook – rule
blouse	door – shirt – **skirt** - skin
cushion	father – willow – quilt - **pillow**
spoon	girl – **fork** – utensil – force
shovel	radio – **spade** – space – rake
onion	detective – oven – **stove** – store
penny	monsoon – dollar – **money** – paint
hedge	family – air – ox – **oxygen**
dog	empire – puppy – **cat** – rat
snow	foot – **package** – parcel – cabbage
iron	ghost – **steel** – lead – wheel
ale	wine – record – bee – **beer**
plate	closet – **horn** – trumpet – corn
book	jail - **magazine** – novel – magic
baby	graduate – **crow** – arrow – hawk
ant	office – sea – **work** – worm
engine	dust – **lobby** – hall – lobster
purse	library – satchel – wall – **wallet**
mountain	key – **daisy** – tulip – dairy
cloud	disc – **pea** – carrot – pear

lorry	timber – **time** – watch – newspaper
giraffe	ferry – **rock** – dock – stone
scissors	island – eye – deer – **ear**
duck	choir – **cloth** – moth – sponge
soil	vine – roof – graph – **grape**
couch	**sofa** – bed – college – soap
chair	seat – sheep – **table** - tail
doctor	park – **dentist** – nurse – dent
flag	aunt – powder – **uncle** – under
sketch	art – straw – locker – **draw**
youth	kid – pig – chief – **child**
rose	moon – shoe – **sock** – lock
bank	lady – **morning** – ceiling - dawn

NB. Words presented in bold indicate the target word.

Appendix C

Difficult-Related (D-R)	
black	maroon
purple	tan
white	lavender
pink	beige
brown	silver
violet	aqua
grey	magenta
turquoise	olive
gold	rose
indigo	mauve

Difficult-Unrelated (D-U) *	
causality	origin
figment	outsider
sulphur	confidence
formation	hint
necessity	pledge
comparison	impulse
joviality	shame
occasion	position
situation	chance
tobacco	length

Easy-Related (E-R)	
apple	tangerine
orange	apricot
pear	pineapple
banana	lime
peach	tomato
grape	strawberry
cherry	watermelon
plum	prunes
grapefruit	raspberry
lemon	blueberry

Easy-Unrelated List (E-U) **	
boy	sea
elephant	teacher
grandmother	sky
joy	college
lake	elbow
policeman	priest
shoes	wife
dove	tree
friend	fox
lord	cat

* mean probability of free recall 0.26; ** mean probability of free recall 0.75; Rubin & Friendly's (1986) free recall norms.

Appendix D

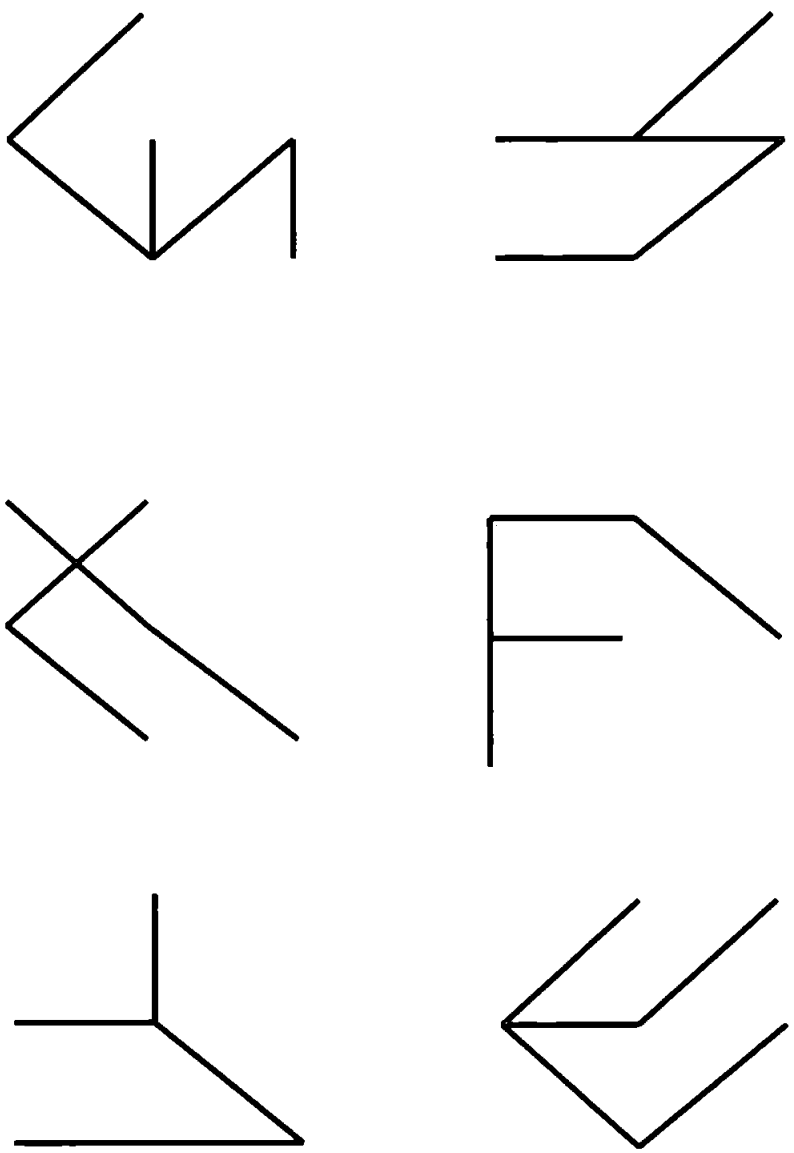
Word pairs*	Level of repetition
tower – monk	1
singer – butter	1
book – elbow	1
nursery – boss	1
fork – paper	1
queen – ship	1
alligator – cell	1
door – toy	1
weapon – moss	1
wine – city	1
oats – temple	1
seat – mathematics	1
corn - world	1
jelly – science	2
bar – village	2
ankle – daffodil	2
spinach – baby	2
basement – arm	2
street – salad	2
king – restaurant	2
truck – bullet	2
home – volcano	2
connoisseur – slipper	2
dust – flood	2
fox – nephew	2
church - meat	2
frog – avalanche	3
animal – law	3
skin – galaxy	3
air - limb	3
boulder – horse	3
tweezers - banker	3
earth – jury	3
child – bowl	3
artist – reptile	3
monarch – officer	3
window – footwear	3
fisherman – armadillo	3
grass - person	3

* All 39 cue and target words had a mean recallability proportion of 0.60 (range 0.53 to 0.67); Rubin & Friendly's (1986) free recall norms.

Appendix E1

Target words		Distracter words	
ocean	amplifier	troops	author
instructor	history	ambassador	oven
cigar	cellar	marriage	nectar
lobster	juggler	sunset	lemonade
tank	nail	geese	lawn
leggings	robbery	fireplace	thorn
table	painter	keg	vacuum
lecturer	winter	water	acrobat
stone	infection	army	flag
library	costume	building	knowledge
lemon	engine	meadow	hotel
hammer	landscape	metal	arrow
vegetable	glacier	hall	butterfly
physician	pudding	tree	circle
soil	yacht	corner	candy
coffee	flask	cattle	avenue
poet	valley	strawberry	gallery
hoof	garments	lip	atmosphere
chin	palace	saloon	golf
bird	barrel	letter	star
blossom	coast	beaver	amazement
macaroni	episode	lark	cuisine
forest	kettle	rod	beast
iron	cotton	rock	invoice
mosquito	diamond	garden	cradle
clock	bacteria	magazine	bagpipe
gift	hairpin	infirmary	amount
infant	chief	mammal	doll
pepper	blacksmith	judge	stain
algebra	bungalow	sugar	volume
leopard	wholesaler	pianist	hound
research	bronze	sultan	contract
coin	industry	snake	honour
ghost	gem	cane	prayer
admiral	blister	anger	goblet
plant	cabin	wheat	mast
caterpillar	utensil	square	joke
flower	heaven	season	tablespoon
simile	spire	newspaper	beggar
nutmeg	lime	vehicle	woods

Appendix E2



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