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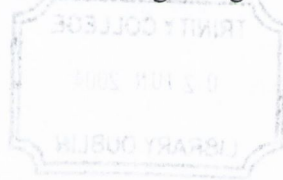
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**The effects of selective amygdalohippocampectomy on episodic memory,
spatial representation and discourse production among human
neurological patients.**

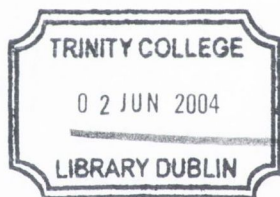
Volume I

by

Maeve Mangaoang



A dissertation submitted for the degree of Doctor of Philosophy of the
University of Dublin, Trinity College, Dublin 2, Ireland.
This research was conducted in the Department of Psychology.
September 2003.



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Declaration

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Summary

The work described in this thesis is directed at investigating the neuropsychological effects of damage to the medial temporal lobes among a group of patients who have undergone surgery for the relief of medically intractable temporal lobe epilepsy (TLE). This investigation focuses on a specific neurosurgical procedure, termed selective amygdalohippocampectomy (SAH) and the effects of this procedure on episodic memory, spatial representation, spatial navigation, and discourse production. The main method of enquiry involves the assessment of post-operative patients on a variety of novel tasks, which were designed to be sensitive to hippocampal damage. A brief synopsis of the work contained in each chapter of this thesis is presented below.

In *Chapter I*, the reader is introduced to the anatomy and functions served by the medial temporal lobes in humans, with specific reference to navigation, cognitive mapping, and episodic memory. This chapter also contains a comprehensive literature review of the main theories of hippocampal function and the experimental paradigms used in these different investigations. The adverse effects of hippocampal damage on aspects of human cognitive functioning are explored with specific reference to temporal lobe epilepsy. Finally, the rationale for the studies presented in this thesis is outlined.

In *Chapter II*, focuses on the methodology of the two validation studies and the main study. The primary aim of this chapter is to provide the reader with a detailed account of the procedures used to select appropriate participants. The secondary aim is to explain and describe the different tasks used in these studies and to explain how these tests were administered and scored.

In *Chapter III*, the results of the thesis are presented, beginning with the data obtained from the validation studies. From there, attention is directed towards the main study, where the performance of the patient groups relative to the control participants on each of the tasks administered is examined. Following

this extensive analysis, the final part of Chapter III explores how these findings may be further explored using factor analytic procedures.

Finally, in *Chapter IV*, the results of this thesis are discussed. In keeping with the format of the previous chapters, this chapter also begins with the findings obtained from the validation studies before turning to the results of the main study. The structure of the discussion is guided by the four main hypotheses of the study and the results are evaluated in terms of their support for these statements and how well they accord with the work of previous researchers. Particular emphasis is placed on the integration of the present findings with current theories of hippocampal functioning and from this synthesis, a new model, which aims to explain the results of this thesis, is proposed. In the concluding sections, the significant contribution of this work to the current literature in the area is highlighted and the limitations and strengths of the thesis are addressed.

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CHAPTER 1 – LITERATURE REVIEW

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Introduction

“You have to begin to lose your memory, if only in bits and pieces, to realise that memory is what makes our lives. Our memory is our coherence, our reason, our feeling, even our action. Without it, we are nothing.”

Luis Buñue, Spanish film maker

This thesis focuses on human memory functioning and the above quotation is an appropriate introduction to this work since it conveys the central and essential role played by memory in our daily lives. Indeed, it may well be that only when the integrity of our memory capabilities becomes challenged that we begin to no longer take it for granted. The catastrophic effects of memory impairments and the frequency with which they are reported among patients suffering from many diverse neurological disorders (e.g. Epilepsy, Alzheimer’s Disease, Korsakoff’s Syndrome, etc.) provides the impetus for striving towards a better understanding of the neural processes underlying human memory functioning.

It is also well known that memory deficits among such patients rarely occur in isolation from impairments in other cognitive domains. In this literature review, a comprehensive account of medically intractable temporal lobe epilepsy as a neurological disorder, which is commonly associated with memory impairments is presented. The specific deficits associated with surgery for the relief of this condition are discussed in detail. Although deficits in memory functioning are most frequently reported following such surgery, additional, associated impairments in spatial representation, wayfinding, navigation, and more recently, discourse production, have also been documented.

However, prior to focusing specifically on temporal lobe epilepsy and its associated neuro-cognitive impairments, the first sections of this chapter are concerned with the anatomy of the medial temporal lobe, human spatial

representation and cognitive mapping, declarative and episodic memory and discourse production. The purpose of these sections is to familiarise the reader with the many diverse neuropsychological approaches that have been used to investigate the neural processes, which govern these functions. It is further intended that from these overviews and summaries, the rationale for this present work will become apparent.

Section 1 – The anatomy of the temporal lobe

1.1 Gross anatomy of the temporal lobe

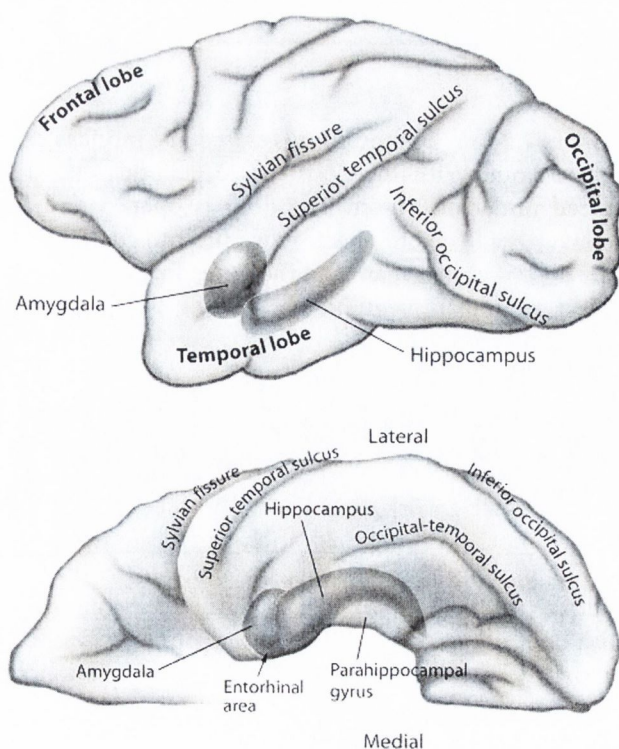
The temporal lobe (TL) is bounded dorsally by the lateral fissure. It contains all the tissue that lies below the Sylvian sulcus and anterior to the occipital cortex (Figure 1.1a). The sulci of the temporal lobe contain a lot of cortex, which is divided into three major gyri, the superior, middle and inferior temporal gyri that are visible on the lateral surface of the lobe. This section will focus in detail on the medial temporal lobe (MTL) region (see Figure 1.1b), also known as the limbic cortex, which includes the amygdala, uncus, hippocampus and surrounding cortex (subiculum, entorhinal cortex, perirhinal cortex) and the fusiform gyrus. The fusiform gyrus and inferior temporal gyrus are functionally part of the lateral temporal cortex.

1.2 Connections of the medial temporal lobe.

Since the late 1960s, many investigations of the major cortical association systems of the entire cerebral cortex have been carried out in nonhuman primates (e.g. Pandya and Kuypers, 1969; Jones and Powell, 1970). The temporal lobes are rich in internal connections, afferent projections from the sensory systems, and efferent projections to the parietal and frontal association regions, limbic system and basal ganglia. It is now clear that cortical association neural systems terminate in the medial temporal lobe and that cortical input is the major afferent for the amygdala hippocampal formation (HF) and parahippocampal gyrus (Suzuki and Amaral, 1994a, 1994b). Van Hoesen (1995) states that these inputs stem from cortical areas that form the limbic lobe, the association areas related to the visual, auditory and somatic modalities and the multimodal association areas. Cortical projections to the

amygdala are highly organised with selective limbic and association cortical areas projecting to selective amygdaloid nuclei or parts of them. The HF receives less direct input from the limbic and association cortices, but nearly all areas that project directly to the amygdala send direct cortical association axons to either the entorhinal cortex and /or the perirhinal cortex surrounding it. From there, the perirhinal cortex sends axons to the entorhinal cortex and the HF. According to Van Hoesen (1995), the entorhinal cortex output forms one of the largest cortical association pathways, the perforant pathway, in the hemisphere and is clearly the largest in the temporal lobe. Regarding the MTL outputs back to cortex, the amygdala contains projections to limbic, association and even primary sensory cortical areas (Amaral, 1984).

Figure 1.1a: Diagrammatic gross anatomy of the medial temporal lobe of the monkey, with the hippocampus, amygdala, enthorhinal area and parahippocampal gyrus. **Top** shows lateral, see-through view of the left hemisphere with the amygdala and hippocampus seen within the temporal lobe. **Bottom** shows the view from the ventral surface of the same hemisphere. (Adapted from Gazzaniga et al., 1998).



1.3 Neuroanatomy of the hippocampal system

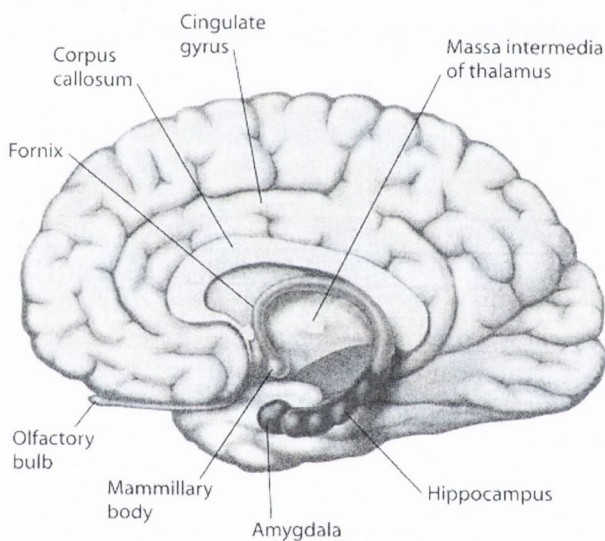
The hippocampal formation (HF) is a bilateral, archicortical structure in the medial temporal lobe consisting of the hippocampus proper (CA1-CA4), the dentate gyrus and the subiculum (Henke et al., 1999). It resembles two 'Cs' leaning together at the top and spread apart at the base. The top portion of the HF is known as the 'dorsal hippocampus' and because of its proximity to the septum, a structure at the midline of the brain, the dorsal tip of the hippocampus is called the 'septal pole' (Amaral and Witter, 1989; Witter, 1989). The internal structure of the hippocampus consists of the hippocampus proper, also known as Ammon's Horn or Cornu Ammonis (CA1-CA3) and the dentate gyrus and each area has its own principle cell layer. The stratum pyramidale or pyramidal cell layer forms the major cell layer of Ammon's Horn, whereas in the dentate gyrus, the stratum granulosum or granule cell layer is the principle cell layer. Although the dentate gyrus is commonly included as part of the hippocampus, it is cytoarchitectonically distinct from the hippocampus proper (Amaral and Witter, 1989; Witter, 1989).

Connections within the hippocampal formation

According to Sherry and Healy (1998), although there is variation among mammals in the size and shape of the hippocampus, its intrinsic circuitry is very distinctive and is conserved across species. The intrinsic connections between the principle cell layers of the dentate gyrus and CA regions of the hippocampus are so clear that Ramon y Cajal was able to determine the major direction of afferent connections or synaptic flow of the 'trisynaptic circuit' through the examination of Golgi stained neurons as far back as 1911 (Andersen, 1975). However, it is now clear that the classical view of the hippocampal trisynaptic circuit (Andersen et al., 1966; Swanson et al., 1978; Witter, 1989) is a simplification. The intrinsic circuitry of the hippocampus is largely unidirectional (Figures 1.2a, 1.2b). Although hippocampal cells project to many subcortical regions outside the hippocampus, the sequence of synaptic activation within the hippocampus follows a route from the entorhinal cortex to CA1 (Amaral, 1987). Direct inputs from the entorhinal cortex to CA1 and CA3 have also been identified, along with direct output from CA1 to the

entorhinal cortex (Jones, 1993). The HF also has extensive feedback projections to the cerebral cortex that arise from its subicular and CA1 pyramids and terminate in much of the cortex of the limbic lobe, as well as orbitofrontal, medial frontal, anterior temporal and posterior temporal association cortices. Considered together, these projections serve powerful hippocampo-cortical neural systems influencing both the limbic and association cortices (Van Hoesen, 1995).

Figure 1.1b: Medial temporal lobe structures including the hippocampus and amygdala (shown in red) (Adapted from Gazzaniga et al., 1998).

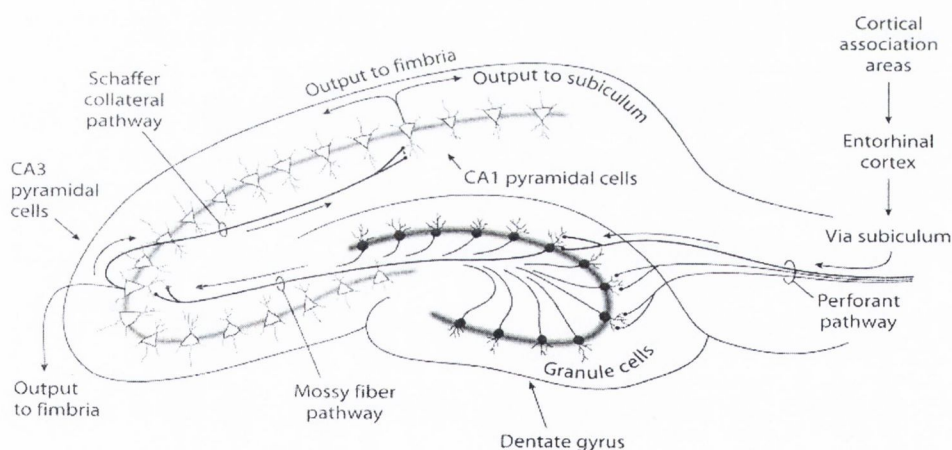


1.4 Organisation of the hippocampal system

According to Rolls and Treves (1998), there are several important principles of organisation in the hippocampal system. Firstly, as shown in Figures 1.2a and 1.2b, the hippocampal system receives a strong convergence of both modality-specific and polymodal input, rendering each component of the system a higher-order polymodal association area. Secondly, sensory information from widespread areas of the neocortical mantle enters the medial temporal lobe primarily via projections to the perirhinal and parahippocampal cortices. These areas provide the major cortical input to the entorhinal cortex, which in turn provides the major input to the hippocampus. Third, the

perirhinal and parahippocampal cortices serve not only as the major port of entry into the hippocampal formation but also as its major cortical output, via dense, reciprocal projections. Thus, the perirhinal and parahippocampal cortices constitute the major communication links between widespread areas of sensory cortex on the one hand and the hippocampal formation on the other.

Figure 1.2a: Diagram of the synaptic organisation of the rat hippocampus, showing the three main synaptic pathways: the perforant pathway that forms excitatory connections between the parahippocampal cortex and the granule cells of the dentate gyrus; the mossy fibres that connect the granule cells of the dentate gyrus to the CA3 pyramidal cells, and; the Schaffer collaterals that connect the CA3 pyramidal cells to the CA1 pyramidal cells. (Adapted from Gazzaniga et al., 1998).

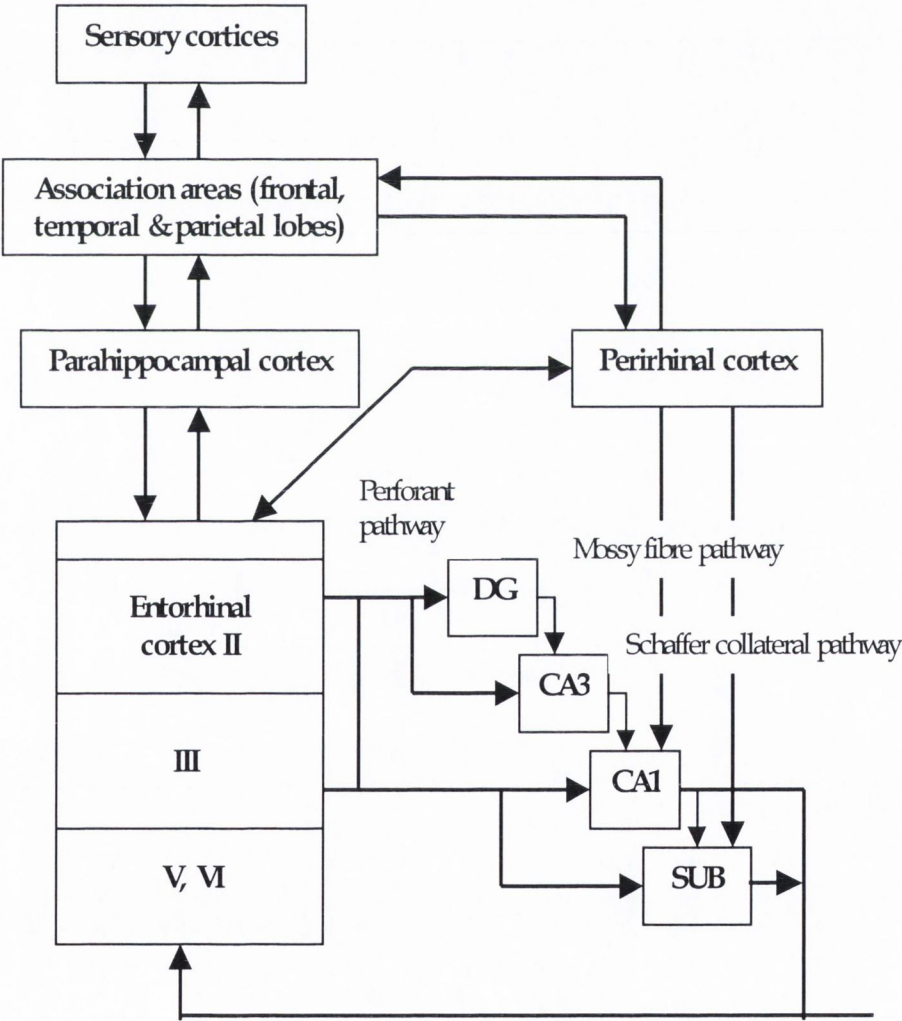


Connections of the hippocampal system

The perirhinal cortex is characterised by its prominent projections from ventral processing streams, receiving nearly two-thirds of its cortical inputs from the adjacent ventral-stream visual areas, TE and TEO (Suzuki & Amaral, 1994a, 1994b). In contrast, the parahippocampal cortex receives a far greater proportion of its inputs from dorsal-stream areas including the posterior parietal cortex, the retrosplenial cortex, the dorsolateral prefrontal cortex and the dorsal bank of the superior temporal sulcus (Suzuki & Amaral, 1994a, 1994b). Since the perirhinal cortex and parahippocampal cortex provide

almost two thirds of all entorhinal cortical inputs, this region serves as a second tier of convergence. The perirhinal and parahippocampal cortices project to the entorhinal cortex in a feedforward manner whereas the entorhinal cortex projects back to these areas in a feedback-like manner. Apart from the entorhinal input, the dentate gyrus and CA cell fields receive few direct inputs from the cortex.

Figure 1.2b: The intrinsic connections of the hippocampal formation, including the projections from the perirhinal cortex to both areas CA1 and subiculum (Adapted from O’Mara et al., 2000).



Outputs

Output from the subiculum and entorhinal cortex is the major pathway by which the hippocampus influences cortical activity. The perirhinal cortex, the cortex of the temporal pole, the caudal parahippocampal gyrus (O’Mara et al.,

2001) and the caudal cingulate gyrus all receive projections from the subicular complex or entorhinal cortex and it is through these pathways that the hippocampal signals ultimately reach temporal, parietal and frontal cortex (Amaral, 1987). Subcortical outputs occur primarily through the fimbria and include projections to the septal nuclei, nucleus accumbens, thalamus and mamillary nuclei. A major source of output through the fimbria is the alveus, which consists of the axons of the CA1 pyramidal cells. There are also extensive commissural connections between the cell fields of the left and right hippocampus.

1.5 Conclusion

In summary, the hippocampus receives, via the adjacent parahippocampal gyrus and entorhinal cortex, inputs from virtually all association areas in the neocortex, including those in the parietal, temporal and frontal lobes (Rolls and Treves, 1998). Therefore the hippocampus has available highly elaborated multimodal information which has already been processed extensively along different and partially interconnected, sensory pathways. Furthermore, the provision a single network for association between any subset of neurons (e.g. the CA3 neurons) may be an important feature of what the hippocampal circuitry provides for memory. Additional inputs to the hippocampus come from the amygdala, and via a separate pathway, from the cholinergic and other regulatory systems. To complement this massively convergent set of pathways into the hippocampus, there are massively divergent sets of backprojecting pathways from the hippocampus via the entorhinal cortex to the cerebral neocortical areas, which provide inputs to the hippocampus. Within the hippocampus, information is processed along a mainly unidirectional path consisting of three major stages:

1. Perforant path: makes synapses with the dendrites of the dentate granule cells and also with the apical dendrites of the CA3 pyramidal cells
2. The dentate granule cells project via the mossy fibres to the CA3 pyramidal cells
3. The CA3 pyramidal project via the Schaffer collaterals to the CA1 pyramidal cells, which in turn have connections to the subiculum.
4. The subiculum in turn sends the major projection to the entorhinal cortex.

Section 2 – Spatial representation and spatial navigation in humans

1.6 The key role of the hippocampus in spatial representation and navigation, wayfinding behaviour and topographical orientation.

Its distinctive anatomy is probably responsible to some degree for the remarkable level of interest in the function of the hippocampus and three key experimental effects have been the main driving forces behind a plethora of investigations, theories and debates on the role of this structure. In the rodent, the discovery of place cells by O'Keefe and Dostrovsky (1971) was a landmark achievement. Similarly, the findings from primate lesion studies and clinical neuropsychological cases that lesions of the hippocampus can cause profound anterograde amnesia (Scoville & Milner, 1957) provided a strong impetus to increase our understanding of the functional role played by the hippocampus. Thirdly, neurophysiological evidence derived from the principles of Hebbian Learning indicated that many of the types of synapse within the hippocampus are modified as a result of experience, implying that the hippocampus provides a neural network capable of storing a large number of different memories (Rolls and Treves, 1998).

The outcome of these experimental effects has been a multitude of different theories and models on hippocampal functioning, the most famous of which is the Cognitive Map Theory proposed by O'Keefe and Nadel (1978). It is important to note that, to date, much of our understanding of the neural bases of spatial representation has come from lesion studies conducted with animals, including nonhuman primates. Detailed accounts of the role of the rodent hippocampus in spatial navigation can be found in Redish (1999), Thinus-Blanc et al. (1998), Schenk (1998), and Mumby et al. (1999). In-depth studies into primate spatial representation have been carried out by Rolls and colleagues (e.g. Rolls, 1996; Rolls and O'Mara, 1995; Rolls et al., 1989a, 1989b; Feigenbaum and Rolls, 1991; O'Mara et al., 1994) and Olson et al. (1999). Finally, comprehensive discussions of hippocampal place cells and head direction cells and path integration, are contained in O'Mara (1995), Redish (1999), Sherry and Healy (1998) and Hartley et al. (2000). While recognising the immense contribution this work has made to our current level

of knowledge about spatial representation, the main focus of this discussion will be on human aspects of wayfinding and topographical orientation. Recent advances in functional imaging techniques have facilitated the development of novel paradigms such as virtual reality (VR) towns (e.g. Spiers et al., 2001a, 2001b), which have enabled the neural correlates of normal wayfinding behaviour to be examined. Indeed the advent of VR has greatly expanded the domain of neuropsychology, and increased our understanding of both normal and, impaired wayfinding behaviour. Overall, such progress has greatly reduced our previous dependence on animal ablation studies.

1.7 Spatial Representation

Introduction

The relationship between living organisms and their environment is crucial for assuring their survival (Bloch & Morange, 1997). The ability to move from one place to another allows both animals and humans means of satisfying their needs (Garling & Golledge, 2000). In order to understand how such transitions occur, one must investigate how knowledge of the environment, which is represented in memory, enables organisms to form and execute movement plans. According to Tversky (2000), at a global level, an organism needs a mental representation of an area and that it is from this overview of space that a feasible route is determined. A route is defined as a trace of the planned or travelled sequence of path segments and turn angles that are followed in order to get from an origin to a specific destination. The process of defining a route and finding one's way along it depends on the purpose(s) of the trip, and whether or not it involves single or multiple stops (Golledge, 1999). Furthermore, the organism needs to know how to negotiate its route i.e. how to maintain course while avoiding obstacles of different sorts. Each of these levels requires different kinds of information from the world and the brain, which is integrated in the formation of spatial representations. Although these representations are useful in orienting in a given environment, they also contribute to the organisation of gathering new incoming spatial information (Thinus-Blanc & Gaunet, 1999). Thus, constructing a spatial representation is an everyday task, and the ability to do so is essential to the survival of organisms. The following discussion will focus on spatial representations in

adults, with a particular emphasis on environmental learning via navigation or route-based knowledge. For detailed discussions on the development of spatial representations in children, see Millar (1994) and Overman et al. (1996).

1.8 Egocentric and allocentric spatial representations

According to O’Keefe and Nadel (1978), there exists a dichotomy between two particular forms of spatial representation or strategy, egocentric (i.e. ego-centred) and allocentric (also referred to as exocentric or exocentred). An egocentric strategy or representation refers to the discrimination of a spatial locus with reference to the body midline or vertical visual meridian. The term has been used in at least two ways. Firstly, to refer to the encoding of spatial positions of distal objects by reference to an ego-centred co-ordinate system, implying a role in the cognition of large-scale spaces and secondly, in terms of the relationship of the observer to near objects, particularly objects that are within reaching distance. Egocentric space is important because it includes the region of central space to which our sensory processes are most sensitively directed and the use of egocentric co-ordinates enables the identification of spatial loci in relation to the body midline (Foreman and Gillet, 1997). However, the body midline and vertical visual meridian are always shifting, as the organism is never completely still and the egocentred system does not produce a stationary egocentred array, except for the briefest periods of time between successive saccadic eye movements or bodily adjustments. Thus, spatial processing becomes more complex once the organism begins to move around in space and involves memory for inter-relationships between objects in a more global or allocentric spatial framework. Consequently, compared with egocentric space, allocentric space is likely to involve a much greater memory component, and utilise a wider range of both perceived and non-visible cues. Sholl (1996) suggests that travel requires humans to activate both processes to facilitate spatial knowledge acquisition – person-to-object relations that dynamically alter as movement takes place (egocentric referencing) and a more stable object-to-object allocentric representation that anchors their cognitive map. It is now well-known that the hippocampus plays a critical role in subserving allocentric representations (O’Keefe and Nadel, 1978; Burgess et al., 2002; Good, 2002).

1.9 Modes of acquiring an internal representation

There are many ways that one can learn an environment (Tellevik, 1992). When the environment is new, novel, or unexperienced, possible learning strategies include active search and exploration, and a priori familiarisation through the use of secondary information sources such as maps, photographs and videos etc. In general it is accepted that the two most common ways of learning an environment are by acquiring route- or survey-based knowledge. Route-based knowledge is characterised as knowledge of a spatial layout from the perspective of a ground-level observer navigating the environment. It is differentiated from survey knowledge, which is characterised by an external perspective, such as an aerial or map-like view, allowing direct access to the global spatial layout (Shelton and Gabrielli, 2002). Evidence for a fundamental distinction between these two types of spatial information has come from the behavioural analysis of human spatial cognition (Peruch et al., 2000; Golledge, 1999; Thorndyke and Hayes-Roth, 1982; Siegel and White, 1975; Tversky, 1991). Route-based environmental learning is perhaps the most common way used by humans (MacEachren, 1992). It involves recognising an origin and a destination and identifying route segments, turn angles, and the sequence of segments and angles that make up the desired path.

1.10 Paradigms used in investigating spatial representation and navigation in humans

According to Tversky (2000) human travel occurs under a variety of circumstances. For example, a person can be transported or otherwise passively guided through an environment. Alternatively, the person can explore the environment without having any particular goal in mind or the individual may actively seek a particular destination. In recent years, there has been a great interest in studying human navigation through the use of many diverse and sophisticated paradigms. However, it is important to note that although the vast majority of studies have not distinguished between route and survey knowledge, they appear to have typically probed route learning and its consequences.

Virtual Reality Environments

According to Held and Durlach (1992), an important advantage of virtual reality (VR) is that it elicits a strong sense of 'presence' compared to table-top tests. This has been defined as the subjective experience of being in one place when one is physically in another. Witmer and Singer (1994) found significant correlations between 'presence' and performance in VR environments; in consequence Burgess et al. (2002) have suggested that there is a good correspondence between the spatial knowledge acquired in a real world and a model of that environment in VR. However, in order to be effective, VR environments must contain features of real-world environments such as realistic landmarks. The majority of VR paradigms involve the participant navigating through a city or town (e.g. Gaunet et al., 2001; Spiers et al., 2001a, 2001b). However, a number of researchers (e.g. Aguirre et al., 1996; Maguire et al., 1998; Astur et al., 1998; Sandstrom et al., 1998) have used virtual maze paradigms, adapted from tasks such as the Morris water maze, (usually associated with studies of rodent spatial representation) to investigate human navigation.

VR town navigation

From their studies focusing on navigation in VR towns, Maguire et al. (1998) concluded that the output of the right hippocampus was a vector that continuously pointed to the goal direction; a finding that was consistent with Burgess and O'Keefe's (1996) model of the rat hippocampus. The left hippocampal activation was associated with successful navigation, but was not as sensitive to accuracy in navigation as the right hippocampus. Maguire et al. suggested that the left hippocampus had a less specifically spatial and possibly a more verbal role in memory. This assumption is consistent with a number of studies (e.g. Astur et al., 2002; Worsley et al., 2001) that have shown how lesions to either the left or right MTL regions in humans negatively affected navigation, although right-sided impairments were more generally associated with spatial memory deficits.

VR maze navigation

The main finding from these studies has been that successful navigation in a virtual maze is associated with increased activity in the parahippocampal gyrus but not the hippocampus, implying that, in human spatial mapping, the parahippocampal gyrus is the crucial neural structure (Aguirre et al., 1998). However, Epstein and Kanwisher (1998) demonstrated parahippocampal cortex activation in their investigation of memory for scenes, when presented as route-perspective images, a finding confirmed in a PET study by Nakamura et al. (2000). The parahippocampal gyrus may support the processing of spatial information that is present in the visual scene, for example, extracting the distances to the nearest landmarks or boundaries (Burgess et al., 2002; Aguirre et al., 1998). A recent study by Astur et al. (2002) used a VR Morris water maze task and reported severe spatial memory impairments in a group of right and left hippocampal patients compared to age-matched patients with resections outside of the hippocampal region and age-matched healthy controls. Astur et al. suggest that these deficits may be attributed to the hippocampal patients' inability to integrate visual motion (optokinetic) and vestibular information in order to successfully engage in path integration or cognitive mapping strategies.

1.11 Real world navigation

In general, imaging studies have repeatedly shown activation of the hippocampus proper in the recall and generation of routes through a real city and recalling a prelearned route in the real world (Burgess et al., 2002). Increases in hippocampal activity have been consistently reported when subjects learned how to navigate through a real town (Maguire et al., 1996), by recalling routes through a real city (Maguire et al., 1997) or by recalling a route learned in the real world before scanning took place (Ghaem et al., 1997). Consistent with the observations from VR town studies, activation of the right hippocampus in real-world navigation tasks is associated with accurate wayfinding, whereas the precise functions served by the left hippocampal activation remain unclear (Maguire et al., 1998). Most importantly, however, Maguire et al.'s (1997) study with London taxi drivers demonstrated experience-dependent structural plasticity in the human brain

and it succeeded in providing evidence for an intimate link between the human hippocampus and navigation. Maguire et al.'s (1997) findings were also supported by Ghaem et al.'s (1997) PET study using a Mental Simulation of Routes (MSR) task, which showed that engaging in mental navigation along a learned, real-world route activated the right middle hippocampal areas, as well as the posterior hippocampal areas bilaterally. Visual recall elicited bilateral activation of the middle hippocampal regions, the left inferior temporal gyrus, and left posterior hippocampal regions. Ghaem et al. (1997) suggested that the left hippocampus was involved in the recall of the relation between whole-body movements and the environment.

Viewpoint dependent studies

VR paradigms have also been designed to test the effects of manipulating the subjects' viewpoint on their subsequent performance of different tests of spatial representation. King et al. (2002) stated that the results from such studies have yielded three important findings. Firstly, automatic processes may support the accommodation of a change of viewpoint within one's mental representation of object location (Wang and Simons, 1999). Secondly, Christou and Bulthoff (1999) showed that the important factor in these studies was the movement of the viewpoint relative to the participants' cognitive model of the world rather than actual movement and the attendant vestibular and proprioceptive feedback or movement of the objects relative to the subject. Finally, when subjects were shown a scene of scattered objects from one viewpoint and given a recognition memory test using scenes from a different viewpoint, their response latencies varied linearly with the angular difference between the views (Diwadkar and McNamara, 1997). These findings are consistent with those obtained by Easton and Sholl (1995) who demonstrated a strong correlation between reorientation distance (either translation or rotation) and reaction times in their investigation of the effects of imagined movements on spatial location. In sum, it is thought that the use of an allocentric process capable of arbitrary manipulations of viewpoint within 3D space appears to be specifically dependent on the hippocampus (Vargha-Khadem et al., 1997).

Passive navigation

VR paradigms have also been used to study passive navigation. Gaunet et al. (2001) examined spatial memory of a virtual city using active, passive and snapshot exploration methods. They found that accuracy in scene recognition and estimation of the direction of the origin of the path was not influenced by the exploration conditions. In contrast, however, the reproduction of the path shape was affected, with greater total distance and angle reproduction error scores following snapshot exploration than active and passive explorations. This finding highlights the importance of continuous updating in learning a novel environment and implies that a continuous stimulation of visual exploration enhances the ability to reproduce the shape of a path previously travelled. Being able to engage in continuous updating requires an ability to fill in the gaps between snapshots based on the interpolation of one's position related to the previous snapshot. Gaunet et al. proposed that during snapshot exploration, the processes used by participants (either creating a mental frame of reference or engaging displacement updating) were not adequate for path shape reproduction.

Blind navigation

Most research on human cognitive mapping has focused on vision since it conveys the important information about the spatial layout of the near and distant environment, and also the details contained in maps, and aerial photographs and so forth. However, it is clear that some blind persons are able to navigate and to form cognitive maps of the environment using the remaining information available to them (audition, olfaction, touch, proprioception and efference copy) (Peruch et al., 2002). A number of researchers (e.g. Loomis et al., 1993; Rieser, 1989; Berthoz et al., 1995) have focused on the ability of sighted individuals to navigate without the use of vision. For a more detailed account of cognitive mapping without visual experience, see Gaunet and Thinus-Blanc (1996), Thinus-Blanc and Gaunet (1997), and Ungar (2000). Thomson (1983) has shown that humans can reach a previously seen target on the floor several metres away with eyes closed. Thus, information about step length, derived from proprioceptive or outflow motor command signals as well as from vestibular signals could contribute to

the updating of the mental representation of the subject's location in space and allow for path integration (Mittelstaedt & Glasauer, 1991; Glaeser et al., 1994). Rieser (1989) and Loomis et al. (1993) have discussed the ability of persons, with and without vision, to imagine standing at a known location and to indicate by pointing or walking toward, the direction of obscured locations. Accuracy was seen to vary considerably depending on the participant's familiarity with the test area. This implies that in unfamiliar environments if directions are not well known large errors in wayfinding may occur either in terms either of actual travel or in verbally describing or sketching where to travel. Sholl (1996) suggests that this difficulty may arise from an inability to relate self-to-object representations to object-to-object representations.

1.12 Neural substrates of route- and survey-based learning.

A recent study by Mellet et al. (2000) focused on brain activation during mental imagery after route and survey learning. Route and survey imagery elicited activation in the right hippocampus, but bilateral activation of parahippocampal gyrus was found for route imagery exclusively. However, this study focused on previously learned environments and not the encoding of novel environments. Recently, Shelton and Gabrieli (2002) investigated the encoding of two different VR environments (one from a route and the other from a survey perspective) among a group of healthy volunteers. They aimed to determine whether the two types of spatial information were distinguished in the brain by recruitment of different areas or differential activation within the same spatial processing network.

The results showed that route and survey encoding led to different mental representations of the spatial environments, as depicted in the ways in which maps of the environments were drawn. However, both types of encoding yielded almost equivalent accuracy in tasks measuring map-drawing and recognition. This was an important demonstration since it implied that any differences in brain activation that were found, could not be attributed to encoding success or failure, but instead reflected differences in the underlying processing. Route, but not survey encoding activated bilateral MTL (including parahippocampal cortex and posterior hippocampus), postcentral gyrus, right

posterior cingulate and left medial frontal gyrus. Survey encoding resulted in greater activation than route encoding in a number of areas also active for route encoding, including bilateral fusiform and inferior temporal gyri and posterior superior parietal cortex.

Shelton and Gabrieli proposed that the increased activation of a specialised subset of regions by survey encoding implied that the survey-based system developed as a secondary system within a larger route-learning system. This idea supported earlier developmental research (e.g. Siegel and White, 1975), showing that children develop route learning before survey learning. Shelton and Gabrieli also stressed two important differences between route and survey encoding that may be critical to the observed brain differences. Firstly, route perspectives facilitate a sense of immersion relative to survey perspectives, with participants reporting that they felt as though they had actually been in the environment. No such experience was reported for survey encoding, with participants describing the condition as a map. Secondly, the form of updating used was a distinguishing feature. Spatial layout learning from a route perspective required the observer to continuously update changes in the local environment based on movements and turns within the space. Thus, global spatial structure must be constructed from a series of views with only limited visual information available at any given moment. Shelton and Gabrieli suggested that the medial temporal lobe and parietal areas identified for spatial navigation are also responsible for binding together the different aspects of the local environment as it changes. In contrast, survey encoding allows more direct access to the global structures of the environment and requires updating that is continuous with this global structure rather than relative to bodily orientation in space. This view contrasts with Peruch et al.'s (2002) suggestion that despite the large differences in the type of information used to acquire environmental knowledge, the resulting representations themselves may be quite similar.

1.13 Path integration as a mode of navigation

Path integration (PI) is the inclusive term referring to the updating of position on the basis of velocity and acceleration information (Gibson, 1950; Loomis et

al., 1999; Etienne, 1992). Is likely to involve an azimuthal reference (e.g. the sun or a mountain range), vestibular inputs, and proprioception, possibly aided by optic flow and local features of the environment (Tversky, 2000). Although PI is based on route information, the internal representation underlying it is very different from what is referred to as route knowledge (Loomis et al., 1999). The internal representation of a route that has been traversed contains information about the various path segments and turns as well as off-route landmarks that might be used in subsequent piloting. In contrast, the representation underlying PI is a constantly updated abstraction derived from computations on the route information. A more detailed account of models of PI can be found in Loomis et al. (1999) who have also investigated the use of spatial language in facilitating updating (Loomis et al., 2001).

Although there is wide support for the idea that the hippocampal formation is involved in PI, these studies have largely been conducted with animals (e.g. McNaughton et al., 1996; Markus et al., 1994); there is a paucity of studies examining the process of path integration in humans. However, a recent study by Worsley et al. (2001) specifically focused on the role of the left and right temporal lobes (including the hippocampal region) in human path integration. From the results of this study, it was concluded that path integration involved a number of key processes. These included the establishment of an initial reference point, the monitoring of the relevant self-motion inputs, the processing of self-motion inputs to derive information about distance and direction travelled, and the integration of distance and directional information to derive a homing vector. Finally, spatial updating is served by a mnemonic component that keeps track of the outbound route and/or the distance and direction of the initial reference point relative to the individual's current position (Worsley et al., 2001).

1.14 The role of the vestibular system in human navigation

A large number of studies have focused on the vestibular system and its role in human navigation. This is largely due to the well-documented vestibular-hippocampal interactions (e.g. Smith, 1997). Taube (1995) and Sharp et al. (1995) have also shown a route from the vestibular nuclei through the anterior

thalamus, the mamillary bodies and the subiculum that could reach the hippocampus after receiving visual environmental information from the parietal cortex. They suggested that this circuit contributed to the reconstruction of spatial localization and movement detection. In an fMRI study by Lobel et al. (1996) caloric stimulation was applied to seven subjects by injection of cold water to the left ear and compared with a rest condition. The results showed bilateral activation of both the hippocampus and hippocampal activation, with this activation being more consistently reported for the right side. Similar activations of the hippocampus in monkeys have been demonstrated by O'Mara et al. (1994) and also in the rat (Gavrilov et al., 1995; Wiener et al., 1995).

Although some researchers (e.g. Reiser, 1989) argue that actual movement is critical for keeping track of orientation, the contribution of the vestibular system to the orientation and localisation of the body in space after a displacement in animals and humans has long been suggested (Beritoff, 1965; Potegal, 1982, Telford et al., 1995). Beritoff (1965) observed that blindfolded deaf-mute children with lesioned labyrinths could not retrace the route along which they had been taken, when compared to normal children. His conclusion that the vestibular organs were necessary for navigation in the dark has been supported by more recent studies (e.g. Ito et al., 1992; Ito et al., 1995; Glauser et al., 1994). Takei et al. (1997) also found that patients with unilateral vestibular damage tended to deviate or even fall to the inside of a circular path when they were turned toward the affected side. In contrast, normal adults could remember a previously walked circular path and reproduce the trajectory with reasonable accuracy when visual and auditory cues were eliminated (Takei et al., 1996).

Berthoz and his colleagues have also shown that humans have the capacity to compute actual displacement during passive whole-body motion on the basis of vestibular signals (Berthoz et al., 1995; Berthoz, 1997; Berthoz, 1999). They proposed that internally simulated action was a fundamental element of perception and spatial memory and that somatosensory and vestibular information was important for keeping track of turning motion. These sensory cues were used to infer headings and spatial relations of surrounding objects

(Berthoz et al., 1995; Takei et al., 1996; Takei et al., 1997). Berthoz (1999) suggested that vestibular patients had a specific deficit of the head-direction cell system, which rendered them unable to store directional information. Furthermore, in the absence of vision or in the presence of conflicting visual cues, it results in a deficit in the evaluation of direction. However, these ideas have not remained unchallenged; Burgess et al. (2002) posited that self-motion produced idiothetic signals that automatically updated the internal spatial representation of an environment in a more accurate way than one's ability to deliberately perform the equivalent mental rotation. However, unlike Berthoz, they stated that this process involved updating a viewpoint within a cognitive mental model that was not dependent upon vestibular or proprioceptive signals.

1.15 Individual differences and gender differences

Detailed accounts of individual differences in wayfinding behaviour and spatial navigation can be found in Eals and Siverman, (1994), Allen (1999) and Maguire et al. (1999) respectively. Gender differences in spatial navigation have also been recently highlighted by the results of a number studies using VR paradigms. Moffat et al. (1998), Astur et al. (1998), and O'Laughlin and Brubaker (1998) have shown male advantages in navigation performance using either landmark-free or landmark-limited environments in computer simulations. Astur et al. (1998) used a VR version of the Morris water maze task to investigate differences between males and females in spatial learning and a consistent sex difference across each of their three experiments was observed. Sandstrom et al. (1998) also investigated the navigation strategies of both sexes, and by manipulating the availability of geometric cues and landmarks as distal cues in a VR water maze task, they found that females relied predominately on landmark cues, whereas males use both geometric and landmark cues. They argued that removal of landmark information was more disruptive to females' performance in this task, implying that males were better able to adapt their search strategy when required to make use of geometric information.

The findings from these studies are consistent with those studies examining real world navigation and wayfinding abilities in men and women (e.g. Brown et al., 1998; Roskos-Ewoldsen et al., 1998; Galea and Kimura, 1992; Ward et al., 1986), which showed that women were less accurate than men on judgements of relative direction. Men have also been found to be more accurate than women in geometric placement of buildings on a map (McGuinness and Sparks, 1983), in locating the direction of landmarks, in estimating travel distances (Holding and Holding, 1989), and in using cardinal reference points to give directions (Ward et al., 1986). These sex differences in human spatial navigational ability may stem from differences in the way males and females represent space (Sandstrom et al., 1998).

Section 3 Cognitive mapping in humans

1.16 How humans record and represent environments

The location of places is usually identified using a global, local or relational frame of reference called 'absolute' location (Golledge, 1999). Instead of using latitude and longitude, people tend to rely on local reference systems, such as street systems or relational forms of references such as 'near the Town Hall' to establish direction. In addition to locating places within some frame of reference, humans also use a variety of 'surveying' practices to locate places and to link the various components such as route integration or triangulation, into a configuration (Golledge, 1999). According to Garling and Golledge (2000), the end product of this selection process is a memory representation or cognitive map of a particular environment.

The term 'cognitive map' was first coined by Tolman (1948) and since then, the term has come into wide usage and is usually taken to refer to the internal representations of perceived environmental features or objects and the spatial relations among them (Golledge, 1999). Cognitive maps are considered the most frequently used representational form of experienced environments in addition to the commonly stored knowledge of individuals or societies and there is emerging evidence that maps are cultural universals (Uttal, 1994). A cognitive map is more abstract than route knowledge and has image-like

properties that allowing an individual to plan effective short-term cuts and detours and to quickly estimate distances and bearings from any location within the map to any other such location (Peruch et al., 2000). It is commonly agreed that cognitive maps consist of points, lines, areas surfaces, and direction, which are learned, experienced and recorded in quantitative and qualitative forms. When quantitatively encoded or interpreted they facilitate manipulation of information using Euclidean geometry and mental trigonometry. When qualitatively encoded they provide information on order, inclusion, exclusion or other topological relations.

1.17 Cognitive Map Theory

In their book, 'The Hippocampus as a Cognitive Map', O'Keefe and Nadel (1978) proposed that the hippocampus was dedicated to creating and maintaining a mental map of space. They suggested that the hippocampal system integrated spatial information into a viewer-independent (allocentric) representation in the form of a cognitive map (Worsley et al., 2001). The allocentric representation may reflect the ability to store a single integrated representation of the environment and the locations of all the objects presented in a single trial, rather than relying on sensory snapshots of the presentation of each object (Burgess et al., 2001). According to Redish (1999), Cognitive Map Theory rested on two observations. The first concerned the discovery that some complex spike cells in the rat hippocampus so called because of their pattern of electrical discharge, were selectively active when the animal was in certain places in its environment (O'Keefe and Dostrovsky, 1971). The second observation for the cognitive map theory was that damage to the hippocampus disrupted spatial orientation in rats; animals with lesions of the hippocampus or with their hippocampus removed could not find their way around, even in familiar environments (Morris et al., 1990). Similar results have been consistently reported from studies of humans with hippocampal damage; for example, see King et al.'s (2002) case study of patient Jon, who had bilateral hippocampal damage. These results indicated that the allocentric behaviour supported by the hippocampus was achieved by mental manipulations of viewpoint within 3-D space, which were applied to viewpoint dependent (i.e. egocentric or iconic) representations as suggested by O'Keefe (1993). Burgess

(2002) proposed that the hippocampus may constrain the set of information retrieved or reconstructed from memory to be consistent with perception from a single position while also facilitating the search through sets of retrieved information consistent with perception from positions defined by bodily movements from other well-remembered positions. Although the idea of the cognitive map has been an important and influential stimulus to research, Sherry and Healy (1998) argue that it is really more a metaphor than a theory. They assert that research on path integration, landmark use and so forth are attempts to specify more concretely exactly what makes up a ‘cognitive map’ of space. In the following parts of this section, the focus will be on different aspects of the cognitive mapping process in humans, with the intention of highlighting the importance of landmarks in these representations.

1.18 Ways of acquiring cognitive maps

Many studies have documented the elaboration of cognitive maps in humans and it appears that this process follows that of environmental learning as mentioned earlier. According to Shemyakin (1962), people first construct ‘route maps’ and then acquire higher levels of spatial knowledge in the form of more detailed ‘survey maps’ which match the topography of the layout. In this manner, humans perform cognitive mapping both while travelling through environments and through the use of ‘spatial products’ (Liben, 1981) such as maps, photographs, videotapes, verbal descriptions and most recently, virtual environments. McEachren (1986) suggests that the simplest way for humans to internally or externally represent a route is through the use of strip maps, which have been in existence for thousands of years.

Siegel and White (1975) and Pick and Lockman (1981) make the distinction between three levels of spatial knowledge, memorisation of main landmarks, integration of those landmarks into a path or a sensorimotor sequence, and elaboration of a survey-type representation where landmarks and paths are interconnected. Thorndyke and Hayes-Roth stated that the nature of the cognitive map formed depends to some degree on the information available during knowledge acquisition. It may first consist of declarative knowledge, which with practice becomes transformed into more automatic procedural

knowledge and a common assumption is that the long-term memory representation becomes more complete and accurate (Tversky, 2000). Golledge (1978) showed that frequency and length of exposure to the environment were found to correlate how accurate recall was. Recently, Mellet et al.'s (2002) PET study investigated the brain areas activated when participants built maps of an environment from reading a descriptive text, and showed that participants were also able to produce accurate drawings of the maps they had created in this way. This indicated that they had formed a veridical representation of the environments described and were able to convert the descriptive text into an image-like representation when required.

Views and scenes

Cognitive maps schematise the two-dimensional horizontal slice of the world (Tversky, 2000). By contrast, views schematise vertical slices of the world. According to Kuipers (1978), views consist of a place description, a path description, a direction, an orientation and a heading. Scenes seem to be so important to human behaviour that a region of the parahippocampal cortex appears to be dedicated to the recognition of them (Brewer et al., 1998; Epstein and Kanwisher, 1998). However Simons (1996) suggested that although human's general recognition of environments was excellent, changes in details and objects often went unnoticed, provided the general configuration remained the same.

1.19 The use of landmarks in cognitive mapping

From the point of view of wayfinding, the most important features of views are landmarks. They may be defined in a number of ways, such as the strategic foci toward or away from which one travels, intermediate foci on courses and routes that assist spatial decision making, or significant physical structures, buildings or culturally defined objects that stand out from their surroundings (Golledge, 1999). Landmarks are often noticed and remembered because of dominance of visible form, peculiarity of shape or structure or because of sociocultural significance. The traditionally-used concept of a landmark has two distinct components: it is capable of attracting attention, being commonly recognised by many people and in some cases, landmarks are accrued

significance in an idiosyncratic way (e.g., place of work). Whether defined quantitatively or qualitatively landmarks usually act as anchor points for organising other spatial information into a layout and may thus act as primary organising features in cognitive maps (Couclelis et al., 1987). Along routes when choices have to be made at intersections, specific memorisation of a landmark can help to specify when to turn and which route to select next.

The significance of landmarks

Daniel and Denis (1998) found that in asking students to describe three routes on a university campus, about 17% of utterances prescribed an action, 36% prescribed an action with respect to a landmark, 33% introduced a landmark and 12% described a landmark. Overall, landmarks seem to be selected on the basis of visibility, pertinence, distinctiveness and permanence. They served several functions: to signal the place of action change, to locate other landmarks and to confirm the route. This finding supported that obtained by Heft (1996), who showed how routes could be learned by film segments rather than language.

Neuropsychological evidence for the existence of a specialised area within extrastriate cortex which is sensitive to ‘building’ stimuli has come from a subset of patients who suffer from topographical disorientation, a disorder characterised by a set of neuropsychological deficits following different, isolated brain lesions (Aguirre and D’Esposito, 1999). One such deficit is landmark agnosia (Whiteley and Warrington, 1978; Levine et al., 1985; Aguirre et al., 1998) and is separate from other agnosias, such as general object agnosia, or prosopagnosia. Aguirre et al. (1998) suggested that landmark agnosia patients had sustained damage to a cortical region that was specialised for the perception of visual stimuli with a particular orienting value (i.e. isolated landmarks as well as ‘scenes’ of the environment). From their fMRI study with healthy controls, Aguirre et al. found a region in the anterior area of the right lingual gyrus, which they tentatively dubbed ‘lingual landmark area’, that appeared to be maximally sensitive to buildings as opposed to objects or faces. Importantly, this critical area is adjacent to the parahippocampal gyrus and Duvernoy (1991) remarked that the anatomic boundary between the

superior lingual gyrus and the parahippocampus was poorly defined. This led Aguirre et al. to propose that the region identified in their studies happened to be the same as that found by Epstein and Kanwisher (1998), which they termed the 'parahippocampal place area'. This line of research is highly consistent with the discovery of hippocampal 'view cells' in the primate hippocampus (Rolls and O'Mara, 1995).

1.20 Functional properties of cognitive maps

Thinus-Blanc and Gaunet (1999) proposed a twofold function of spatial representations. Cognitive maps are necessary for planning trajectories such as shortcuts and detours, but they also control the organisation of the spontaneous acquisition of new spatial information. Scholl (1996) and Thinus-Blanc and Gaunet (1999) proposed that existing cognitive maps shaped the nature of newly constructed maps, which in return, modified and updated previously established maps. The importance of the cognitive map in preserving the object-to-object relations of the real world independently of any change in perspective resulting from altered location cannot be overstated. Furthermore, the results from King et al.'s (2002) viewpoint-dependence study, provided strong evidence for idea that the hippocampus is crucial in subserving allocentric spatial representations. Sholl (1987) also showed that humans could point successfully to unseen but familiar locations in space. By superimposing the polar coordinate body centred self-to-object relations over the stored object-to-object relations, continuous positional updating takes place (e.g., piloting in air and sea navigation by humans; Golledge, 1999).

1.21 Limitations of cognitive maps

All conceptions of cognitive maps recognise that not all the information in the environment is represented; much of it is left out and what is included is schematized, simplified or idealised (Tversky, 2000). At later stages of acquisition when the cognitive map guides choices of places, paths and wayfinding decisions, furthermore limitations are applied to the subsequent selection of information about the environment. Therefore, the cognitive map is unlikely to be fully complete and many inaccuracies are never corrected (Garling & Golledge, 2000). Incompleteness of cognitive maps resulting from

deliberate selection of available information leads to a hierarchical organisation of information in memory and the use of human-based methods in creating spatial representations implies that humans' cognitive maps are error prone, leading to distortions and fragmentation (Golledge, 1999).

Sex differences in cognitive mapping

Although it has been argued that males and females tend to use different strategies when engaging in navigational tasks and wayfinding behaviour, adopting one strategy over another may not lead to advantages in the cognitive maps acquired. In their study of cognitive mapping, and mental rotational ability, O'Laughlin and Brubaker (1998) found a gender difference favouring men for the mental rotation tasks, but no gender differences were found in the cognitive mapping test. This finding implies that although men and women use different strategies to generate spatial representations, their cognitive mapping abilities were equivalent. However, O'Laughlin and Brubaker noted that women expressed less confidence in the accuracy of their abilities, a finding supported by Lawton (1994). More detailed accounts of sex differences in spatial abilities from an evolutionary perspective, are contained in Gaulin and Fitzgerald (1986,1989), Greary, (1995,1996), Self and Golledge (2000) and Tooby and Cosmides (1992).

1.22 Summary of Sections 2 and 3

The discussions contained in Sections 2 and 3 of this chapter have provided unequivocal support for the involvement of the hippocampal formation in human spatial representation, navigation and in the acquisition of cognitive maps. The evidence provided by Shelton and Gabrieli's (2002), which showed that route learning involves activation of bilateral parahippocampal cortex and posterior hippocampus strengthens this assertion, which is further supported by the Ghaem et al.'s observation that recalling a route learned in the real world prior to scanning activates the hippocampus. In addition, viewpoint-dependent studies such as those carried out by King et al. (2002) and Burgess et al. (2001), have shown how patients with hippocampal and/or parahippocampal lesions are impaired in the recognition of environments from a new viewpoint. These findings provide support for O'Keefe and Nadel's

(1978) suggestion that the hippocampus supports spatial behaviour when a representation of the relative positions of the elements making up an environment is required i.e. an allocentric frame of reference is needed. In the following section of this chapter, attention is directed towards memory outside the spatial domain and the focus will be on a particular type of declarative memory, namely episodic memory.

Section 4 Declarative memory and the role of the hippocampus

1.23 How is memory organised in the brain?

Declarative memory is the conscious memory of facts and events, associated with the characteristic phenomenal experience of recollection. Autobiographical memory is a typical form of declarative memory, which includes both episodic and semantic aspects (Perani, 1999). The episodic and semantic components of autobiographical memory have been integrated and subsumed into the phenomenon of ‘everyday memory’ by Sutherland et al. (1984). There have been many diverse views on how memory is organised in the brain, from James (1890) considering memory as a warehouse, to the idea of memory being encoded in specific modules that was popular during the 1960s. However, Eichenbaum and Cohen (2001) reject this idea and argue against the use of metaphors which misleadingly treat memory as a special category of brain events or brain activities. Instead, the view of memory organisation they propose has emerged from two basic insights. Firstly, the notion that memory is a fundamental property of the brain and its storage is intimately linked to ongoing information processing in the brain, and secondly, that memory is manifested in multiple ways by multiple functionally and anatomically distinct brain systems.

Multiple memory systems

The idea of multiple memory systems can be traced as far back as 1840, when the philosopher de Biran (cited in Eichenbaum and Cohen, 2001) proposed that habits were expressed in three distinct forms of memory differing in their mechanisms and properties. He named these representative, mechanical and sensitive memory. The primary and secondary memory distinction was

proposed by James (1890), who recognised memory as something altogether different from habit and came up with what is now classed as short-term or working memory and long-term memory. Although the rise of behaviourism was at the expense of the generation of ideas on multiple memory systems, the challenge of cognitivism that came from Tolman and Honzik (1930) spurred researchers on to new ways of thinking about memory. The importance of demonstrating flexibility in the cognitive maps of rodents was paralleled by Bartlett's (1932) development of Schema Theory, which suggested that remembering was not simply a process of recovery or forgetting of items but that memory seemed to evolve over time. The emergence of a cognitive neuroscience of memory began with Hebb's (1949) treatise, 'The Organisation of Behaviour', which provided a possible link between the stimulus-response and field theory views. Importantly, Hebb validated the findings obtained from Tolman's and Lashley's research but he is most famous for his model of synaptic efficacy now known as long-term potentiation (LTP; Bliss and Collingridge, 1993). He also extended Bartlett's views of new learning as guided by and imposed on previously acquired schemata. Further breakthroughs came from the study of human amnesia, the most famous case being that of H.M. (Scoville and Milner, 1957). According to Eichenbaum and Cohen (2001), the findings from this case renewed interest in writings of Ribot (1882), who described several cases of retrograde amnesia and Muller and Pilzecker (1890) and Burnham (1903), who were the first to use the term consolidation. The H.M. case also highlighted an exception to global amnesia, by showing the preservation of the ability to learn new motor skills and repetition priming.

The dissociation between procedural and declarative memory systems was first proposed by Warrington and Weiskrantz (1968) and further investigated by Cohen and Squire (1980) who observed the complete preservation of the acquisition, retention over three months and expression of perceptual skills in amnesic patients who showed severe impairments in recognition and episodic memory. They attributed this finding to functionally distinct memory systems, specifying declarative memory to be critically dependent on the medial temporal lobes and midline diencephalic structures. These remarkable findings

encouraged other researchers such as Graf and Schacter (1985) in their explorations of another dissociation, this time between explicit and implicit recollection. Tulving (1993) also focused on cases of amnesia with impaired episodic memory but preserved semantic memory. From these lines of research, the overall distinction has been between hippocampal-dependent and hippocampal-independent memory in humans.

A taxonomy of memory systems

In the last decade a number of taxonomies of memory systems have been put forward (e.g. Squire and Zola-Morgan, 1991; Schachter and Tulving, 1994), with the most recent being that proposed by Eichenbaum and Cohen (2001) shown in Figure 1.3 below.

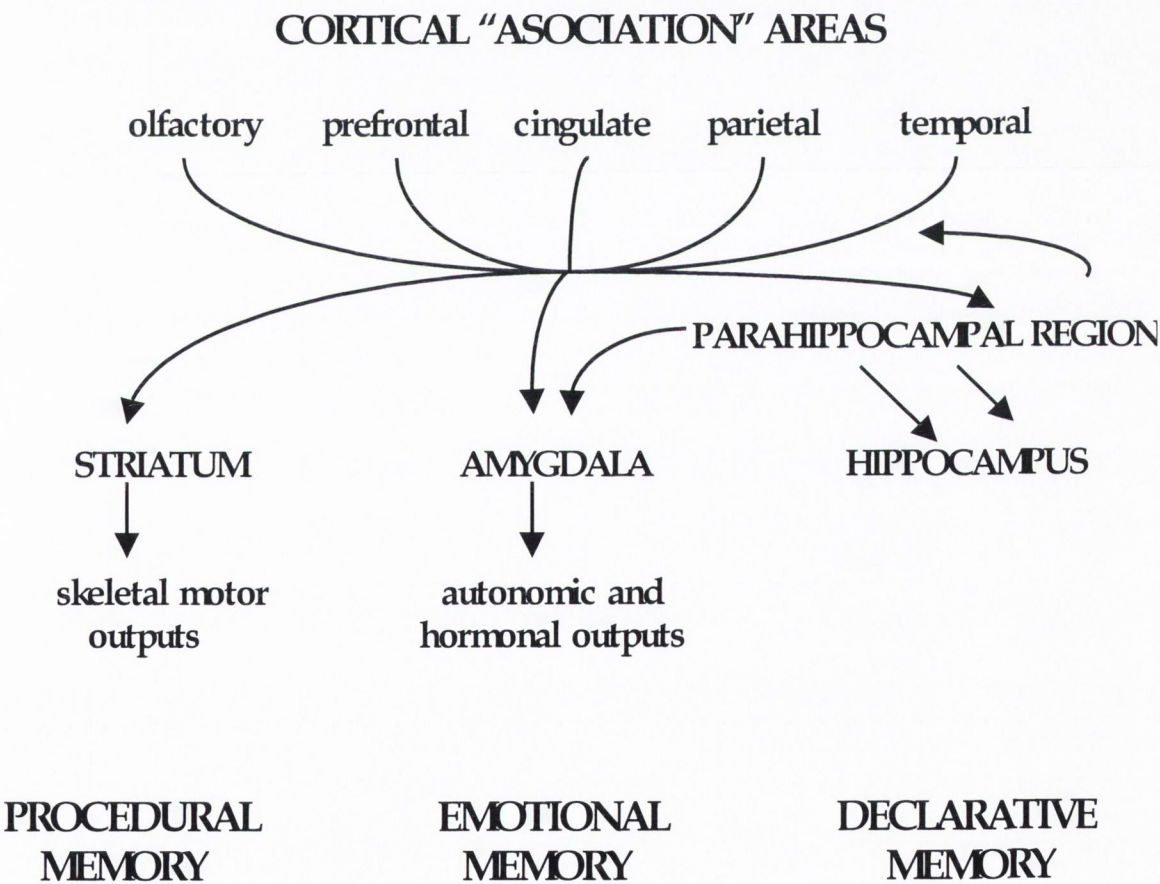


Figure 1.3: Eichenbaum and Cohen’s (2001) proposed taxonomy of brain systems.
(Adapted from Eichenbaum and Cohen (2001) p.56)

This taxonomy outlines the memory systems of the brain and illustrates the multiple pathways for emotional, procedural/habit and declarative memory

systems. What is interesting about this framework is Eichenbaum and Cohen's emphasis on the functional roles of all of the brain structures involved in each of these systems. They also stress the importance of considering the nature of neural coding and neural plasticity that mediates memory at each stage. A detailed account of the emotional and procedural/habit memory systems is contained in Eichenbaum and Cohen (2001); this section focuses on the system for declarative memory.

Categorising memory in terms of capacity and duration

In addition to dividing the phenomenon of memory into different systems, it can also be categorised in terms of capacity and duration. The main concepts of memory used to explore its duration are short-term memory, working memory, recent, or intermediate memory, and long-term memory (Rains, 2002). Short-term memory contains information that is available only for a matter of seconds unless continuous rehearsal takes place and it is vulnerable to distraction. Its limited capacity of about seven items (Miller, 1956) is another characterising feature of this form of memory as is the process of chunking. The notion of short-term memory has been integrated into the more inclusive concept of working memory (Baddeley, 1986, 1994), which is thought to contain two components: a general temporary store (workspace) and an executive function. Working memory is also considered to be important for the regulation and guidance of ongoing behaviour and mental processes and its content is temporary and constantly changing (Rains, 2002). Recent or intermediate memory provides the link between short-term memory (seconds or minutes) and long-term memory (which may be maintained for a lifetime) by retaining information for a time period between these interval extremes. Long-term memory has been hailed as one of the great marvels of our cognitive endowment (Rains, 2002) since it comprises a system that stores an amount of information that is so large that its limits have not yet been defined. Even more remarkable is the way in which this information can be retained over time-scales of years or even a lifetime.

1.24 The cognitive mechanisms that underlie declarative memory

According to Eichenbaum and Cohen (2001), three main theories of hippocampal memory function have emerged from animal models and have strongly influenced theories of human declarative memory. These consist of cognitive mapping theory (O'Keefe and Nadel, 1978), conditional and contextual association theory (Hirsh, 1974) (later revised by Sutherland and Rudy (1989) and termed configural association theory), and 'working' memory theory by Olton et al. (1979). Although McDonald and White (1993) have argued that the hippocampus is a critical part of a memory system for the acquisition and flexible expression of (spatial) relationships among stimuli, Kesner (1990) suggested that the hippocampus encoded both spatial and temporal attributes for stimuli. In the following section, the main reasons why the hippocampus has become the main focus for research into the brain mechanisms underlying declarative memory will be explored.

1.25 The research paradigms used to investigate hippocampal involvement in memory.

Animal research paradigms

Eichenbaum and Cohen (2001) assert that O'Keefe and Nadel's central contribution was to assign Tolman's cognitive mapping system to the hippocampus and to use emerging data on the functional correlates of hippocampal neural activity to interpret the behavioural effects of hippocampal damage in animals in terms of this hypothesis. Their findings from hippocampal ablation studies and the discovery of hippocampal place cells (O'Keefe and Dostrovsky, 1971) led O'Keefe and Nadel to conclude that the hippocampus mediates spatial memory via a locale system. Further accounts of this theory can be found in Redish (1999).

Synaptic plasticity model – hippocampal LTP as a model memory mechanism

LTP was first discovered by Bliss and Lomo (1973), and what fascinated researchers were the remarkable parallels between properties of LTP and memory. Morris (1989) noted a number of fundamental properties that made LTP such an attractive model of memory. LTP is a prominent feature of the physiology of the hippocampus and develops very rapidly, as would be expected in a plausible memory mechanism. Furthermore, the effects of LTP

can be enduring and it has the sort of specificity that one would require of a memory mechanism. This phenomenon parallels the natural specificity of our memories, in which we are able to remember many different specific episodes with the same person and thus would be a key requirement of any useful cellular memory mechanism. Finally, the property of LTP associativity is especially appealing because it offers a cellular model of Hebb's (1949) postulate regarding the mechanism for structural change in neural connections. However, the discovery of another form of potentiation within the CA3 region of the hippocampus led Eichenbaum and Cohen (2001) to stress the importance of considering the possibility of multiple hippocampal plasticity systems.

Human amnesia studies

According to Eichenbaum and Cohen (2001), the exceptions to severe global amnesia exhibited by H.M. led to further insights into the nature of hippocampal processing in memory. Additional insights came from the work by Cohen and Squire (1980) whose findings concerning procedural and declarative memory were considered a revelation about memory-processing functions of the MTL. The spared learning abilities in amnesia can be summaries to include general skill learning, habit learning (Nissen and Bullemer, 1987), and conditioning (e.g. eyelid conditioning task of Weiskrantz and Warrington, 1979).

1.26 Summary

This section has discussed at length the variety of ways in which hippocampal involvement in declarative memory has been researched. The anatomical characteristics of the hippocampal region, and the high level of connectivity between the hippocampal region and other brain areas such as the inferior temporal cortex, posterior parietal cortex, and prefrontal cortex have been extremely important in the development of different theories of hippocampal functioning. The following section will now focus specifically on the role played by the hippocampus in episodic memory.

Section 5 Episodic Memory

1.27 Introduction

When the concept of episodic memory was first introduced by Tulving (1972), it was thought of as an information processing system that received and stored information about temporally dated episodes or events, about temporal-spatial relations among these events and that retained various aspects of these events. It was also viewed as transmitting specific retained information to other systems, including those responsible for translating it into behaviour and conscious awareness (Tulving, 1999). However, in recent years, there has been a considerable change in this concept, with Tulving (1999) stating that episodic memory is one of several specific memory systems and subsystems. Episodic memory refers to a memory system that makes possible mental ‘time travel’ through subjective time, from the present to the past and to the future, a feat that other memory systems cannot perform. It does so by allowing the individual to re-experience previous events, and to project similar experiences into the future. The mechanism which mediates this process has been termed ‘autonoetic consciousness’ (Tulving, 1983). Autonoetic consciousness enables organisms to perceptually register, internally represent and behaviourally respond to aspects of past events; it ‘confers the special phenomenal flavour to the remembering of past events, the flavour that distinguishes remembering from other kinds of awareness, such as those characterising perceiving, thinking, imagining or dreaming’ (Tulving, 1985, p.3).

1.28 Episodic memory versus autobiographical and semantic memory: distinctions and similarities

The common feature shared by autobiographical and episodic memory is that both are concerned with the recall of personal events and episodes. However, Nelson (1993) asserted that specific events (such as what one had for breakfast), which are part of one’s episodic memory, could fail to become integrated into autobiographical memory due to lack of distinctiveness and

relevance to one's overall life story. It could also be argued that autobiographical memories for lifetime periods do not contain the same level of specificity as is characterised by episodic memory.

Whereas episodic memory is characterised by the presence of a specific spatial and temporal labelling of the memories (Perani, 1999), semantic memory refers to our general knowledge; things we know without any connection to personal experience. This distinction was first made by Tulving (1972), when he stated that episodic memory was associated with the recall of specific events and incidents that were part of an individual's personal history. In contrast, semantic memory was viewed as containing conceptual and factual knowledge that is not consciously linked to events in one's personal lives. Thus, there is a strong phenomenological difference between these two types of memory (Rains, 2002), a difference which was described by James (1890), when he stated that 'Memory requires more than mere dating of a fact in the past. It must be dated in my past. In other words, I must think that I directly experienced its occurrence' (p. 650). In contrast, Rains (2002) states that no such intimacy accompanies facts in semantic memory; they are simply part of our mental lexicon and encyclopaedia.

Similarities between episodic and semantic memory

However, Tulving (1999) also acknowledges that episodic and semantic memory are, in many ways, very similar in that both are complex forms of memory, capable of storing vast amounts of information of many different kinds. Both are cognitive (declarative, or representation) systems whose 'contents' can be described in terms of propositions about objects and their relations and both episodic and semantic memory enable individuals to acquire factual information through different sensory modalities. Furthermore, the acquisition of episodic and semantic information can occur very rapidly, sometimes as a consequence of a single glimpse, or sound of a relevant input. Additionally, both systems can be thought of as being concerned with 'remembering that' rather than 'remembering how' (Tulving, 1999). Finally, episodic memory and semantic memory are similar in that the contents of both forms of memory can be accessed through various routes, most commonly

through conscious, effortful recollection. The important implication from this statement is that access to declarative memories enables individuals to solve new problems by making inferences from memory (Eichenbaum and Cohen, 2001).

1.29 Methods of studying everyday memory in normal populations

There are many diverse ways in which the phenomenon of everyday memory has been explored and the following section will focus on some of the main paradigms used and the problems encountered when trying to investigate episodic and autobiographical memory. Issues concerning the way in which autobiographical memories are structured have been addressed by researchers such as Conway and Bekerian (1987), who suggested that three specific levels of organisation underlie autobiographical memory: lifetime periods, general events and event-specific knowledge. In contrast, Barsalou, (1988) and Conway and Rubin (1993) proposed a hierarchical system of organisation.

Diary studies

From the detailed diary studies that were conducted by Linton (1975) and Wagenaar (1986) a number of interesting findings emerged. Firstly, Linton (1975) noted that one of the main reasons why events were forgotten was because they were so similar to each other. She also found that, as time went by, semantic knowledge increased but memory for specific events decreased. From Wagenaar's extensive recording of events over a six-year period, the types of retrieval cues used were found to greatly facilitate recollection. He also noted that events associated that were emotionally laden and highly salient were far more likely to be remembered.

Event dating

Linton and Wagenaar's research also showed that they could date events in their lives with reasonable accuracy. According to Brown et al. (1985), people sometimes use the amount of information they can recall about an event as a guide in determining how recently it took place. From their 1987 study, Brown et al. observed that participants relied heavily on the use of either public or private 'landmarks' i.e. events whose date they knew reasonably well, to assist

them in the task of public (political and non-political) event dating. More recent studies by Means et al. (1989) and Belli (1998), also highlighted the importance of landmarks in assisting event dating. According to Thompson et al. (1988) and Huttenlocher et al. (1992), many strategies are used in dating events. Thompson et al. found that when subjects attempted to reconstruct the date of an event by referencing it to another event, the other event was almost certain to have been an experienced rather than a reported event. They concluded that reference to an experienced event produced substantially more accurate dating than other strategies (e.g. general reference, prototypic data etc.).

1.29 The self-reference effect and the importance of self-schemas

Rogers et al. (1977) were the first to investigate the 'self-reference effect', which refers to the notion that information about oneself should be better remembered than information of a more impersonal kind. They found that the types of self-schemas or ways of organising knowledge about oneself can play a strong role in shaping the content of an individual's memories by influencing how personal information is perceived and retrieved. Rogers et al. presented participants with a series of adjectives, asking one group to make self-reference judgements and other groups to make semantic, phonemic, or structural judgements. They found that recall of the adjectives was approximately twice as high following self-reference than semantic judgements, an observation that has been consistently replicated by Eysenck (1992). Rogers et al. attributed this effect to activation of a self-schema, which incorporates our self-knowledge into long-term memory. They argued that self-referred judgements engaged this self-schema, particularly in cases of positive judgements. During retrieval, the self-schema acted as a powerful retrieval cue by activating a network of associations.

This view has been challenged by Bower and Gilligan (1979), who argued that self-knowledge did not possess special characteristics. The results of their study, which compared recall following a self-reference task and an other-person reference task, showed that the level of recall was contingent upon familiarity with the person in the other-person reference tasks. For example,

memory performance in the other-person reference task was almost as good as that in the self-reference condition when a person, who was well-known to the participant, was used as a referent.

However, it is generally accepted that schemas influence the encoding, storage and retrieval of information related to a particular domain. For example, daily schemas are descriptions of a typical day. In a more recent study by Eldridge et al. (1994), the researchers focused on whether schematic influences operated in the recall of daily work activities. Participants were asked to describe a typical day at work and were asked to free recall their activities from two different days, yesterday and a day in the previous week. The results showed that people recalled fewer activities from last week than they did from yesterday and those activities that were recalled from last week tended to be those that were in the daily schema. In addition, there was a tendency for individuals with highly elaborated daily schemas to recall more activities from last week when compared with those who had poorly elaborated schemas.

Accuracy of autobiographical memories

Eysenck and Keane (1997) state that one of the major difficulties in this line of research is that of trying to establish the accuracy of an individual's recollection of their personal life experiences. However, this issue was tackled by Neisser (1981), in his examination of the tape-recordings that were at the centre of the Watergate scandal from which he suggested that rather than being strictly accurate, an individual's memory is more likely to be 'true' in that they remember the 'gist' of events. This conclusion was supported by Barclay (1988), who asserted that memory for autobiographical information was sometimes inaccurate in detail, but truthful overall.

1.30 Neuroimaging of episodic memory

The study of episodic memory has been an extremely active area of investigation in the neuroimaging field and the neural correlates underlying this type of memory have been investigated with many paradigms, using various stimuli (verbal and visual) and tasks (recognition or recall). For a detailed review of fMRI and PET studies of medial temporal activations in

episodic memory encoding and retrieval see Schacter and Wagner (1999). Tulving (1999) states that among the most popular approaches are studies comparing semantic and episodic retrieval (Schacter et al., 1995; Maguire and Mummery, 1999; Davachi and Wagner, 2002; Wagner, 2002) and those comparing episodic-memory encoding and retrieval (e.g. Buckner and Koutstaal, 1998; Nyberg et al., 2000; Stark and Squire, 2000; Fernandez et al. 1998). The general consensus is that declarative memory, including autobiographical, episodic and semantic retrieval is dependent on the hippocampal system, whereas non-declarative, implicit memory, as measured by priming tasks is independent of this system (Manns et al., 2000; Schacter et al., 1995; but see also Chun and Phelps, 1999).

1.31 Neural correlates of episodic memory encoding

The most important finding to emerge from studies of encoding has been that hippocampal activation, due to repeated exposure and deep encoding, appears to be associated with successful subsequent recollection, as shown in high recall conditions. Nyberg et al. (1996) found strong positive correlations between verbal episodic retrieval and blood flow in left medial temporal structures. These regions were dominant components of a series of brain regions that distinguished high retrieval from low retrieval conditions. A more recent study by Davachi and Wagner (2002) used event-related fMRI to examine the role of specific MTL structures in learning during relational/configural associative learning and item-based processing. The results showed that the hippocampus proper was activated bilaterally during both the relational and item-based processing but activation was greater for relational processing. In addition, the hippocampal activation during relational processing was correlated with later memory. However, there was no correlation between MTL activation and subsequent memory following rote rehearsal, suggesting the importance of relational processing. Finally, relative to associative processing, item-based processing was associated with greater entorhinal cortex and posterior parahippocampal activation, pointing to a functional dissociation between these regions and the hippocampus.

In their fMRI study of verbal episodic memory encoding, Fernandez et al. (1998) found correlations between the number of successfully encoded words and the level of activation in the posterior part of the hippocampus. Furthermore, across participants, there were no differences between the left and right hippocampal activations. Previous results by Gabrieli et al. (1997) found posterior parahippocampal activation during the encoding of novel pictures, whereas Stern et al. (1996) demonstrated posterior hippocampal and parahippocampal activations using a similar task. However, Fernandez et al. stated that they were not aware of any human lesion study that compared the impact of anterior versus posterior hippocampal lesions, although Sullivan et al. (1995) showed that anterior hippocampal volume reductions in chronic alcoholics were not correlated with episodic memory impairments. Thus episodic memory may not critically depend on the anterior hippocampus. Fernandez et al. proposed a model of episodic memory consisting of two distinct stages of encoding. The first stage involves an initial encoding process such as novelty detection subserved by the parahippocampal cortex and in the second stage a process of memory formation subserved by the hippocampus takes place. This model suggests that preliminary storage of the event then takes place via the pathways between the entorhinal cortex, dentate gyrus, and CA3 region of the hippocampus, including the recurrent collaterals, which enable autoassociative encoding, storage or binding processes (Alvarez and Squire, 1994; McClelland and Goddard, 1997; Rolls, 1997).

1.32 Episodic memory retrieval

According to Nyberg et al. (2000), there is substantial evidence that episodic memory encoding and retrieval processes have different neuroanatomical correlates. A major distinction within the retrieval process can be made between retrieval 'mode', as proposed by Lepage et al. (1999) in their REMO (episodic memory retrieval) model and the recovery of stored information. Retrieval mode is a necessary condition for any episodic retrieval to occur, it is a 'set for treating stimulus events as cues facilitating access to stored episodes' (Tulving, 1983). The second major constituent of the retrieval process is 'ecphory' or actual recovery of stored information. Ecphory occurs when the retrieval cue 'contacts' relevant stored information (Tulving, 1983).

1.33 REMO and HIPER models

Lepage et al.'s (1999) REMO model refers to a neurocognitive state, during which an individual refrains from task-irrelevant processing, and becomes consciously aware of the product of successful ecphory or retrieval. Their PET study attempted to identify the cerebral regions that were selectively activated in REMO. Significant activations were observed in six specific bilateral cortical regions with a prominent right hemisphere bias during both the recognition testing of previously-learned items and the testing of new items. It was concluded that these sites were involved in the establishment and maintenance of a brain state that subserves the cognitive set of episodic memory REMO. These findings point to the necessity for a revision of the retrieval-related aspects of Tulving et al.'s (1994a) 'hemispheric encoding/retrieval asymmetry (HERA) model. However support for the HERA model was provided by Maguire et al. (1999), who concluded that the two hemispheres show an overall disposition for specialisation in episodic memory processes; the left more actively involved in encoding than the right and the right more actively involved in retrieval than the left. Grasby et al. (1993a, 1993b) demonstrated strong positive correlations between verbal episodic retrieval and blood flow in left medial temporal structures. These regions were dominant components of a series of brain regions that distinguished high retrieval from low retrieval conditions. Further evidence of this asymmetry came from Tulving (1999), who observed that in the right temporal areas, encoding and retrieval activations occurred more or less evenly but encoding activations predominated in the left temporal region.

In 1998, Lepage et al. put forward a Hippocampal Encoding/Retrieval (HIPER) model, which proposed that an orderly spatial distribution of changes in blood flow is associated with encoding-related and retrieval-related processes in the hippocampal regions of the brain. Encoding activations were found predominately in the rostral hippocampal regions, whereas retrieval activations predominated in the caudal region. However, these findings have been directly challenged by a number of fMRI studies (Stern, et al., 1996;

Gabrieli, et al., 1997; Fernandez et al., 1998) showing encoding activations in the caudal portion of the hippocampal region instead of the rostral area. Lepage et al. attempted to explain this discrepancy by suggesting that their model may not hold for stimuli such as landscapes or complex scenes and that the processing of such 'spatial' information involves activation of the caudal hippocampal formation.

1.34 The dissociation between the retrieval of personally-relevant episodic events and semantic stimuli.

Although the dissociation between self- and non-self relevant recollection has not received much attention in imaging studies, anatomical and neuropsychological data have stressed the crucial role of the temporal pole in self-relevant memory (Kapur et al., 1992; Markowitsch et al., 1993). It has also been suggested that this area encodes the spatiotemporal uniqueness of specific events, and combines information from hippocampal structures and posterior association regions (Damasio, 1989). Burgess et al. (2002) state that several neuroimaging studies of personal or autobiographical event memory have implicated the medial temporal lobes (Fink et al., 1996; Maguire et al., 2000b; Maguire and Mummery, 1999), and particularly the left hippocampus (Maguire et al., 2000b; Maguire and Mummery, 1999) in personal episodic memory compared with semantic memory (Maguire et al., 2001b). However, activation of left hippocampus in navigation neuroimaging studies (Gron et al., 2000; Maguire et al., 1998a) makes the precise division of labour between the left and right hippocampi unclear.

Maguire and Mummery (1999) stated that the richness and complexity of human memory requires neural bases involving more than one brain region and they focus on the distinction between whether or not events are personally relevant. Tulving (1983) was the first to suggest that memory could be classified into impersonal facts (semantic) and personal events with a specific temporal context (episodic) and more recently, Tulving and Markowitsch (1998) showed that dissociations between episodic and semantic memory could occur, implying that retrieval of stored information could be differentially affected by MTL damage. However, a major distinguishing

feature between clinical and imaging studies is the nature of the stimuli used in studying episodic memory, with clinical work demonstrating the debilitating memory loss in real-world situations, and the latter using more artificial tasks. Maguire and Mummery (1999) attempted to bridge this gap by examining patterns of activation associated with the recall of long-term real-world memories of autobiographical, and public events and autobiographical facts and general knowledge between the years 1977-1998. The specific aim was to assess if connectivity within the memory retrieval network changed as a function of the type of memory being recollected.

The results of this study showed that recalling memories of any type utilised a common neural network. However, a subset of areas within this region responded preferentially to personal time-specific memories, whereas other regions are active for information retrieval in general. Furthermore, it was observed that brain areas located adjacent to each other showed different patterns of activation. For example the lateral temporal cortex and the parahippocampal gyrus were involved with the retrieval of information per se, whereas the temporal polar cortex and the hippocampus were more active for personally relevant time-specific episodes. This suggests that a brain region can have multiple functions during memory retrieval, modulating not just its activity but also its connectivity dependent on the task at hand. These findings, which support those of Tulving and Markowitsch (1998) were later confirmed by Maguire et al. (2001). The observation of hippocampal activation for all memory types is also compatible with declarative theory of memory (Cohen and Eichenbaum, 1993; Squire and Knowlton, 1995). However, the additional activation of the hippocampus for personal time-specific memories suggests that it is this aspect of memory retrieval for which the hippocampus is crucial and is impaired with hippocampal pathology.

Maguire and Mummery (1999) concluded that the left hippocampus plays a more amodal role than the right hippocampus in retrieval and is particularly sensitive to retrieving memories that are time/context specific and personally experienced. However, the precise nature of the left hippocampal role in personal temporal specific memory retrieval remains to be elicited. Further

support for the suggestion that the hippocampus is differentially involved in the recollection of episodic details relative to non-episodic memory has come from studies by Eldridge et al. (2000) and Davachi and Wagner (2002), who stress the crucial role of the hippocampus in relational encoding. Their findings are also consistent with the suggestion that hippocampal activation during associative encoding conditions reflects learning mechanisms important for later remembering, as demonstrated in earlier PET (e.g. Doland and Fletcher, 1997; Henke et al., 1999) and recent fMRI (e.g. Sperling et al., 2001; Stark and Squire, 2000) observations. These studies have specifically shown that the level of activation of the hippocampus during relational encoding was correlated with subsequent memory performance. It is thought that through the establishment of links between these studied items, the hippocampus facilitates the subsequent recall of the learning episode. Thus, a large body of evidence supports the assertion that the episodic and semantic components of declarative memory seem to be dissociable, with the episodic component being more dependent on the integrity of the hippocampal region than the semantic component (Henke, 1999; Conway and Rubin, 1993).

Furthermore, there is evidence that this region is part of a network that supports the screening of incoming information for its novelty value – a process that precedes encoding as proposed by Fernandez et al. (1998). Studies of amnesic patients (e.g., Nadel and Moscovitch, 1997; Vargha-Khadem et al., 1997; Kapur, 1999; Viskontas et al., 2000; Rosenbaum et al., 2000), have shown a dissociation between episodic and semantic memory. In these studies, patients with dense retrograde amnesia for autobiographical episodes and public events were shown to have intact general semantic knowledge for words that came into use during this same period. Kapur (1999) demonstrated that unilateral TLE patients did not show impairment on the recollection of personal semantic memories implying that semantic memories are dually represented in both hemispheres and that bilateral damage is necessary to show such impairment. For episodic memories, however, different aspects may be represented in each hemisphere, making them more vulnerable to loss in the event of unilateral damage. Vargha-Khadem et al. (1997) also showed that children, with bilateral hippocampal damage, were

severely amnesic for time-specific events but showed preserved levels of semantic and factual knowledge. From these results it was suggested that the extra-hippocampal cortex supported context-free semantic memories but that the context-rich episodic memories required additional processing provided by the hippocampus.

1.35 Dissociation between frontal and temporal lobe activation in episodic memory encoding and retrieval

According to Tulving (1999), the results of initial experiments have shown that when subjects have been set into the episodic retrieval mode through appropriate task instructions, a number of cerebral regions, especially prominent in the right prefrontal cortex, become activated regardless of the extent of ecphory, i.e. the actual recovery of specific stored information. The results obtained by Buchner and Koutstaal (1998) and Schachter et al. (1995) suggest that hippocampal activation is more closely associated with the actual recollection of a past event than with the effort involved in attempting to remember the event. The frontal lobes are known or assumed to have many functions, summarised under concepts such as supervision, organisation, integration, executive function, working-with-memory, and self-awareness. Tulving (1999) proposed that the frontal lobes were also involved in episodic retrieval mode, epoch set and autonoetic awareness of the past; for a more detailed account of the contributions of the prefrontal cortex to episodic memory see Wagner (2002). Wagner et al. (1998) identified five sites in the frontal lobes that showed activation associated with episodic retrieval mode. Three of these were in the right prefrontal cortex. They concluded that the consistent prefrontal activation seen in tasks involving episodic retrieval signifies a general orientation of the subject towards the past. They further suggested that the specific brain regions associated with such an orientation depend on the 'context' i.e. the specific features of the retrieval task and subjects' strategies in carrying out the task.

Kirchhoff et al.'s (2000) event-related fMRI study found that the same prefrontal, medial temporal and lateral temporal regions that were sensitive to stimulus novelty also predicted subsequent episodic recall, implying that these

regions played a crucial role in the encoding of events. Although previous studies (Tulving et al. 1994a; Knight, 1996, Schacter and Buckner, 1998a, 1998b) indicated that prefrontal and MTL regions respond differentially to novel relative to repeated stimuli, Kirchhoff et al. were the first to provide evidence of a link between the encoding of novelty and subsequent explicit recall in these regions. For example, Saykin et al. (1999) had demonstrated a dissociation between the processing of novel and familiar words. Although selective left-lateralised MTL activation for both novel and familiar stimuli was observed, within this region, an anterior-posterior dissociation was found; novel words activated an anterior area in the left hippocampus, and familiar words activated an area in the left posterior parahippocampal region. Additionally, the right dorsolateral prefrontal, right superior frontal and left medial parietal regions showed activation to the familiar words. These results showed greater MTL involvement for auditory-verbal word presentation in contrast to right or bilateral activation for visual stimuli seen in prior studies (e.g. Stern et al., 1996; Aguirre and D'Esposito, 1997).

Burgess et al. (2002) state that extensive prefrontal activation has been observed in the retrieval of context-dependent memory in virtual reality paradigms as well as in laboratory settings. However, autobiographical memory studies (Maguire and Mummery, 1999; Maguire et al., 2000b) typically activate only a single area of medial prefrontal cortex. Burgess et al. explain this discrepancy by stressing the similarity of the events used in the VR studies which contrasts with the large variety and differing timescales of autobiographical events. They conclude that much of prefrontal involvement in VR episodic memory tasks may reflect attempts to overcome the interference caused by the similarity of the events and contexts. This hypothesis would be consistent with studies highlighting the role of the frontal lobes in the use of organisational strategies in encoding and retrieval, and the contrasting role of the temporal lobes in the storage of episodic memory (e.g. Owen et al., 1996; Davachi and Wagner, 2002).

Recently Maguire et al. (2001) used event-related fMRI to examine the divergent views on the time-scale of neocortical and hippocampal involvement

in autobiographical memories, knowledge of public events and recall of general knowledge. The results showed that activity in the ventrolateral prefrontal cortex (most notably on the right) was highest during the recall of recent memories and decreased in activation the more remote the memories became. This was true in the case of autobiographical event memories but not for public event memories. In contrast, no overall changes in MTL or specifically hippocampal activity were detected in relation to memory age; the hippocampus was activated when any of the memory types was compared with a control task. It was also found that left hippocampus was particularly activated for autobiographical and public event memory.

The role of the right ventral frontal cortex in episodic memory was also examined by Levine et al. (1998) in their case study of patient M.L. who sustained damage to this region. The results showed a dissociation between frontal and temporal brain regions; although M.L. did not episodically re-experience post-injury events to the same extent as control subjects, he could use familiarity or other non-episodic processes to distinguish events he had experienced from those he had not. Levine et al. concluded that M.L. had impaired autonoetic awareness attributable to right ventral frontal lobe injury, including right frontal-temporal disconnection and that his spared anterograde memory was mediated through increased reliance on MTL structures.

1.36 Theories of Episodic Memory

A plethora of diverse theories of episodic memory functioning have been proposed over the last two decades. Among the most influential are the theories of Declarative-Procedural memory, later termed the theory of Representational Flexibility (Cohen and Eichenbaum, 1993), Consolidation Theory (Squire, 1992; Squire and Alvarez, 1995), and Multiple Memory Trace Theory (Nadel and Moscovitsch, 1997).

Representational Flexibility

According to Eichenbaum and his colleagues (Eichenbaum et al., 1994; Eichenbaum and Cohen, 2000), two characteristics are unique to declarative memory; representational flexibility and compositionality. This idea shares

common features with a number of other recent theories such as the concept of the hippocampus as an autoassociation network proposed by Rolls and his colleagues (e.g. Rolls, 1999; Rolls and Treves, 1998). Eichenbaum's views are also consistent with those of Morris and Frey (1999), who suggested that the hippocampus is critically involved in the automatic recording of attended experience. In addition, O'Reilly and Rudy's (2000) computational principles of learning in the hippocampus and neocortex also stress that the hippocampus learns rapidly, using separated representations to encode the details of specific events while suffering minimal interference.

Further support for the idea of representational flexibility has come from Henke et al.'s (1997) PET study, which showed that human amnesics with bilateral hippocampal damage were more impaired on tests of associative memory than tests of single item memory. Davachi and Wagner (2002) also provided evidence in favour of the idea that the hippocampus is involved in relational or configural processing, whereby multiple features or components of an experience are bound together into an integrated memory (Cohen et al., 1997; Eichenbaum, 2000; O'Reilly and Rudy, 2001). Finally, the idea of a flexible relational memory system is also consistent with King et al.'s (2002) concept of viewpoint dependence which proposes that the hippocampus may constrain the set of information retrieved from memory to be consistent with perception from a single position. However, Good (2002) has remarked that Eichenbaum and Cohen's (2001) over-emphasis on the role of the hippocampus in higher-order association learning implies that this framework has now become less focused on episodic memory functioning.

Consolidation Theory and Multiple Memory Trace Theory

The controversial idea that the hippocampus may play a time-dependent role in the consolidation of information into long-term memory has been strongly debated over the last decade. The most lively discussions on this issue have taken place between the proponents of Classic Consolidation Theory (CCT) (Squire, 1992; Squire and Alvarez, 1995) and those who support Multiple Memory Trace Theory (MTT) (Nadel and Moscovitch, 1997; Nadel et al., 2000). The former account assumes that although the hippocampus is involved

in the encoding of both semantic and episodic information, neocortical areas are responsible for its storage and subsequent retrieval. According to this hypothesis, the hippocampal formation (HF) forms a temporary memory trace, which holds the information about what neocortical regions were simultaneously activated when an event has been registered. Subsequently, consolidation takes place when the HF repeatedly reactivates the cortical and subcortical sites in the same way that they were activated during encoding thereby strengthening the connections between these regions over time. By the time the cortico-cortical connections between the storage sites of the particular event are established, it can subsequently be retrieved without the participation of the hippocampi. This view supports the idea of temporally-graded retrograde amnesia with sparing of remote memories (Squire, 1992; Squire and Alvarez, 1995).

The idea that the hippocampal formation as a temporary store for 'aspects' of information held in short-term memory is similar to the concept of an episodic buffer recently proposed by Baddeley (2000). Although this theory also has links with Qin et al.'s (1999) and Sutherland and McNaughton's (2000) accounts of consolidation, recently Burgess et al. (2002) have highlighted the failure of CCT to address the relationships between different types of explicit memories i.e. topographical, semantic, and episodic. They suggested that the gradual learning of spatial knowledge shows greater correspondence with ideas of semantic rather than episodic memory.

However, the most direct challenge to CCT has come from Nadel and Moscovitch's (1997) MTT which argues that traditional models, such as those proposed by Squire (1992), and Squire and Alvarez (1995) can not account for evidence of very extensive retrograde amnesia gradients, especially for autobiographical memory among amnesic patients. Such theories also failed to explain cases of relatively preserved general semantics (e.g. vocabulary) acquired during these retrograde amnesia periods (Viskontas et al., 2000; Rosenbaum et al., 2000). MTT assumes that the hippocampal complex and neocortex continue to be involved in both the storage and retrieval of episodic memory traces throughout life. In contrast, general semantics are learned and

represented outside the hippocampal complex or medial temporal lobe. Thus, Nadel and his colleagues emphasise a critical distinction between episodic and semantic memory; both are influenced by the hippocampal complex, but only one becomes hippocampally-independent during the course of consolidation.

Strong support for MTT has come from Nadel et al.'s (2000) study, which found that unilateral TL patients showed a retrograde amnesia for autobiographical episodes that extended to childhood. In addition, this effect was shown to be independent of the side of the lesion, indicating that both the right and left temporal lobes contribute to autobiographical memory. More importantly, there was no interaction between lesion onset and retrograde memory loss. Nadel et al. (2000) concluded that each of the regions of the hippocampal complex makes separate contributions either to encoding, storage or retrieval (Gabrieli et al., 1997; LePage et al., 1998; Schacter and Wagner, 1999) and is crucial to memory representations of a particular type, such as spatial, object or objects in particular locations (Aguirre et al., 1996).

1.37 The relation between spatial and non-spatial aspects of hippocampal function.

This section aims to provide the reader with an account of how cognitive map theory has been the driving force behind a number of different theories which aim to bridge the gap between the spatial representation and episodic memory aspects of hippocampal functioning. According to Good (2002), evidence from a plethora of studies with rodents has shown that the hippocampus contributes to processes supporting episodic recognition memory, spatial navigation and context-dependent retrieval processes. He states that the common denominator underlying these forms of learning is a principle that has emerged in many recent theories of hippocampal function, namely that the hippocampus plays a fundamental role in integrating representations. Good asserts that this idea has come from psychological and computational theories of hippocampal function (e.g. Burgess et al., 2001; Eichenbaum, 2001; Rolls and Treves, 1998; O'Reilly and Rudy, 2000). Such theories are based on the premise that representations of objects/events and their spatio-temporal

context are integrated within a neural network instantiated in the hippocampal formation.

1.38 The importance of Cognitive Map Theory

O'Keefe and Nadel's (1978) Cognitive Map Theory has been a primary impetus behind the quest for a better understanding of hippocampal functioning. Although the main focus of the research (on both humans and animals) generated by Cognitive Map Theory (O'Keefe and Nadel, 1978) has been in the spatial domain, the hypotheses pertaining to the role of the hippocampus in episodic memory functioning have recently begun to attract attention. O'Keefe and Nadel (1978) proposed that episodic memory was supported by an allocentric spatial framework which incorporated a linear sense of time and verbal/linguistic inputs (from the left hippocampus). More recently, O'Keefe (1996) proposed that the left hippocampal involvement in episodic memory derived from its undoubted role in the storage of verbal material but that this verbal role may also have a spatial derivative. This implies that the left hippocampus is particularly specialised for extracting the gist of a narrative that has been transformed from an allocentric into an egocentric representation. Thus, in animals the hippocampal formation supports spatial navigation but that in humans, the spatial role has been extended to include episodic memory (Burgess et al., 2002).

1.39 Theories linking spatial and episodic functioning to the hippocampus

A variety of different theories have recently been proposed to account for the link between the role of the hippocampus in spatial and episodic memory functioning. The three theories most pertinent to this study are Viewpoint Dependence Theory (King et al., 2002; Burgess, 2002; Burgess et al., 2002) the Hippocampal Reinstantiation Theory (Redish, 1999) and Autoassociation Theory (Rolls and Treves, 1998; Rolls, 1999).

Viewpoint Dependence Theory suggests that cognitive map theory relates episodic memory to the human hippocampus by storing the spatiotemporal context of personally- experienced events. This idea is consistent with that

proposed by Tulving (1983), when he claimed that episodic memory relied on the hippocampus and enabled locations in the environment to be remembered. Recent VR studies, which examined the relative contributions of the hippocampi to topographical and context-dependent episodic memory (e.g. Burgess et al., 2002; Burgess et al., 2001; Spiers et al., 2001a, 2001b), have suggested that the hippocampal role in context-dependent episodic recollection arose from its ability to represent a viewpoint moving within a spatial framework. Burgess (2002) posited that the retrieval of spatial information from long-term storage required the imposition of a particular viewpoint, derived from an allocentric representation. This type of representation was deemed to be appropriate for long-term storage of spatial information because the individual would have moved between encoding and retrieval.

Viewpoint Dependence Theory is an interesting means of applying the tenets of cognitive mapping theory to both spatial and episodic memory in humans. It has also effectively explained the nature of the deficiencies in performance among humans with hippocampal lesions (e.g. Spiers et al., 2001a, 2001b; King et al., 2002). However, alternative accounts of how the hippocampus contributes to spatial and episodic memory functioning have also been proposed by a number of other researchers (e.g. O'Reilly and Rudy, 2000; Redish, 1999; Morris and Frey, 1999; Rolls and Treves, 1998). Like viewpoint dependence theory, these frameworks have also been greatly influenced by cognitive mapping theory.

The hippocampal reinstantiation theory

This theory of hippocampal reinstantiation (Redish, 1999) has strong links with the earlier ideas of Hirsh (1974), Sutherland and Rudy (1989) and has been supported by Burgess et al. (2002). In the navigation domain, Redish (1999) stated that the hippocampal role was to reset an internal coordinate system and to replay recently travelled routes during sleep states, as proposed by Levy (1989). The replaying of recent memories implies that the hippocampus is replaying the general context and the episodic memory of the event. Redish suggests that an inability to successfully restantiate a previously experienced context is one of the key problems that patients with

hippocampal lesions have. This account offers an interesting way of explaining the effects of hippocampal damage in humans; Redish refers to the cases of patients, such as H.M. (Scoville and Milner, 1957), and Jimmie G. (Sacks, 1985), who can hold normal conversations but they cannot remember facts across different conversations. Short delays without major distractions can be bridged by rehearsal, but remembering events across context-switches requires a reinstatement. Studies of nonhuman primates (e.g. Murray and Mishkin, 1996) have provided growing evidence for the role of the hippocampus in bridging context-switches. Redish claims that these results and the observations of H.M. and Jimmie G. can be explained in terms of reinstatement of context, implying that these patients are unable to reinstantiate the context of the prior event.

Autoassociation Theory

According to Rolls (1999; Rolls and Treves, 1998) episodic memory, involves an arbitrary association of a particular set of events which describe a past episode. This view aims to explain why it is that non-spatial tasks such as paired associate word learning tests (Gaffan et al., 1984) are also impaired as a result of hippocampal damage. In these tasks a memory of a particular episode or context rather than a general rule is involved and the ability to form arbitrary associations between words is necessary. Rolls and Treves (1998) suggested that the hippocampus was important for both spatial and non-spatial types of memory because it contained the CA3 state, which acts as an autoassociation memory. This enables arbitrary sets of concurrent activity (e.g. the spatial context where an episode occurred, the people present during the episode and what was seen then) to be associated together and stored as one event. Similar to Redish (1999), Rolls suggested that later recall of that episode in response to a partial cue led to reinstatement of the activity in the neocortex that was originally present during the episode.

These ideas concerning the formation of episodic memory are very similar to the principles of learning proposed by O'Reilly and Rudy (2000), which emphasise the mechanisms of hippocampal plasticity in the forms of Hebbian learning and error-driven learning as underlying the formation of episodic

memories. Both theories also share the idea that the hippocampus and neocortex act as complementary memory systems, with the hippocampus being used for rapid, unstructured storage of information involving activity potentially arriving from many areas of the neocortex. The suggested role of the hippocampus as a temporary buffer store is also consistent with Baddeley's (2000) recent addition of an 'episodic buffer' component to his theory of working memory.

1.40 Summary and limitations of the above theories

In reviewing the current theories of hippocampal functioning in both spatial and episodic memory, Good (2002) concluded that these different accounts possess a common organising principle i.e. that the hippocampus contributes to the binding together of memories of events and their spatiotemporal context. Although the importance of the hippocampus for the encoding of new memories has been consistently highlighted, a number of different researchers (e.g. Nyberg et al., 1996; Fernandez et al., 1998; Davachi and Wagner, 2002; Zeineh et al., 2003) have shown how the level of hippocampal activation at the time of encoding is specifically associated with subsequent retrieval success. However, the controversial debate surrounding the transfer of short-term memories into long-term memory, has given rise to a number of differing views; the crux of the problem concerns the role of the hippocampus in memory storage and whether or not it is time-dependent.

Data supporting Consolidation Theory tends to show that hippocampal lesions have decreasing effects with time, whereas evidence in favour of Multiple Trace Theory shows hippocampal activation for both recent and remote memories (Debiec et al., 2002). Although these two positions have not yet been reconciled, the concept of systems reconsolidation, recently proposed by Debiec et al. could mediate a resolution between these opposing views. Reconsolidation refers to the suggestion that old, reactivated memories undergo another round of consolidation, and that this process shares a number of common properties with the original consolidation state (Debiec et al., 2002). These include a requirement of protein synthesis in order for the memory to persist, time windows during which protein synthesis blockade is effective and that this blockage would disrupt both processes of consolidation

and reconsolidation. From their extensive research using a contextual fear paradigm in rodents, Debiec et al. demonstrated hippocampal reconsolidation after remote memory reactivation and suggested that this process could explain the hippocampal activation associated with remote memory recall that is found in imaging studies. The concept of reconsolidation is thus a powerful means of integrating the previously divergent results obtained from CT and MTT.

Section 6 Discourse Production

1.41 Introduction

In this section, attention will be directed away from the spatial and episodic memory aspects of hippocampal functioning to focus specifically on the area of discourse production. There are three main reasons for including this discussion, the first stemming from O'Keefe and Nadel's (1978) extension of the tenets of cognitive map theory to explain aspects of human language functioning. Secondly, there is now a growing body of evidence documenting discourse production deficits associated with temporal lobe epilepsy. Thirdly, to date, there has been no research investigating the discourse production deficits following selective surgical procedures for unilateral intractable TLE among left- and right-resected adult patients.

1.42 Why study discourse production?

The impetus for studying discourse among patient and healthy populations has emerged from developments in 'schema theory' within psychology and computer science (Mandler, 1984; Schank and Abelson, 1977). According to Duchan (1994), discourse is created, understood and remembered in accordance with complex mental representations or conceptual schemas (e.g. Bartlett, 1932). Examples of schemata that have been hypothesised as structures underlying different types of discourse are event scripts, used in the creation and understanding of event descriptions (Nelson, 1986) and story grammars, used for interpreting and recalling simple stories (Roth and Spekman, 1994; Stein and Glenn, 1979).

1.43 Cognitive Map Theory and discourse

Cognitive mapping in humans allows one to engage in mental activities such as thinking, imagination and creativity because these representations allow one to call up and manipulate items not related to the present sensory array (O'Keefe and Nadel, 1978). Thus, one can change and create new patterns by substituting different items in a manner akin to perspective taking in discourse production where it may be necessary to imagine how another person is thinking. These optional strategies for information manipulation within the 'map' enable humans to imagine things they have never experienced. Thus the cognitive mapping system is liberated from its spatial connections, since it no longer needs to represent a 'real-world' spatial relationship. Influenced by Bower's (1970) work on imagery, O'Keefe and Nadel suggested that imagery works through the long-term storage of an abstract information set, which captures the relationships between an interacting group of elements and from which an image can be easily reconstructed. They also proposed that long-term memory for connected discourse (e.g. sentences) involved the retention of the meaning or sense of the discourse typically with a loss of specific lexical elements and syntactic information. In their view, they claim that it is necessary to postulate a kind of semantic 'deep structure' that incorporates the meaning of discourse without preserving lexical elements. They hypothesised that a map structure could provide the basis for understanding these facts and it could also serve as the form within which deep structure is articulated. The catalyst for these ideas came from the concept of deep structure proposed by Chomsky (1957, 1965) and Jackendoff (1976) which led O'Keefe and Nadel to suggest that 'the sense' of an item was derived from its relation to other items within the structure of language. They proposed that the cognitive mapping system could function as a deep structure for language.

Although Bamberg (1991) and Duchan (1994) have argued against treating discourse as a direct mapping of language onto conceptual structures, Cognitive Mapping Theory does allow for creativity in the relationship between thoughts and their telling. The verbal expression of an experience involves many choices and is likely to differ from the original experience not only in its temporality but also in the personal point of view of the narrator. This implies that story-tellers can enhance the narrative by adding in suspense,

changing the temporal order of events and so forth to convey particular feelings to the listeners.

1.44 Functions of language

Language is generally thought to perform certain functions in order to achieve effective communication. According to Ferguson (1996), communication and its effectiveness need to be considered in terms of the effect on the interpersonal relationship between the individuals involved and the way in which language is used in communication. Thus, the focus should be broader than the content of the message conveyed. This idea places emphasis on communicative effectiveness as a jointly produced outcome and therefore, the contribution of each of the participants should be explored. Among the specific tasks that language needs to perform is referencing and tracking the participants, and marking the nature of relationships between adjacent sentences and larger units of discourse such as episodes (Duchan, 1994). What is critical to the current study, is Duchan's emphasis of the importance of tracking the spatial, temporal and personal perspectives of the discourse. The significance of referencing and tracking participants has been further supported by Wilson and McAnulty (2000), in their account of pragmatic impairments. They specifically stated that such impairments could be attributed to difficulties in referential behaviour, with an inability to take account of another's knowledge in providing relevant topic responses.

Referencing problems and a 'theory of mind'.

Wilson and McAnulty refer to Baron-Cohen's (1995) theory of mind model as a means of explaining the nature of the conversational disabilities experienced by children with specific pragmatic impairments. This model states that human beings must be able to take account of each other's views and representations of a shared world and that they must be able to represent not only their own beliefs, but also those beliefs of other individuals. A topic can be defined as the information context mutually constructed for the progress of talk within a sequentially defined frame (Wilson and McAnulty, 2000). It constitutes an informational frame and although it may not be identical for the

speaker and hearer, a level of shared access must exist in order for discussion on the topic to develop and progress.

Within this framework, reference plays a crucial role in marking out objects and concepts in differing ways so that they may be brought into focus and maintained within an emerging description, conversation or story (Schober and Clark, 1989). Wilson and McAnulty state that this may be achieved either directly through physical location or indirectly through inference or reflection. What is of primary importance in either case, is the online access and integration of elements either in the world or in the mind of both the speaker and hearer, which is achieved through reference and topic construction. From the study of children who have difficulty providing correct reference or topic constraints, Baron-Cohen (1995) concluded that their impairments lay in the inability to construct a 'shared attention mechanism'. Alternatively, and in line with Wilson and McAnulty's view, the problem could be based at the level of theory of mind itself and that such children could have been constructing the beliefs of others as if they were their own beliefs. However, they agree with Baron-Cohen's concept of a 'mindreading system' which humans have developed as a means of making sense of their own and others' behaviour. They also share his view that this system is central to communication itself and agree with the fundamental tenet of 'mindreading theory', which emphasises the importance of achieving some kind of shared and monitored attention which focuses on listener needs as they operate in specific contexts.

1.45 The role of memory in discourse production

Particularly relevant to the present research is the emphasis placed on memory in Wilson and McAnulty's account of pragmatic impairments. They specified how a difficulty in taking account of another person's viewpoint and representing their beliefs could be further compromised with increases in processing loads, which place greater challenges on the ability to monitor the beliefs of others. Such increases in processing demands arise when individuals are required to talk about ideas or objects that must be retrieved from memory and then compared with the knowledge systems the hearer may or may not have in mind. Wilson and McAnulty suggested that this account of the

influence of memory load could explain why children with theory of mind problems find it easier to engage in discourse about objects that are present rather than those they have to recall.

Distinctions in the levels of pragmatic impairment

Pragmatic disability impairments may operate at a number of different levels. For example, a Primary Pragmatic Disability (PPD) is thought to be associated with intact linguistic abilities but impaired communicative performance, which is attributed to a failure or problem with central processing systems including memory impairments (Perkins, 2000). This contrasts with Secondary Pragmatic Disability, which is viewed as arising from difficulties in syntax/morphology, word finding, phonology or prosody. The inclusion of a third category, Complex Pragmatic Disability takes account of possibility that these first two types of impairments may not be mutually exclusive but may share some common elements. For example, lexical location or word-finding difficulties could be influenced by memory functioning.

Previous research exploring the use of language in the process of communication has tended to focus primarily on linguistic, sociological or philosophical terms. In contrast, Perkins (2000) proposed an alternative approach to the study of pragmatics, which is based in cognitive neuropsychology but has not been widely applied to the area of pragmatic disability. Importantly, this line of reasoning shifts the emphasis from communicative behaviour to underlying cognitive functioning and therefore is extremely useful in characterising the nature of a pragmatic disability. In considering the distinctions between Primary, Secondary and Complex Pragmatic Disability, Perkins emphasises the need to specify whether such disability is a result of a nonlinguistic impairment, a linguistic impairment or a combination of both.

The major cognitive systems, which Perkins assumes to underlie primary pragmatic ability, include inferential ability, social cognition, theory of mind, executive function, memory, affect and world knowledge. The most relevant of these systems in the context of the present study are memory, inferential ability, social cognition and theory of mind. In their illustration of how

memory impairment may contribute to PPD, Perkins et al. (1996), suggested that excessive repetitiveness and topic bias could be seen as a compensatory conversational strategy used to conceal the fact that the client could not remember what had been and was being talked about. They found that among patients with closed head injury, there was a tendency towards switching to a favourite default topic or to provide a general statement of opinion. The significance of inferential reasoning in the ability to communicate effectively was also highlighted. Inferential reasoning may be verbally mediated or may occur as an independent cognitive process (Johnson-Laird, 1995). Bishop and Adams (1992) found that children with specific language impairment (SLI) were unable to construct an integrated representation from a sequence of propositions even when these were presented nonverbally.

Social Cognition and Theory of Mind

McTear and Conti-Ramsden (1992) defined social cognition as the ability 'to make social inferences about the actions, beliefs and intentions of other persons in order to understand the behaviour of others and to be able to adapt messages to their needs'. The 'theory of mind', concept, discussed earlier by Wilson and McAnulty and Baron-Cohen has also been defined by Carruthers and Smith (1996) as the ability to 'explain and predict the actions, both of oneself, and of other intelligent agents' and is thought to be an integral part of social cognition. Deficits in social cognition range from an inability to predict precisely how much information to encode in one's utterances to satisfy a listener's needs, to an inability to entertain the possibility that other people might have mental states such as beliefs, intentions and desires, which occurs in the case of autism (Perkins, 2000).

This emphasis on the significance of social cognition underlying PPD has been recently supported by Field et al. (2001). This study is the only investigation to focus specifically on discourse production for story-telling among a sample of left TLE patients. Field et al. attributed the increased verbosity they observed among these patients to a dysfunction at the macrolinguistic or global level of discourse production. They also suggested that this impairment was influenced by underlying social and motivational

factors, including a desire to preserve social contact, and in doing so, to compensate for a declining information content. Field et al.'s study is also important in the way it serves to integrate various different aspects of discourse production, which until now have not been investigated in the context of temporal lobe epilepsy. For example, Field et al.'s line of reasoning is highly consistent with the memory problems associated with left temporal lobe damage. In addition, their conclusions are also in accordance with Wilson and McAnulty's and Perkins' account of PPD, which has stressed both the social cognition and memory functioning aspects. Furthermore, Field et al.'s focus on left temporal lobe epilepsy patients suggests a differential influence of the two hemispheres on discourse production.

1.46 Differential hemispheric responsibility and discourse production

The contrast between left and right hemispheric responsibility has been investigated by Bloom (1998), who examined patients with unilateral left and right hemisphere damage. Classical explanations of the central language mechanism posit that the left hemisphere contains the neural structures that are critical for the processing of words and sentences. This account was originally proposed by Wernicke (1874) and remains the most accepted model of the central language-processing mechanism. It is now known that neuroanatomic structures in the left hemisphere do not function in isolation from other parts of the brain (Bloom, 1998). However, damage to the brain disrupts the functioning of the cognitive, social and linguistic systems that contribute to normal discourse production. Following unilateral left or right brain damage, the capacities of the two hemispheres become differentiated. Bloom (1998) asserted that analysing the discourse production capabilities of these two populations was extremely important in shedding light on the overlapping and interconnected neural networks throughout the brain. He suggested that unilateral damage to the left and right hemispheres resulted in two distinct clinical syndromes. Bloom's view is similar to that of Perkins and suggests that the main problem for children and for adults with right-sided brain damage appears to be an inability to coordinate a sufficiently varied range of frames of reference. This results in a tendency towards over-reliance on immediate context and difficulty with inferring the perspectives of the

listeners, a suggestion that has strong links with Viewpoint Dependence Theory. Furthermore, Bloom hypothesised that RH patients may be unaware of these deficits and he concluded that fully informative discourse production involved cognitive processes subserved by both hemispheres and that any model of discourse production must take into account both the left- and right-hemisphere processes.

1.47 A model of discourse production

In Bloom's (1998) model, discourse production is thought to be achieved through the integration of simultaneous and successive processing networks, which are contained in the right and left hemispheres and which interact to create the linguistic, pragmatic and content aspects of discourse. This framework acknowledges that basic linguistic functions (e.g. phonology, morphology, syntax) are mediated primarily by the left hemisphere but argues that the RH plays the part of a simultaneous processor. Through this model Bloom attempted to describe the system necessary for the implementing and production of discourse among both healthy controls and patient populations. In contrast to the classical, left-hemisphere model, Bloom's account is based on the assumption that discourse processing involves integrative and mutually exclusive components i.e. during discourse production, neuroanatomic structures (e.g. Broca's area) do not function in isolation from other parts of the brain. Although this model is used to explain the bilateral cortical contributions to discourse production, it also stresses the importance of considering the effects of subcortical lesions since they may impair discourse production through the dysfunction of areas to which they are connected.

What is attractive about Bloom's model is that it provides a framework, which explains how the content, form and pragmatic components of the language system could be adversely affected following unilateral brain damage. The inclusion of a specific visuo-spatial component is of particular relevance in the context of sections of this chapter, which focus on the spatial representation abilities dependent upon the hippocampus. From Bloom's perspective, discourse analysis provides clinically significant information that contributes

to a better understanding of the linguistic, social and cognitive status of patients with brain damage. It is an extremely useful tool which has great potential for differentially diagnosing a variety of clinical populations and making predictions about the impact of the language disorder on communication in real-life situations.

Section 7 Epilepsy

1.48 Introduction

This section focuses on the disorder of epilepsy and in particular, on temporal lobe epilepsy (TLE). The stages involved in the diagnosis of epilepsy, the investigations used in this process, the surgical treatments available, and the importance of neuropsychological evaluation, will be discussed before concluding with a brief consideration of the main factors surrounding quality of life issues. More detailed accounts of different aspects of epilepsy, which fall outside the scope of the current discussion can be found elsewhere (e.g. Shorvon, 1986; Berg et al., 2001; Kanner and Barry, 2001).

1.49 Definition, Diagnosis and Etiology of Epilepsy

Epilepsy is a chronic condition of various etiologies characterised by a predisposition to recurrent, usually spontaneous, epileptic seizures (Guberman & Bruni, 1999). Regarding the epidemiology, epilepsy is a common disorder, with a lifetime population risk of 2-3% (Lynch, 2001). Guberman and Bruni (1999) state that, after headache, epilepsy is the second most common chronic neurological condition seen by neurologists. The incidence of epilepsy peaks in the first ten years of life, where a number of age-specific epileptic disorders are identified, and then levels during early and middle adulthood before increasing once again from the age of fifty (Lynch, 2001). It ranges between 40-70 per 100,000 in most developed countries and between 100-190 in developing countries (Guberman and Bruni, 1999).

The diagnosis of epilepsy is a four-part process involving the differentiation from events mimicking epileptic seizures, seizure classification, syndrome classification and finally the determination of etiology (Guberman and Bruni,

1999). The definition of epileptic seizure was originally proposed by Hughlings Jackson in 1889, and is still used today. It described a seizure as, 'A sudden excessive discharge of the grey matter'. For a more detailed discussion of early investigations into seizure classification, see Wieser (1986) and for an introduction to seizures, see Jeavons and Aspinall (1985).

Etiology

An epileptic syndrome consists of one or more specific seizure types in addition to a number of other clinical features such as age at onset of epilepsy, neurological features including the presence of cognitive impairment, specific EEG findings, and family history (Lynch, 2001). The international classification of epileptic syndromes, in association with the International League Against Epilepsy, consists of many readily-identifiable syndromes which lend themselves well to clinical management. In brief, there are three main etiological classifications: remote symptomatic, cryptogenic, and idiopathic. Remote symptomatic epilepsy is caused by a known or identifiable previously acquired brain lesion. Cryptogenic, on the other hand, is due to an acquired brain lesion (including prenatally acquired developmental anomalies) that has not been identified or that is of unknown cause. Most partial epilepsies fall into this category. Finally, in the case of idiopathic epileptic syndromes, the etiology is unknown, but the syndrome is well recognised and has a presumed genetic basis. Most primary generalised epilepsies and benign partial epilepsies of childhood fall into this category. Approximately 60% of all epilepsies are idiopathic or cryptogenic (Guberman and Bruni, 1999).

1.50 Temporal Lobe Epilepsy

Temporal Lobe Epilepsy (TLE) is characterised by an onset in early childhood, and is frequently associated with a history of febrile convulsions, most notably complex febrile seizures. Seizures typically disappear for several years and return in teens or early adulthood. A pattern of simple or complex partial seizures, with or without secondary generalisation may occur. Auras are very common in TLE and may include epigastric sensations, autonomic features, psychic symptoms such as fear (amygdalar involvement), déjà vu, jamais vu, olfactory/gustatory (uncus involvement) and visual phenomena. TLE is also frequently associated with automatisms: oroalimentary,

vocalisations, repetitive movements and complex activities. Dystonic posturing of one limb may occur contralateral to the focus. It is important to note that, compared to other types of epilepsy, TLE shows a greater resistance to anti-epileptic drug (AEDs) therapy.

Mesial Temporal Sclerosis

Closely related to TLE is the condition of mesial temporal sclerosis (MTS). This is the most common pathologic finding in patients undergoing temporal lobectomy for temporal lobe epilepsy and is found in approximately 40% of resected specimens for intractable temporal lobe epilepsy (Van Paesschen et al., 1997). The pathology of MTS frequently involves a variable degree of neuronal loss and gliosis, especially in the CA1 and CA3 fields. The dentate gyrus and amygdala may also be affected and the damage may occur bilaterally. 'Dual pathology' i.e. concurrent cortical or subcortical dysplasias, vascular malformations or tumours may also occur. The etiologies of MTS are likely multiple, with prolonged febrile convulsions in childhood most often identified (Guberman and Bruni, 1999).

Prognosis

The prognosis of epilepsy is generally discussed in terms of the prognosis for long-term seizure remission (whether treated or untreated), the long-term psychosocial outcome and the morbidity and mortality related to epilepsy. The long-term impact of epilepsy as a chronic illness has been explored by Taylor (1993) and more recently by Fisher et al. (2000) and Bjornaes et al. (2001). According to Shorvon (1984), overall mortality rates for persons with epilepsy are approx. 2-4 times those of age- and sex-matched controls and this excess mortality is greatest among young adult subjects. There are a number of reasons underlying this. First, the conditions underlying epilepsy may cause death and obvious examples include brain tumour, cerebrovascular disease etc. Second, accidental death may occur because of a seizure. Third, the epileptic seizure itself may result in death. Finally, the psychiatric, psychological (Trimble, 1985) and psychosocial (Masland, 1985) aspects of epilepsy may carry their own mortality.

1.51 Investigations

The main ways in which epilepsy is investigated is through the use of EEG recording, and both static and dynamic brain imaging techniques such as CT, PET and MRI. Brief descriptions of EEG and MRI are presented below since these are the primary investigative tools used in Beaumont Hospital. A detailed review of these imaging techniques can be found in Kolb and Whishaw (2001).

Electroencephalography (EEG)

Apart from assisting in the diagnosis of epilepsy and the classification of seizure type, EEG also serves a number of other purposes in the investigation of epilepsy. It is used to quantify seizures or epileptic bursts and to aid in the decision of whether to stop anti-epileptic drug (AED) treatment. What is of most interest in the case of TLE is the way in which EEG is used to help localise the focus of the seizure among pre-surgical candidates. However, in many instances, definite answers about electro-anatomic-clinical correlations of seizures can only be provided by stereotaxic implantation of multilead depth probes and the subsequent chronic recording of spontaneous ictal EEG changes simultaneously from surface and depth sites combined with detailed observation of behaviour using closed-circuit television.

According to McMackin and Staunton (1991), epileptiform activity as measured by EEG is characterised by paroxysmal discharges occurring synchronously in a large population of cortical neurones. The EEG manifestation of this hyperexcitable state is the spike or sharp wave. Large depolarisation shifts in the resting membrane potential accompanied by high frequency bursts of action potentials underlie the interictal spike or spike wave discharge. Ictal onset can be recognised as a distinct change in background activities, which can be seen visually either prior to or simultaneously with the onset of the clinical seizure. Patterns of ictal onset include periodic discharges, high-frequency, low-voltage, rhythmic discharge, profound flattening of background activity or rhythmic spiking. More detailed discussions of EEG

including its merits and demerits as a diagnostic aid can be found in Clemens et al. (2000), Neufeld et al. (2000) and Wieser (1986).

Neuroimaging

Neuroimaging, including MRI, fMRI, PET and CT has become an increasingly important part of the presurgical workup to identify epileptic foci in candidates for epilepsy surgery. A detailed account of the way in which recent advances in brain imaging have led to great improvements in the diagnosis and treatment of epilepsy has been prepared by Sperling (1995). Insofar as possible, all patients with epilepsy have initial CT or MRI scans. MRI is generally the procedure of choice because it can detect abnormalities including subtle atrophies in the medial temporal regions, cortical gyral dysplasias, low-grade gliomas and small cavernous hemangiomas, all of which may be missed on CT. Regarding TLE, features of hippocampal sclerosis on MRI commonly include unilateral atrophy (including dilation of temporal horn), loss of internal architecture on inversion recovery images, increased signal on T2-weighted images and decreased signal on T1-weighted images (Guberman and Bruni, 1999).

1.52 Surgical Treatment for Epilepsy

Surgical treatment is generally considered for patients with refractory partial seizures. The tendency to operate on children has recently increased in the hope of averting the long-term consequences of uncontrolled epilepsy during the formative years (Dlugos et al., 1999; Bjornaes et al., 2001). The aim of surgery is to remove the focus of origin of the seizures and/or to prevent spread of the seizure discharge. The presurgical evaluation process involves a number of stages. These include patient selection, neuropsychological evaluation, assessment of language dominance via the Wada test, and a consideration of the most beneficial type of surgery to be offered to the patient.

Patient selection

Prior to any consideration for surgical therapy all patients undergo adequate trials of AEDs. Generally, surgical candidates must have medically intractable

epileptic seizures and/or seizures that are significantly socially disabling (Crandall et al., 1985). An absence of severe fixed neurologic and cognitive deficits in addition to seizures must be confirmed and patients should show a well-established seizure pattern spanning at least 1-2 years. An identifiable focus of origin for the majority of the seizures must be clear and there must be a relatively low risk of severe neurologic deficit if surgery of the focus is being considered. The overall risk of severe neurologic complications from epilepsy surgery is approximately 1% (Guberman and Bruni, 1999; but see Oxbury et al., 1997), with the forms and incidences of complications depending on the type and extent of the surgical procedure. Motivation and willingness to cooperate with the investigations and follow-up on the part of the patient is extremely important, as is the absence of medical contraindications to surgery. Finally, the importance of an adequate social support system is strongly emphasised.

Neuropsychological Evaluation

The main objectives of neuropsychological assessment are to establish the patient's level of intellectual functioning and in doing so to document areas of functional deficit; to assess the localising value of neuropsychological tests; to conduct speech lateralisation studies (e.g. Wada test) to determine cerebral dominance and, to predict neuropsychological deficits that might occur as a result of surgery (most notably an assessment of the risk of developing global amnesia). Finally, the neuropsychological examination takes account of the potential gains in the patient's quality of life as a result of surgery. A large focus of neuropsychological evaluation has been on tests sensitive to temporal lobe dysfunction (e.g. Jones-Gotman et al., 1993). Most reliance has been placed on comparing a patient's performance on verbal and non-verbal short-term memory tests, the immediate and delayed recall of prose, associative learning and visual-reproduction subtests of the Wechsler Memory Scale (Wechsler and Stone, 1945) and the Rey-Osterrieth draw and recall tests (Osterrieth, 1944). In the absence of other cognitive deficiencies, a verbal memory deficit has been correlated with a dominant (left) temporal lobe lesion while a deficit in recalling material such as a line drawing has been associated with a lesion in the non-dominant (right) temporal lobe (Crandall, 1985). A

more detailed account of memory assessment in clinical practice is contained in Mayes and Warburg (1992).

Wada Test

The intracarotid injection of amytal, based on Wada's description (Wada and Rasmussen, 1960), is performed to lateralise language dominance and to test each hemisphere's ability to support short-term memory (Milner et al., 1962). Transfemoral catheterisation is used to deliver 125mg sodium amobarbital into the internal carotid artery. Memory function is then tested by examining the patient's ability to recognise pictures of common objects, written words and unfamiliar forms, using a continuous performance task administered within four minutes of the injection. Simultaneous EEG recording is used to aid the determination of spread and duration of drug action. Recently Alpherts et al. (2000) examined the importance of the Wada Test in the prediction of seizure focus lateralisation and the use of this test to predict the presence of hippocampal sclerosis has been discussed by Davies et al. (1999). The simultaneous use of SPECT and intracarotid amobarbital testing to determine language dominance has also been investigated by McMackin et al. (1998).

1.53 Types of surgery for TLE

McMackin and Staunton (1991) described the origins of neurosurgery for epilepsy which can be traced back to 1886, when Horsley performed the first resective surgery to control intractable epilepsy in London. He operated on the basis that the clinical symptoms suggested a cortical origin to the seizures, and these suspicions were confirmed by evidence of gross pathology at surgery. The first surgical operations for complex partial epilepsy were guided by macroscopic pathology such as cysts, depressed skull fractures, brain atrophy or tumours. After EEG criteria were developed, the underlying pathological substrate of the temporal lobe was not recognised for many years because the limbic structures of the medial portion were removed by suction techniques. Following Falconer's (1953) introduction of the '*en bloc*' anterior temporal lobectomy, it was possible to describe the underlying microscopic pathology involving the limbic structures.

Types of Surgical Procedures used in TLE

There are three main surgical procedures that are used in treatment of TLE: the anterior temporal lobectomy, the selective amygdalohippocampectomy and the neocortectomy. Regardless of the type of treatment chosen, the main objectives of surgery remain the same: to improve the patient's quality of life by maximising seizure control (ideally through the elimination of seizures) and to minimise surgical neurological deficits. Secondary aims include the reduction of psychosocial disability and globally, to reduce medical morbidity (Guberman and Bruni, 1999). *Anterior temporal lobectomy* (ATL) involves removal of 4.5cm of anterior temporal lobe on the speech-dominant hemisphere and 6cm on the non-dominant hemisphere. This operation focuses on a maximal removal of hippocampal formation and amygdala and limits removal of lateral neocortex.

Selective amygdalohippocampectomy (SAH), which is the focus of this thesis, is performed in patients with focal pathology such as mesial-temporal sclerosis or developmental tumors confined to mesial-temporal structures. If seizure control is not satisfactory, more extensive resection can be considered. This procedure was first described by Niemeyer in 1958, who approached the amygdala and hippocampus through an incision on the middle temporal gyrus (Park et al., 1996). However, it was only in the late 1980s that SAH became an accepted surgical treatment for medically intractable mesial TLE. Jones-Gotman et al. (1997) have claimed that the main advantage with this type of surgery is a reduced risk of visual field defects and dysphasia. In the technique outlined by Olivier (1991) and Hori et al. (1993), the approach is made through the first or second temporal gyrus or through the floor of the superior temporal sulcus. Through this corridor, the medial structures, including most of the amygdaloid nuclei and the anterior 2-3cm of the hippocampal formation along with the surrounding structures of the parahippocampal gyrus are removed, while the rest of the lateral and inferior temporal neocortex is spared. A more recent variation of the SAH technique, which uses the parahippocampal gyrus as the operative approach, has been put forward by Park et al. (1996). An MRI scan of a patient who underwent a right-sided SAH procedure for the relief of intractable TLE is shown in Figure 1.4 below. From

this image, the resected areas of right temporal lobe can be clearly compared with the relatively intact left temporal lobe.

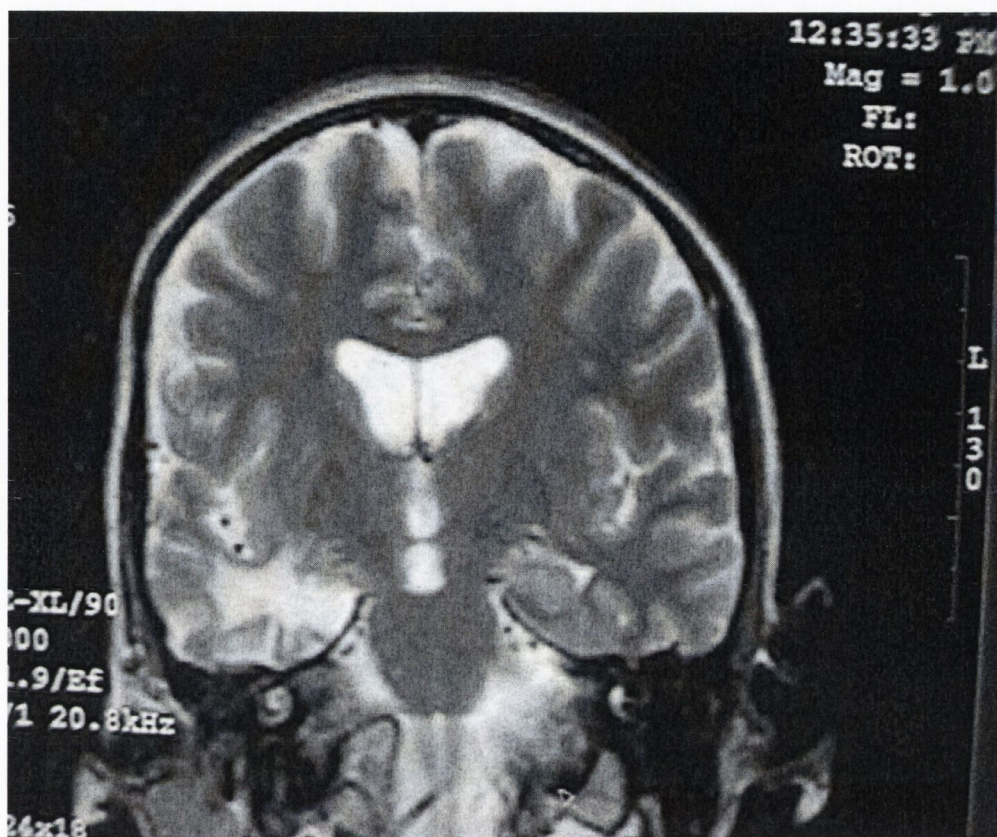


Figure 1.4: A T2-weighted MRI scan of patient J.C. who underwent a RSAH.

Neocorticectomy involves the posteriorly extended resection of an area of 4.5-6cm from the tip to the temporal and taking in the lower half of the superior temporal gyrus and the middle and inferior gyri (Keogan et al., 1992). The incision extends to the temporal horn, which is opened and angled posteriorly to include a greater portion of the inferior gyrus. The amygdala and hippocampus are not removed.

1.54 Results of Surgical Treatment

The results of surgery for epilepsy are usually considered from a number of perspectives, with the primary focus on seizure outcome. The neuropsychological, psychosocial, and psychiatric effects of surgical treatment are then taken into account. Detailed discussions on the outcome of epilepsy surgery from a neuropsychological perspective can be found in Naugle (1991),

Lewis et al. (1996), Helmstaedter et al. (1998), and Keogan et al. (1992). Bearing in mind the goals of surgery, evaluation of the results of such treatment tends to focus primarily on the post-surgical classification of seizure outcome as proposed by Engel (1993) shown in Table 1.1 below.

Table 1.1 The Classification of Seizures (from Engel, 1993)

Class	Description
Class I	• Completely seizure-free • Auras only
Class II	• Rare seizures • Nocturnal seizures only
Class III	• Worthwhile decrease in seizures
Class IV	• No significant decrease in seizures • Seizures worse

The results of surgical treatment for focal lesions depend largely on the nature of the underlying pathology and its location. It is generally accepted that the best prognosis is for patients displaying mesial-temporal sclerosis with hippocampal atrophy, temporal lobe low-grade gliomas, or development tumors and in such cases 70-80% of patients become seizure-free (Guberman and Bruni, 1999). Another 20-25% of patients experience a significant but incomplete reduction in seizures. The outcome with extratemporal resection is less satisfactory, with only 30-50% of patients becoming seizure-free. The least favourable prognosis, found among individuals with extensive cortical dysplastic lesions, is attributed to the difficulty in resecting the entire epileptogenic zone. Watson et al. (1995) proposed a revised pathological grading system for hippocampal sclerosis and correlated the results of this procedure with MRI volumetric measurements of the hippocampus. The results of this analysis showed a strong correlation between the severity of hippocampal sclerosis, as measured by the preoperative MRI volumetrics, and their revised pathological grading system.

Quality of life, psychosocial and psychiatric outcomes

Although psychosocial improvement after successful surgery generally occurs, some patients have difficulty adjusting to life without seizures; their longstanding lack of life or vocational skills may prevent significant improvement in their post-surgery quality of life (Guberman and Bruni, 1999). Wheelock (1998) examined the expectations and life changes associated with surgery for intractable epilepsy and found that the reputation of successful epilepsy surgery led some patients to expect that being relieved of seizures would greatly improve other significant aspects of their lives. The positive effects listed by the seizure-free participants who were interviewed consisted of regaining feelings of autonomy and competence, being able to drive, being able to achieve independence through work and other activities. Secondary to these effects was an improvement in mood. However, the least anticipated negative outcome were the psychosocial difficulties following surgery that were experienced by a large proportion of the patients. These problems concerned the individual's difficulty in adjusting to their change in health status i.e. to their new role as a healthy family member. The results of this study provide support for Engel's (1987) observation that seizure elimination may lead to a deterioration of family structure and function.

1.55 Summary

This section aimed to provide the reader with an introduction to the disorder of epilepsy, and specifically TLE. Issues concerning the diagnosis of epilepsy and the classification of seizures and syndromes were explained before focusing on the types of surgical treatments available for intractable TLE and the extensive pre-operative investigations and assessments. Finally, the factors that are important in the measurement of treatment success were considered.

Section 8 Memory, Temporal Lobe Epilepsy and the effects of right-sided resections.

1.56 Introduction

In this section, the association between temporal lobe epilepsy (TLE) and memory problems will be discussed, with attention focusing on the types of questionnaires used to assess subjective memory functioning. The factors

influencing memory preservation and predicting memory impairment following surgery for TLE will then be described. From there, the particular memory deficits associated with surgery to the right temporal lobe will be considered.

1.57 Measuring subjective memory difficulties

Loiseau et al. (1988) stated that memory deficits in patients with epilepsy merited special attention since they sought help for these more frequently than for other cognitive impairments. The general consensus from recent studies investigating memory in epileptic patients (e.g. Aikia et al., 2001; Giovagnoli et al., 1997) has been that, for memory tasks, the performance levels of these patients are lower than those of healthy subjects. In the last two decades, a plethora of questionnaires and inventories have been developed to assess the extent and type of subjective memory difficulties in patients with epilepsy. Among the most frequently used are the Everyday Memory Questionnaire (Sunderland et al., 1984), the Memory Observation Questionnaire (McGlone and Wands, 1991) the Subjective Memory Questionnaire (Bennet-Levy et al., 1980) and the Cognitive Failures Questionnaire (Broadbent et al., 1982). The nature of memory failures in patients with medically controlled or intractable seizures has also been examined by Thompson and Corcoran (1992) using the Retrospective Questionnaire and a Prospective Memory Checklist. Other researchers such as Hermann et al. (1995) and Vermeulen et al. (1993) have used additional questionnaires such as the Multiple Ability Self-Report Questionnaire and the Inventory of Memory Experiences. However, despite the development of such questionnaires and their use in aiding the exploration of patients' memory problems, the association between the results from these tasks and performance on laboratory tests has not been thoroughly investigated (Thompson and Corcoran, 1992; Morris et al., 1995; Maguire et al., 1996). Further research is also needed to establish the reliability of self-evaluation questionnaires (Giovagnoli et al., 1997).

1.58 Factors influencing and predicting memory functioning – the question of laterality effects

The main factors influencing memory disorder in epilepsy include the following: the presence of brain damage, the frequency of seizures, the duration of epilepsy, the age at onset of the condition and the type of medication the person is taking (Loiseau et al., 1988). However, a considerable amount of work has also focused on the prediction of memory deficits following surgery for intractable temporal lobe epilepsy. According to McMackin and Staunton (1991), the issue of the degree of post-operative memory deficits becomes very important when the patient is faced with a choice of surgical procedures. Memory deficits specific to the side of surgery have been well documented, with right as opposed to left TL resections being associated with greater impairments in a broad range of tasks designed to measure visuo-spatial abilities (Bohbot et al., 1998; Abrahams et al., 1997; Feigenbaum et al., 1996). In contrast, left TL resections tend to impair performance in the verbal and episodic memory domain to greater extent than right-sided resections (Engel, 1996; Dobbins et al., 1998; Jones-Gotman et al., 1997; Morris et al., 1995; Burgess et al., 2002).

However, in recent years, the assumption of laterality of function has been challenged by the findings of a number of studies (e.g. Dobbins et al., 1998; Owen et al., 1995; Feigenbaum et al., 1996) which have shown that patients with left and right unilateral TL resections show impairments on both verbal and visuospatial memory tasks. Such findings are at odds with the material specific or ipsilateral deficit model proposed by Saykin et al. (1992), which maintains that the left hemisphere regulates verbal memory with the right regulating visuospatial memory. Instead, these controversial findings may be better explained by the functional adequacy model of hippocampal functioning proposed by Chelune (1995). This model proposed that it was the functional adequacy of the tissue to be resected in the ipsilateral TL that determined the nature and extent of memory loss following surgery. This argument directly challenges the traditional theory of functional reserve (Baldwin, 1956; Walker, 1957; Penfield and Milner, 1958), which posited that decrements in memory were related to the capacity or reserve of the contralateral TL to support

memory after resection of the ipsilateral lobe. Detailed discussions on this controversial issue are contained in Trenerry et al. (1995a, 1995b) and Zaidel et al. (1998).

1.59 Specific impairments associated with surgery to the right temporal lobe

The most frequently documented impairments following right-sided surgery include deficits in visuospatial learning and memory (Milner et al., 1999), and allocentric spatial representations (Smith and Milner, 1981; Abrahams et al., 1997; Bobhot et al., 1998). However, impairments in the recognition of changes in scene compositions (Baxendale et al., 1998), the ability to learn abstract designs or geometric patterns (Jones-Gotman et al., 1997), and delayed match to sampling and paired associate conditioning tasks (Owen et al., 1995) have also been reported. A plethora of research in this area has highlighted a number of critical factors, which should be kept in mind when the findings are being discussed. These include the location of the lesion within the medial temporal lobe (hippocampus, parahippocampal gyrus, amygdala, perirhinal cortex etc.), and the type of methodology used (e.g. standard neuropsychological tests, novel table-top tasks or VR analogues of animal paradigms or real-world environments).

The element of delay

In some cases, impairments in performance on tasks are only apparent when a delay is introduced between the presentation and recall of the stimuli used in the task. Smith and Milner (1981, 1984, 1989) demonstrated the impairment of patients with extensive right hippocampal lesions on a task involving the recall of the location of 16 toy objects within an array. They consistently found that both the detection of the absolute location of the object and also its relative location to the other neighbouring objects were impaired but only after a delay of 4mins; at zero delay all groups performed normally. Crane et al. (1995) extended these findings to include patients who had undergone LTL, RTL and also a group who had undergone a selective left or right amygdalohippocampectomy, sparing the lateral and polar temporal neocortex. The results showed that both the right hippocampal and right selective AH

groups were impaired relative to the normal control group, but they did not differ from one another. It was also shown that, in contrast to their impaired learning over multiple trials, the RTH and RAH groups performed normally on the first recall trial. This implies that their impaired learning stems from abnormally rapid forgetting during the 2-3min inter-trial intervals.

Extent of resection

A number of researchers (e.g. Morris et al., 1999; Good et al., 2002; Nunn et al., 1998a; Jones-Gotman et al., 1997; Miller et al., 1998) have investigated the relationship between the extent of operation and the effects on visuo-spatial memory. According to Milner et al. (1999), following right anterior temporal lobectomy, impairments have been found on a variety of spatial learning and spatial memory tasks but only if both the hippocampus and/or the parahippocampal gyrus were removed. Ploner et al. (2000) examined the effects of lesions to either the right perirhinal or right parahippocampal cortices on a memory-guided saccade delay task. Patients with right perirhinal cortex lesions but with intact parahippocampal cortices showed normal performance on this task with delays of up to 30s. However patients with combined perirhinal and parahippocampal lesions showed significant impairments in memory for saccades at delays longer than 20 seconds. These results are also consistent with those obtained by Bohbot et al. (1998) who found that patients with right hippocampal damage but intact parahippocampal cortices were impaired on an object location task and the Rey Figure at immediate and delayed recall. This implied that the right hippocampus was essential for learning in visuo-spatial tasks.

Similar findings were also demonstrated by Abrahams et al. (1997), who found spatial memory deficits in both pre- and post-surgical patients with right temporal lobe damage, whereas patients with corresponding left temporal lobe damage showed preserved spatial memory, when compared to normal controls. In contrast, no differences were found between patient groups on the non-spatial object memory components of the task. The findings of the study supported a specialised role for the right human hippocampus in the processing and manipulation and recall of spatial as opposed to object

information, and were confirmed by Nunn et al. (1998a) and Morris et al. (1999).

The recognition of scenes, designs and faces

According to Burgess et al. (2002) the right parahippocampal cortical areas are required for iconic representation of scenes and the right hippocampus is additionally required when memory for locations in 3D space is being assessed. Baxendale et al. (1998) examined the deficits in memory for specific features of a complex scene and found that RTL patients took significantly longer to identify changes in orientation, figurative detail and in the filled and unfilled spaces in the compositions. Recently Spiers et al. (2001b) demonstrated that RTL patients were impaired at the recognition of both environmental scenes and objects in a VR town. The results of these studies support those previously obtained by Pigott and Milner (1993) and imply that the right temporal neocortex is implicated in the recognition of visual detail and the identification of figurative detail changes.

Jones-Gotman et al. (1997) investigated the effects of anterior temporal lobectomy (ATL), temporal neocorticectomy (NC) and selective amygdalohippocampectomy (SAH) on patients' ability to learn a series of novel abstract designs. In contrast to the results obtained on the word learning task, patients with right-sided lesions showed a significant impairment in design learning. Jones-Gotman et al. suggested that learning designs required visuospatial processing for successful encoding and that this process was carried out more efficiently in the right hemisphere. These results supported those obtained by Morris et al. (1995) who assessed unilateral TL patients on the Recognition Memory Test (RMT) (Warrington, 1984) and found that the RTL group was more impaired at the recognition of faces task than the left group. Interestingly, the reverse was observed for the recognition of words.

More recently, Crane and Milner (2002) examined the contribution of right temporal lobe structures to the recognition of previously unfamiliar face among a group of SAH and TL patients (with lesions either sparing or radically invading the hippocampal region). The paradigm involved selecting

12 previously studied faces from an array of 25 photographs, in addition to administration of the Mooney Closure Faces Test (MCFT). The results showed that the groups who were most impaired at recognising previously unfamiliar faces were those where the excision invaded the right hippocampal region (i.e. the SAH and TL groups with hippocampal removal). Crane and Milner stated that these deficits were not due to an impaired face processing ability since there were no group differences on the MCFT. Thus, the right medial temporal region appears to be critical for remembering but not perceiving faces. This pattern of subtle deficits after right anterior temporal lobectomy and more pronounced deficits after more posterior damage to the right temporal lobe is consistent with the location of the so-called 'fusiform face area' that is typically activated by face stimuli in functional imaging studies (Kanwisher et al., 1997). Crane and Milner concluded that since right anterior TL usually spares this important face-processing region, it is not surprising that this removal is associated with smaller deficits than those seen after more posterior right-hemisphere lesions.

Owen et al. (1995) demonstrated a double dissociation between patients with TL lesions and those with frontal lobe lesions on a computerised battery of tests designed to measure visuospatial learning and short-term pattern and spatial recognition memory. They found that TL patients and those with SAH were impaired on the pattern recognition task whereas the frontal patients showed deficits in spatial memory recognition. These results were supported by Gron et al. (2001), but what was most surprising was the finding that the left and right temporal and AH sub-groups were indistinguishable on all measures of performance across each of the tasks. Owen et al. concluded that impaired performance on these tests of visuospatial recognition memory and learning in patients following TL or AH was unrelated to the side of removal.

1.60 Deficits in the topographical and allocentric domains

A plethora of studies has also investigated topographical orientation, spatial navigation and allocentric spatial representation in patients with unilateral temporal lobe resections. What is most striking about the results is the level of conflicting data concerning the effects of laterality on task performance, with

some researchers (e.g. Kopelman et al., 1997; Abrahams et al., 1997; Morris et al., 1999; Feigenbaum et al., 1996; Worsley et al., 2001) arguing in favour of the specialised role of the right hippocampal region in mediating these abilities, whereas others (e.g. Owen et al., 1995; Astur et al., 2002) providing evidence showing the involvement of both the left and right hippocampal regions. The best approach to take may be that subscribed to by Berthoz (1999) when he asserted that it is important not to ascribe a crucial role in spatial memory to any one particular area of the cortex.

Furthermore, the nature of the different paradigms used may partly account for this discrepancy in the findings. Recently, VR paradigms have become popular as ways of investigating topographical and episodic memory in patients with MTL lesions (e.g. Spiers et al. 2001a, 2001b; Burgess et al., 2002; Burgess, 2002). VR analogues to the classic Morris water maze task used with rodents have even been used with humans (Astur et al., 1998; Astur et al., 2002). Furthermore, a variety of novel table-top and computerised tasks have also been developed to assess allocentric spatial representations among such patient groups (Feigenbaum et al., 1996; Baxendale et al., 1998). According to Aguirre et al. (1998), the medial temporal lobes are regionally sub-specialised for the acquisition of topographic information. This assertion is supported by evidence from lesion and neuroimaging studies (e.g. Maguire et al., 1996; Maguire et al., 1997) which suggests that the parahippocampus subserves the neural computations that are predominately required for the acquisition of novel topographical knowledge.

1.61 Investigations

VR paradigms and table-top tasks

In a recent study by Astur et al. (2002), patients with hippocampal damage performed a virtual analogue of the classic Morris water maze task. Spatial learning and memory impairments were found in this task among patients with unilateral hippocampal removals, independent of the side removed. Importantly, this study was the first of its kind to use a nonhuman paradigm to demonstrate allocentric learning and memory impairments in humans with

hippocampal damage and is consistent with findings reported in previous literature. What is most interesting about these results, however, is the way in which the impairments were not shown to be lateralised, a finding that is atypical following surgery for temporal lobe epilepsy, but that is consistent with the results obtained by others e.g. Owen et al. (1995).

Previous investigations of allocentric spatial memory which have shown strong laterality effects have been conducted by Feigenbaum et al. (1996) who developed the Rotating Spatial Memory Task, which is similar to the executive golf task; both tasks require the participant to recall the spatial locations of objects on a computer screen (Morris et al., 1999). As with the golf task, only the right TL group was impaired on this task. However, Morris et al. concede that remembering spatial locations while the participant remains static, may make different processing demands than when a subject is moving around an environment.

Deficits in landmark recognition and environmental learning

In 1996, Maguire et al. demonstrated anterograde topographical disorientation following right TL lesions in post-surgical TLE patients. Furthermore, a specific impairment for landmarks was found from the poor performance of patients in the free recall of major landmarks in the sketch map task. What was particularly interesting, however, was the observation that one patient, who showed no significant pre- and post-surgery change on neuropsychological tests of visuospatial memory, had a gross impairment on topographical orientation tests and produced a very impoverished sketch of the route. Maguire et al. also noted that patients' perceptions of their way-finding skills for novel places did not differ from those of controls. This implies that patients may not recognise their deficits and may be using compensatory strategies to assist them, an assertion that was later supported by Aguirre and D'Esposito (1998).

According to Ploner et al. (2000), anterograde topographical disorientation may result from deficits in creating durable representations of landmarks and spatial relationships between items of the environment (allocentric

representation) and/or spatial relationships between items of the environment and the subject (egocentric representations). In this context, the parahippocampal cortex has been related to the representation of allocentric space and is supported by a plethora of fMRI studies (e.g. Aguirre et al., 1998; Shelton and Gabrieli, 2002; Mellet et al., 2000). Support for this view has also come from Worsley et al.'s (2001) study, which found that damage to the hippocampal formation impaired the ability of human unilateral temporal lobectomy patients to successfully engage in path integration and spatial updating during blindfolded navigation. The observed deficits were attributed to an impairment in allocentric spatial memory, resulting from damage to the hippocampal formation.

However, Ploner et al. (2000) also demonstrated memory deficits in patients with parahippocampal cortex lesions on a task requiring memory of egocentric spatial representations. They suggested that establishing an egocentric frame of reference was a function of the posterior parietal cortex and that lesions of the parahippocampal cortex could disrupt this function. In recent studies by Spiers et al. (2001b), lateralised topographical and episodic memory deficits were found in a group of RTL patients using a VR town. Although RTL activation was shown to be strongly associated with accurate navigation, both RTL and LTL patients were impaired on a task of map constructing. In contrast, although the RTLs showed deficient context-dependent episodic memory, their performance was not as poor as that of the LTL patients. These results are consistent with those of Van der Linden and Meulemans (1998) and Van der Linden and Seron (1987) which showed severe topographical disorientation in a patient with right TL damage using a task designed to investigate network-map and vector-map representations.

Barrash et al. (2000) recently investigated the neural correlates of route learning impairments in a real-world environment among a large group of patients with stable, focal brain lesions, distributed throughout both hemispheres. Participants were required to learn their way along a route, containing no verbal cues but rich with visual cues. The results of the study provided the first empirical confirmation that defective route learning was

strongly associated with lesions of the medial occipitotemporal cortices in either hemisphere as well as the right MTL, with damage to the right inferotemporal region being highly correlated with defective route learning. Barash et al. stressed the role of the right parahippocampal gyrus in topographical learning and stated that patients with topographical disorientation due to parahippocampal gyrus damage tended to show deficits in scene recognition and the knowledge of spatial-topographical relationships, a finding highly consistent with previous research. It may be that the critical role of the parahippocampal gyrus is to combine visuoperceptual information regarding topographically-relevant scenes and spatial information regarding their locations into integrated representations of specific places (Habib and Sirigu, 1987).

These studies are also closely related to the research on topographical disorientation carried out by Aguirre and his colleagues (e.g. Aguirre and D'Esposito, 1997, 1999; Aguirre et al., 1998), which implicated the right inferior ventral cortex. This area is similar to that reported for landmark agnosia (Epstein and Kanwisher, 1998) but with more precise localisation to the parahippocampus. McNaughton et al. (1989) suggested that the parahippocampus associated particular landmarks (represented in ventral occipitotemporal regions) with particular spatial relationships (represented in posterior and retrosplenial cortex). In his account of the hippocampal and parietal contributions to topokinetic and topographical memory, Berthoz (1999) stated several strategies could be used to remember topographic routes and that a clear dissociation has been found between these different strategies in patients with brain lesions. For example, there is considerable evidence for a dissociation between the ability to recognise familiar landmarks (Whiteley and Warrington, 1978) and the ability to describe routes, with the capacity to recognise landmarks being unaffected (Paterson, 1994). Berthoz stresses the importance of realising that topographical function may be distributed over several areas, each making a distinct contribution. For example Courtney et al. (1996) demonstrated the involvement of the frontal cortex in visuospatial memory and Guariglia et al. (1993) showed this area to be active in the mental recall of complex environments. Thus, Berthoz concluded that the critical

areas for spatial memory include the parietal and parietoinsular cortex, insula, cingulate cortex, hippocampal formation, and the dorsolateral frontal cortex.

1.62 Summary

This section has examined the nature of the memory impairments commonly reported following temporal lobe damage, and has focused specifically on the effects of lesions to the right hippocampal formation in humans. Detailed accounts of the various types of spatial memory deficits associated with such lesions were discussed, providing unequivocal support for the critical role of the hippocampus in spatial navigation, and allocentric spatial representation.

Section 9 Deficits associated with left temporal lobe damage

1.63 Introduction

Neuropsychological studies of the effects of left TL resection on memory have also shown some lateralization of function (Burgess, 2002) and verbal memory loss after left temporal lobectomy is a well-documented morbidity in adult patients (Engel, 1996). The most commonly documented memory impairments are for lists of words (Bohbot et al., 1998; Dobbins et al., 1998; Jones-Gotman et al., 1997; Hermann et al., 1992a, 1997; Morris et al., 1995; Helmstaedter et al., 1996; Seidenberg et al., 1996) and a number of risk factors for postoperative verbal memory loss in adults have been proposed. These include a high level of preoperative memory functioning (Helmstaedter and Elger, 1996), absence of hippocampal sclerosis (Hermann et al., 1992b; Oxbury and Oxbury, 1989; Seidenberg et al., 1996) and older age of epilepsy onset (Hermann et al., 1995). In this section, however, the emphasis will be placed on the different kinds of impairments that have been documented following resection of the left TL. This discussion will extend beyond the verbal memory domain to include the findings from studies on language functioning, episodic memory and spatial representation among post-operative left temporal lobectomy patients.

1.64 Language functioning and temporal lobe epilepsy

In contrast with the vast amount of research that has focused specifically on verbal memory following left TL damage, there has been a paucity of research focusing on the language deficits that have also been found to be associated with left TLE and left temporal resections. Among the few studies that have been conducted, aspects of language functioning such as confrontation naming (Bell et al., 2000), verbal and semantic fluency (N’Kaoua et al., 2001; Troster et al., 1998), discourse production (Field, et al., 2000) and reading comprehension (Dlugos et al., 1999) have been investigated. The overall consensus from these studies has been that left TLE and left TL resections are associated with significant language-related cognitive deficits, the most widely documented being confrontation naming impairments (Hermann et al., 1994a; Bell et al., 2002; Mayeaux et al., 1980).

According to Brockway et al. (1998), left medial TL structures appear to be heavily involved in language-generated memory but the role of the right TL in language functioning remains less clear cut and more controversial. Certain researchers (e.g. Lifrak and Novelly, 1984; Martin et al., 1990; Field, 2000) propose that lexical retrieval deficits such as impairments in semantic fluency, can be attributed to right TL damage, whereas others (e.g. Chan et al., 2001) maintain that semantic memory is subserved by the left anterior TL. Support for this latter view has come from Bell et al. (2000) who investigated pre- and post-operative confrontation naming among a sample of 43 patients who had undergone a left anterior temporal lobectomy and found that 26 patients showed a post-operative decline in performance on the Boston Naming Test (BNT). Furthermore, the age of acquisition of the words was the only significant predictor of performance following left anterior temporal lobectomy; object names that were typically acquired later in childhood were least accessible to left TLE patients before and after surgery. Bell et al. attributed the association between naming performance and age of acquisition of the words to an impairment at the levels of semantic and phonological processing. They suggested that words acquired very early in life could be stored in relatively complete form enabling more effective retrieval compared with words, which are learned later in life. In contrast, the more complex

processing required for the later-learned words rendered them inaccessible following brain injury.

These ideas were supported by Lambon Ralph et al. (1998) who argued that object familiarity was a key factor in predicting confrontation naming since it reflected the strength of semantic representations of words. The roles of semantic networks and search efficiency in verbal fluency performance were also investigated by Troster et al. (1995) in their work with left and right TLE patients. Using the Supermarket Fluency Task (REF), it was found that the left group was impaired relative to the controls in semantic verbal fluency output. However, both right and left groups produced fewer words per category sampled than did the normal controls and this deficit was attributed to a smaller content in patients' semantic networks. It was also found that both right and left groups tended to generate category labels (e.g. fruit) rather than specific category exemplars (e.g. pear, apple). Troster et al. proposed that these deficits were not due to inefficient search or retrieval strategies since the TLE patients and controls did not differ on measures of these variables. Instead, the semantic fluency deficits and impairments in storing linguistic information that were found in TLE patients were attributed to the adverse impact of seizure activity upon the more specific rather than global content of semantic networks.

The proposal that disruption of semantic networks underlies deficient semantic verbal fluency in both left and right temporal lobe epilepsy patients is consistent with the findings of other lines of research focusing on the effects of right hemisphere damage (e.g. Joanette and Goulet, 1986; Lifrak and Novelly, 1984; Martin et al., 1990). This line of reasoning has also been used to explain the interictal word naming deficits in TLE patients (e.g. Mayeux et al., 1980 and Saykin et al., 1992). However, the arguments put forward by Troster et al. concerning the adverse impact of seizure activity have been challenged by a recent study by Aikia et al. (2001) which demonstrated impaired verbal memory performance in both newly diagnosed and chronic left TLE patients relative to healthy controls. Interestingly, the results showed that clinically significant, moderate memory impairment was not associated

with the presence of marked hippocampal volume reduction or the early onset of epilepsy. Aikia et al. concluded that the memory problems observed in patients with chronic left TLE could not be attributed solely to the effects of recurrent seizures and prolonged use of medications. They suggested a multifactorial origin, implying that a number of epilepsy-related and demographic factors interacted with the hippocampal pathology in shaping the memory deficits.

Although disturbances of language production in nonaphasic patients with TLE have been acknowledged for some time, the focus of research had been directed at the single-word level of production and specifically on confrontation naming tasks. However TLE language is also associated with a particular type of discourse known as circumstantiality, which is characterised by three main features (Field et al., 2000). These include, verbosity (the tendency to use a larger number of words to convey the same information than the noncircumstantial speaker), longer speaking time in a standard situation compared to healthy controls, and reduced fluency, i.e. producing fewer words per unit time relative to controls.

In this study, Field et al. examined discourse production among a group of thirty-three left TLE patients using an eight-frame cartoon (Cowboy Story) derived from Joannette and Goulet (1989). Analysis of patients' word counts on each of the three recounts of the story showed a pattern opposite to that found among the control group, with a tendency for the patients to become more verbose with each retelling and the controls to use fewer words to tell the story. Field et al. argued that these findings demonstrated a distinction between micro- and macrolinguistic skills in the TLE group, with patients showing dysfunctions at the more global level only. The microlinguistic level relates to the lexical and syntactic aspects of discourse production, whereas the macrolinguistic level relates to the interrelatedness between sentences, which is fundamental to the narrative itself. Field et al. attributed the discourse production differences shown by the TLE patients to a number of factors such as variations in attention and memory and social-motivational pressures. They suggested that increasing verbal output, in the context of a decline in

processing demands, arose from a capacity limitation. This implied that the TLE group were unable to form an internally condensed 'message-type' version or 'discourse record' of the narrative, and could not give a dynamic and structured representation of content, goals and current focus. The verbosity of the TLE patients was thought to reflect a psycholinguistic effect, consisting of a possible social-motivational condition. Field et al. alleged that increased language output could be partly attributed to an active attempt to compensate for declining information content in the interests of preserving social contact at all costs.

1.65 Post-operative language deficits following left TL resection

Dlugos et al. (1999) demonstrated clinically significant language-related post-operative cognitive declines among a sample of post-surgical left TL children, which were not determined by pre-operative standard IQ testing. The children were assessed on a variety of measures and significantly decreased performances on verbal learning, naming, reading comprehension and verbal IQ were observed. These deficits were clinically significant in four of the five patients and led to declines in educational performance. In contrast, no significant declines were found among children who had undergone right TL surgery. Furthermore, the subjective complaints of the patients were also recorded and ranged from annoying forgetfulness to more serious educational difficulties not present before surgery. These included an inability to learn a foreign language, trouble recalling subjects just learned in class, having to re-read text several times to understand it, forgetting instructions, forgetting well-known places, problems with recalling definitions, vocabulary and grammar rules and difficulties with answering open-ended questions. Dlugos et al. stated that the heavy reliance on verbal learning in secondary school made school-aged children particularly vulnerable to symptomatic deficits in this form of learning.

With regard to the effects of left TL resections on confrontation naming, a more recent study by Bell et al. (2002) with early- and late-onset left TLE patients, demonstrated that the early-onset patients showed significantly less overall postoperative decline in naming ability compared to the late-onset

group. Bell et al. attributed the more stable pre- to post-operative naming performance of the early-onset group to the protective benefit of intrahemispheric reorganisation of language. This phenomenon is thought to occur in patients with early acute left hemispheric injury, involves a shift of language functions to the uninjured right hemisphere and has the effect of decreasing visuospatial abilities for which the right hemisphere is typically dominant (Strauss et al., 1990). In such cases, it is thought that the right hemisphere mediates both verbal memory and speech (Sass et al., 1995).

The phenomenon of intrahemispheric language transfer following LTL has also been investigated by Gleissner et al. (2002), who described a preoperative neuropsychological pattern suggestive of intrahemispheric language transfer (i.e. marked nonverbal memory deficits, relatively preserved verbal memory and language performance) among three left TL patients. Following surgery, significant improvements in nonverbal memory functioning were found in all three patients, prompting Gleissner et al.'s suggestion that the distinctness of the pre- and post-operative cognitive patterns implied a functional reorganisation of memory functions that took place over a relatively short period. Furthermore, since their patients were aged between 27-44years, previous allegations of a critical cut-off period between ages 5-16years for cerebral reorganisation processes to occur (Jokeit and Markowitsch, 1999) were clearly not supported. Instead, Gleissner et al. suggested that the adult brain was capable of neuronal plasticity and reorganisation of higher cognitive functions in a manner analogous to the reorganisation of the primary somatosensory cortex observed among adult amputees or chronic pain sufferers (e.g. Flor et al., 1995; Spitzer, 1997). This assertion echoes that of Helmstaedter and Elger (1998) who demonstrated a reorganisation and compensation of verbal memory functions following left ATL, which they attributed to plasticity in neural functioning.

1.66 Episodic memory deficits associated with left TL damage

In recent years, attention has also become focused on the episodic memory deficits found in TLE patients, with researchers such as Viskontas et al. (2002) and Rosenbaum et al. (2000) demonstrating remote episodic memory

impairments among pre- and post-surgical unilateral TLE patients. Viskontas et al. observed three key features of remote memory impairments among a group of left and right unilateral TL patients. These included a defective retrieval of episodic memories with sparing of personal semantic memories, and a lack of a temporal gradient to the episodic memory deficits, which meant that the duration extended to the early childhood period. This finding is partly consistent with the results obtained by Hermann et al. (1994b) who demonstrated preserved semantic functioning and impaired episodic memory but only among their left TL patients without significant hippocampal pathology. However, Viskontas et al.'s findings are in strong agreement with those of Cipolotti et al.'s (2001) in their case study of patient VC. Viskontas et al. concluded that these findings were in accordance with Nadel and Moscovitch's (1997) Multiple Trace Theory of hippocampal function but failed to support Squire's (1992; Squire and Alvarez, 1995) Consolidation Theory.

Burgess (2002) suggested that the role of the hippocampus in episodic memory related to its ability to represent a viewpoint moving within a spatial framework. Support for this postulation comes from recent studies by Burgess et al. (2002), Spiers et al., (2001a, 2001b) and Maguire (2001) using VR town paradigms to investigate spatial navigation and episodic memory functioning among healthy controls and patient samples. In one such study, Spiers et al. (2001b) used a large-scale VR town to assess the topographical and context-dependent episodic memory of patients with unilateral TL damage. Patients were tested on tasks of navigation, scene recognition, map drawing and episodic memory. The results showed an interaction between laterality and the type of tests used, with the right TL patients being impaired to a greater extent than the left-sided patients on topographical memory and also on object and scene recognition memory. In contrast, the overall performance of the left TL patients on the context-dependent memory questions was significantly worse than the controls, while the right TL patients showed an intermediate level of performance. The greatest difference between the left and right groups was observed in the ability to perform temporal discriminations in episodic memory (Spiers et al., 2001b).

This study was the first of its kind to provide evidence of a neural dissociation between topographical memory and context-dependent episodic memory and strongly implicated the left hippocampus in the nonverbal episodic memory task (Burgess et al., 2001; Spiers et al., 2001b, 2001a). Thus, it confirmed previous functional neuroimaging (Maguire and Mummery, 1999) and neuropsychological (Barr et al., 1990; Hokkanen et al., 1995; Kapur et al., 1996; Tanaka et al., 1999) findings of left hippocampal or MTL involvement in the retrieval of autobiographical event memories using verbal paradigms. Furthermore, the observation that there was little difference between both groups of patients on standard tests of memory highlighted the significance of using 'real-world' situations in studying memory problems in these patient populations.

A number of speculative hypotheses concerning the role of the left hippocampus in episodic memory have recently been proposed (Good, 2002; Burgess, 2002). One such hypothesis is that the episodic role of the left hippocampus derives directly from its spatial role in the rat and may serve to provide the spatial context for retrieval (Burgess, 2002). The necessity of supporting spatial behaviour, such as returning to a goal from a new direction, may have forced the hippocampus to specialise in allocentric memory, which is sensitive to changes in one's position between encoding and retrieval (Becker and Burgess, 2001). Alternatively, the left hippocampal involvement in episodic memory may derive from its undoubted role in the storage of verbal material such as word lists, narratives and paired associates. However, this verbal role may also have its basis in a spatial domain and the mechanism of abstracting an allocentric representation from the egocentric detail of sensory perception may have resulted in the left hippocampus becoming specialised in storing the gist of the narrative (O'Keefe, 1996).

What is appealing about this view is its consistency with the results of a number of studies which have demonstrated spatial memory deficits after left as well as right TL damage (e.g. Owen et al., 1995; Astur et al., 2002). The results also fit in nicely with imaging studies documenting left hippocampal

activation in topographical navigation and wayfinding (e.g. Maguire et al., 1998; Ghaem et al., 1997). Such observations present a challenge to the traditional laterality hypothesis (e.g. Saykin et al., 1992) but they may be better explained by Burgess et al.'s account of spatial processes, which attempts to explain the specialised role of the left hippocampus in verbal and episodic memory functioning.

1.67 Summary

In this section, the effects of left MTL damage associated with intractable TLE were discussed. Although the significance of the verbal memory deficits associated with left-sided resections was acknowledged, the main intention was to highlight the less researched, but nonetheless important impairments in linguistic functioning found among these patients. From there, the episodic memory deficits observed following left-sided hippocampal lesions were also discussed. When considered in addition to the literature cited in the previous section, the immense contributions of the hippocampus to human spatial representation, episodic memory and language functioning can be appreciated. However, what is particularly striking is the failure of any previous researchers to simultaneously investigate the effect of hippocampal damage to each of these components. It appears that the focus on spatial and episodic memory functioning, while necessary and extremely important, has been incomplete since it has completely neglected to take account of the deficits in discourse production. In a similar manner, the research into language functioning among TLE patients has not been extended to adequately consider the spatial and episodic memory impairments.

Section 10 Summary of the literature review and rationale for current study

1.68 Introduction

From the detailed discussions presented in this chapter, the critical role of the hippocampal formation in subserving spatial representation and episodic memory in humans has clearly been established. The important influence of O'Keefe and Nadel's (1978) Cognitive Map Theory has also been

demonstrated. This theory has provided the impetus for a large number of theories and models of hippocampal function, and the large body of human and non-human research it has generated serves to confirm its significance. Insights into the effects of hippocampal damage on both spatial representation and episodic memory have also been gained from the discussion of temporal lobe epilepsy and the effects of damage to the medial temporal lobe in humans. When combined with the studies of normal hippocampal functioning, these data have greatly contributed to our current understanding of the functions of the hippocampus. What is most striking about these findings is the complexity of the interactions between the different spatial, episodic and mnemonic functions which depend on the medial temporal lobe. Indeed it has been a great challenge for any one theory to account for both the spatial and episodic aspects of hippocampal function.

1.69 Theories

A number of recent theories such as Viewpoint Dependence (e.g. King et al., 2002), Reinstantiation of context (Redish, 1999), and Autoassociation Theory (Rolls, 1999; Rolls and Treves, 1999) have provided some very interesting frameworks for explaining how the spatial processes of the hippocampus could also serve as a basis for episodic memory formation. However, it appears that certain aspects of hippocampal functioning remain unexplored. In particular, the contribution of the hippocampus to language functioning originally proposed by O'Keefe and Nadel (1978) has been largely ignored in comparison to areas of spatial and episodic memory which have generated a huge amount of research. A more complete understanding of what roles the hippocampus serves in humans may not be acquired unless these linguistic aspects are more thoroughly explored. More specifically, questions concerning how verbal or written discourse production is affected by damage to the hippocampal formation need to be addressed. This is extremely important since previous research documenting spatial and episodic memory deficits among TLE patients has failed to consider the linguistic component: indeed, to the best knowledge of this researcher, no one study has focused on all three domains simultaneously.

Furthermore, certain aspects of everyday memory merit further research. For example, the discrepancy between neuropsychological or laboratory assessments and real-world measures of everyday memory, as well as the paucity of research into self-referred or personally-relevant episodic memory has been highlighted. In addition, the use of real-world tasks in assessing spatial representation also requires further investigation, particularly in the light of the potential link between hippocampal involvement in spatial and linguistic functions. Finally, the effects of damage to the hippocampus, within the area of human spatial navigation, is another important aspect that has remained largely unexplored.

1.70 Rationale for the current research study

The driving force behind this current study has come from the results of the previous research concerning the contributions of the hippocampal formation to the broad spatial and episodic memory domains. The failure of these investigations and resulting theories to focus on the third component of hippocampal functioning, i.e. the linguistic aspect, was a major catalyst for conducting this study. The desire to develop more realistic, real-world measures of both episodic memory and spatial representation was another important incentive. In this current study the spatial, episodic and discourse production abilities in a group of left and right post-operative unilateral TLE patients and age- and gender-matched normal controls was assessed using a variety of novel tasks. The overall aim of the study was twofold: the first part aimed to validate a variety of novel tasks designed to measure spatial representation, episodic memory and discourse production among healthy controls and patient populations. The second part of this aim was to determine whether or not impairments in each of the three domains could be found in the patient groups using these novel tasks. A third aim concerned the nature of the deficits and the interaction between them. The findings of this study were then related to the current theoretical frameworks and in this context, the fourth aim was to provide a more complete understanding of hippocampal functioning in humans.

1.71 Hypotheses

In the light of the literature review, a number of specific hypotheses were proposed at the outset:

Hypothesis 1 predicts that on tasks of everyday memory, both patient groups will show impairments relative to the normal controls. Furthermore, the left-resected group will show a greater level of impairment compared to the right-resected group.

Hypothesis 2 predicts that on tasks of spatial representation, both patient groups will also show deficit performance relative to normal controls. However, in this domain, the right-resected group will be more impaired than the left-resected group.

Hypothesis 3 predicts that on tasks measuring discourse production, both patient groups will show impairments compared to the normal controls.

Hypothesis 4 predicts that on spatial navigation tasks focusing on route reproduction and spatial circular trajectory estimation, there would be no differences between the patients and controls.

CHAPTER 2 - METHODOLOGY

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2.1 Questionnaire and Interview Validation Study

2.1.1 Design

The first part of this validation study was correlational in design and compared the scores obtained on two questionnaires, which were completed by each participant. The questionnaires used were the Cognitive Failures Questionnaire (CFQ) (Broadbent et al., 1982) and the Mundane Memory Questionnaire (MMQ) (Mangaoang, et al., 2002) and they were presented in counterbalanced order to control for order effects.

The second part of the study consisted of interviewing a sub-sample of participants who had completed the first part of the study. An experimental design was used here as the participants were randomly assigned to one of four different interview formats in order to determine the effect of interview format on episodic memory recall.

Ethics approval was applied for and granted by the Department of Psychology Ethics Committee prior to data collection.

2.2 Part I of the Memory Questionnaire Validation Study.

2.2.1 Participants

The questionnaires were administered to 422 adult volunteers. The sample was generally one of convenience, as questionnaires were distributed to personal contacts who then passed them on to work colleagues and friends (e.g. teachers, lawyers, college students including Junior and Senior Freshman students in the Department of Psychology at Trinity College Dublin). The Psychology students were given research credits for their time. Of the 422 participants included, 152 were male and 270 female, ranging in age from 18 to 79 years.

Table 2.1: Age and gender of participants.

Gender	Age (yrs) – mean (S.D.)	Range
Males (n = 152)	42.11(16.37)	18-77yrs
Females (n = 270)	39.45(15.78)	18-87yrs

Table 2.2: Number of participants in each counterbalanced order of presentation.

Gender and Counterbalanced Order	N	Mean Age in Years (S.D.)
Males		
CFQ, MMQ structured	45	40.98 (18.07)
CFQ, MMQ random	25	47.44 (16.38)
MMQ structured, CFQ	40	37.32 (14.35)
MMQ random, CFQ	42	44.69 (15.37)
Females		
CFQ, MMQ structured	58	39.41 (17.50)
CFQ, MMQ random	56	38.86 (16.22)
MMQ structured, CFQ	75	40.16 (14.57)
MMQ random, CFQ	81	39.23 (15.51)

2.3 Materials

2.3.1 The Cognitive Failures Questionnaire

This questionnaire is a measure of self-reported failures in perception, memory and motor function that have occurred in the last six months, and was developed by Broadbent, et al. (1982). It consists of twenty-five possible failures, which were assembled from events that had happened to either the authors or their colleagues, with the aim being to find episodes that the majority of people would accept as occurring to them at least occasionally. The frequency of these mistakes is rated on a five-point scale ranging from ‘never’ to ‘very often’. Higher scores indicated a greater frequency of lapses. A copy of the CFQ including the instructions and response format used, is shown in Appendix 2.1.

Procedure

In administering the CFQ, participants are asked to read the instructions and then to proceed through the questionnaire, circling the most appropriate rating for each item. No time limits are imposed.

Scoring

The numbers circled for each of the twenty-five questions are summed to give a total score for participants on the CFQ.

2.3.2 The Mundane Memory Questionnaire

The Mundane Memory Questionnaire (MMQ) has been developed by Mangaoang and O'Mara. The design of the survey was influenced by the interview study of everyday memory by Eldridge et al. (1994), discussed below. Whereas Eldridge et al. asked their participants to verbally describe what would constitute a typical day, the MMQ addresses what would constitute a typical day for most people (e.g. "Do you recall getting dressed this morning? If so, what did you wear?") in question form, rather than in scale format, thus encouraging written recall.

This twelve-item questionnaire was developed with the intention of focusing on the temporal order of everyday, mundane events and aims specifically to measure the rate at which such experiences are forgotten over a period of four consecutive days. The MMQ was presented in two forms, either structured or random, in a counterbalanced manner. In the structured form, the questions followed the temporal order of a 'typical' daily routine from morning to evening, whereas in the random form there was no pattern or structure to the order of the questions. A copy of the MMQ in both the structured and random formats, along with the instructions given to participants is presented in Appendix 2.2

Procedure

In administering the MMQ, participants were asked to read the instructions carefully and then to proceed with each item of the questionnaire for each of

the four days of recall. The specific details of an event that were recalled were written in the space provided otherwise the space was left blank.

Scoring

In scoring the MMQ, one point was given for a ‘Yes’ response for each question and one mark was given for filling in the specific details required. No points were given for ‘No’ responses and blank spaces. For each participant, five scores were recorded: a total score for the overall questionnaire and also a score for each of the four days. Thus, the maximum score for the twelve questions was 24 points per day and 96 points over the four days. Higher scores indicated greater levels of recall.

2.3.3 Memory Rating Scale

A five-point Likert scale was designed by Mangaoang and O’Mara in order to measure how well participants rated their memory. Using this scale, ranging from 5 (excellent memory) to 1 (very bad memory), participants were asked to rate their memory. A copy of the scale is shown in Figure 2.1.

Figure 2.1: Memory Rating Scale

Having completed this questionnaire and survey, how would you rate your memory overall?

Excellent	Good	Neither Good nor Bad	Not so Good	Very Bad
5	4	3	2	1

Scoring

The rating circled by the participant was the measure used in this task.

2.3.5 Demographics

Participants were also asked to include their age and gender in their questionnaire booklets.

2.4 Procedure

Each participant was given a questionnaire booklet, which included an information sheet, consent form, the CFQ and MMQ, an instructions page, the Memory Rating Scale and the two demographics questions relating to gender and age. Participants who were interested in taking part in the interview study were requested to leave their e-mail addresses. These booklets were distributed to friends and colleagues of the researcher who also passed extra copies onto others to be completed. Most of the booklets were collected by the researcher although some were received by post.

2.5 Part II – Interview Validation Study

2.5.1 Participants

Twenty-one students from TCD took part in the interview study. All the participants had previously completed the questionnaire part of the study and had agreed to be interviewed. Junior and Senior Freshman Psychology students were awarded research credit for participation. Of the twenty-one participants interviewed, there were four males and seventeen females, ranging in age from 19 to 36 years.

Table 2.3: Age and gender of participants in the Interview Study.

Gender	Age (yrs) – mean (S.D.)	Range (yrs)
Males (n = 4)	25.00 (7.35)	21-36
Females (n = 17)	21.00 (1.14)	19-25

2.6 Interview Study

The questions asked in the interviews were based on those used by Eldridge et al. (1994) in their study “Autobiographical Memory and Daily Schemas at Work,” assessing whether schematic influences operate in the recall of daily activities. Eldridge et al. asked participants to describe a typical day, and then to free recall activities from two different days, with occasional probes. Based on this paradigm, participants in this study were asked to describe the following giving as much detail as possible:

- A typical day at work/home,
- Yesterday at work/home,
- A day in the previous week at work/home.

The order of presentation of these descriptions was counterbalanced across subjects in the following way: half of the subjects carried out the ‘Typical’ description first and half received the recall tasks first. The order of presentation of the recall tasks was balanced so that overall, half of the time the recall for Yesterday was carried out before the recall for Last Week, and half of the time the recall for Last Week was carried out before the recall for Yesterday. This counterbalancing resulted in four different orders of the three descriptions as shown in the table below. All the interviews were recorded on cassette with the participants’ permission, and transcribed at a later time.

Table 2.4: Number and mean age of participants in each interview condition.

Gender and Interview Order	N	Mean Age in Years (S.D.)
Males (n = 4)		
Typical, Yesterday, Last Week	1	21.00 (.)
Typical, Last Week, Yesterday	1	21.00 (.)
Yesterday, Last Week, Typical	1	22.00 (.)
Last Week, Yesterday, Typical	1	36.00 (.)
Females (n = 17)		
Typical, Yesterday, Last Week	3	21.00 (.00)
Typical, Last Week, Yesterday	6	20.83 (.98)
Yesterday, Last Week, Typical	5	20.60 (1.52)
Last Week, Yesterday, Typical	3	22.00 (2.65)

2.6.1 Procedure

At the beginning of each interview, each participant was told that the aim of the study was to assess memory for everyday events and asked to give as much detail as possible. Permission was then requested to tape record the

interview and participants were assured that any information they gave would be treated with confidence and used only for research purposes.

Each participant was then asked to describe a typical day, yesterday and this day last week. The format of the interview was counterbalanced as described above. Since the sample was comprised of college students, all participants described a typical day at college. Participants were free to recall their activities in any way they wished. They were not interrupted during recall and were not allowed to refer to any external aids.

Depending on the content and length of the recalls, some subjects were probed for additional information after they finished. The number and type of probes varied across subjects, and consisted of general questions, such as ‘Could you tell me more about what you did in the morning/afternoon/evening?’ or ‘Is there anything else you would like to include?’. Interviews took place on several different days of the week, so some participants described weekend days as well as weekdays. Each interview lasted from 5 to 10 minutes and was transcribed for the purposes of verbal protocol analysis.

2.9.1 Scoring

From the transcripts of the interviews with each participant, the number of basic activities recalled for each day was calculated. This unit of analysis was operationally defined to occur if there was a significant change in person, location and/or object(s) of concern from previous and following activities (Eldridge et al., 1994). A basic activity was only counted if it was evident that the activity was actually being remembered, not guessed. This resulted in an overall score for total number of basic activities recalled during the interview as well as separate scores for the three specific days i.e. Typical, Yesterday and Last Week.

2.7 Data Analysis

The data were analysed using version 10.0 of the SPSS statistical package. Analysis involved the use of both parametric and non-parametric statistics such as multivariate analyses of variance, Pearson correlational analyses and the Kruskal-Wallis test.

2.8 Landmark Task Validation Study

2.8.1 Design

The study was an independent samples quasi-experimental design comprising two parts: a survey and a pointing task. Ethical approval was applied for and granted through the psychology department at Trinity College Dublin prior to administration of the tasks.

2.9 Part I - Landmark Task Validation Study

Participants

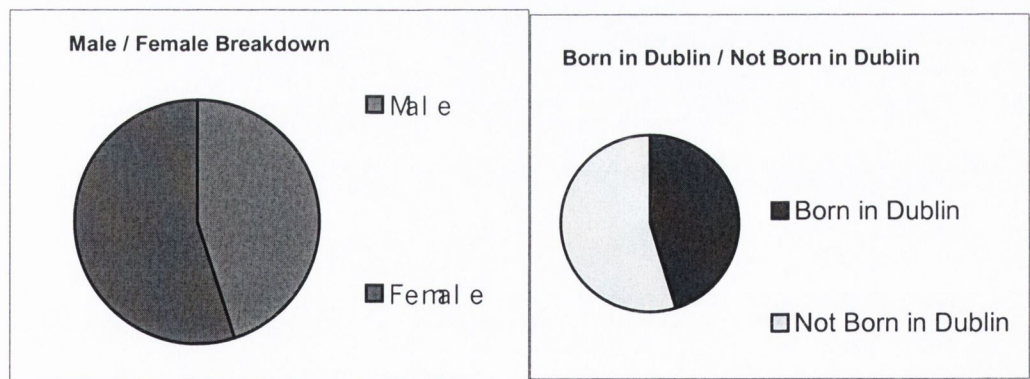


Figure 2.2: Demographic characteristics of the sample

The sample consisted of 185 normal adults, 102 females and 83 males. 84 were born in Dublin and 101 were not (as shown in Figure 2.2 above). The sample constituted an opportunistic or convenience sample, which included students and staff at TCD, and staff from three Dublin secondary schools (in Rathgar, Tallaght and Coolock respectively). Junior and Senior Freshman students from the Psychology Department at TCD were given Research

Credits for participating in the study. The mean age and years spent in Dublin for each subgroup are shown in Table 2.5 below.

Table 2.5: Participants’ mean age and years of residence in Dublin.

Category	N	Age	Years lived in Dublin
Born in Dublin	84	Mean (S.D.)	Mean (S.D.)
Males	43	33.19 (14.41)	29.77 (16.92)
Females	41	33.41 (14.19)	31.12 (15.40)
Not born in Dublin	101		
Males	61	33.40 (13.38)	11.71 (12.39)
Females	40	32.05 (13.00)	10.64 (11.49)

2.10 Materials

The questionnaire booklet consisted of three tasks (Landmark Recognition, Landmark Location and Route Description described below), a rating scale and three questions relating to demographic information. Figures 2.2-2.4 below contain copies of the materials used.

The order of the Landmark Recognition Task and Landmark Location Task was counterbalanced to reduce order effects. Thus, in half of the surveys, participants were given the Landmark Recognition Task before the Landmark Location Task, while in the remaining half, the Landmark Location Task was presented before the Landmark Recognition Task.

2.10.1 Landmark location and naming task

This task was developed by Mangaoang et al. (2002) in order to measure how well people can correctly name different landmarks shown at various locations on a map of Dublin city. A black and white map of Dublin’s city centre of A4 size was used in this task. All street and landmark names were erased from the map, so it was entirely blank, and instead, letters A-E were used to represent the location of famous landmarks. The landmarks indicated on the map at the different points were the GPO (A), the Customs House (B),

Trinity College (C), Christchurch Cathedral (D) and St. Stephen’s Green Shopping Centre (E). A copy of this map is shown in Figure 2.3 below.

Table 2.6: Number of participants in each counterbalanced order.

Task presented first	N	Age	Years lived in Dublin
Landmark Recognition	96	Mean (S.D.)	Mean (S.D.)
Males	38	34.21 (16.07)	22.05 (18.16)
Females	58	37.17 (15.19)	24.77 (17.77)
Landmark Location	89		
Males	45	32.51 (11.77)	11.11 (16.85)
Females	44	26.57(7.27)	10.64 (10.80)

Procedure and scoring

The map was included in the questionnaire booklet that was given to each participant. Participants were asked to name each of the landmarks at the different locations on the map. No time limit was imposed and if a participant was unable to name any landmark, he/she was asked to continue on to the next one.

Each correctly named landmark was allocated one point. The total number of points was recorded for each participant, with the maximum score being 5 points.

2.10.2 Landmark Recognition Task

Materials

The materials used for this task were colour pictures of the following landmarks: Trinity College, St. Stephen’s Green Shopping Centre, Christchurch Cathedral, the Customs House, the GPO, the Phoenix Park and Dail Eireann. The pictures, which are shown in Figures 2.4a-h, were all approximately about the size of a standard postcard and were presented to participants in the questionnaire booklet.

Figure 2.3: Map of Dublin’s city centre used in the Landmark Location Task.



Procedure and scoring

Participants presented with the pictures and asked to name each landmark. One mark was awarded for each correctly named landmark; thus the maximum score in this task was 7 points.

Figure 2.4a: Trinity College Dublin



Figure 2.4b: St. Stephen's Green Shopping Centre



Figure 2.4c: Christchurch Cathedral



Figure 2.4d: Customs House



2.10.3 Dublin Familiarity Scale

This likert-type scale was designed by Mangaoang and O’Mara as in order to measure participants’ familiarity with Dublin’s city centre. Participants were asked to rate their current knowledge of the city centre on this five-point scale ranging from one to five (1 = ‘excellent’ knowledge and five = ‘very bad’ knowledge). The measure taken in this task was the participant’s rating on this scale. A copy of the scale is shown in Figure 2.5 below.

Figure 2.5: Dublin Familiarity Scale

Please rate your current knowledge of Dublin’s city centre:

Excellent	Very Good	Neither good nor bad	Not so good	Very Bad
5	4	3	2	1

Figure 2.4e: General Post Office (GPO)

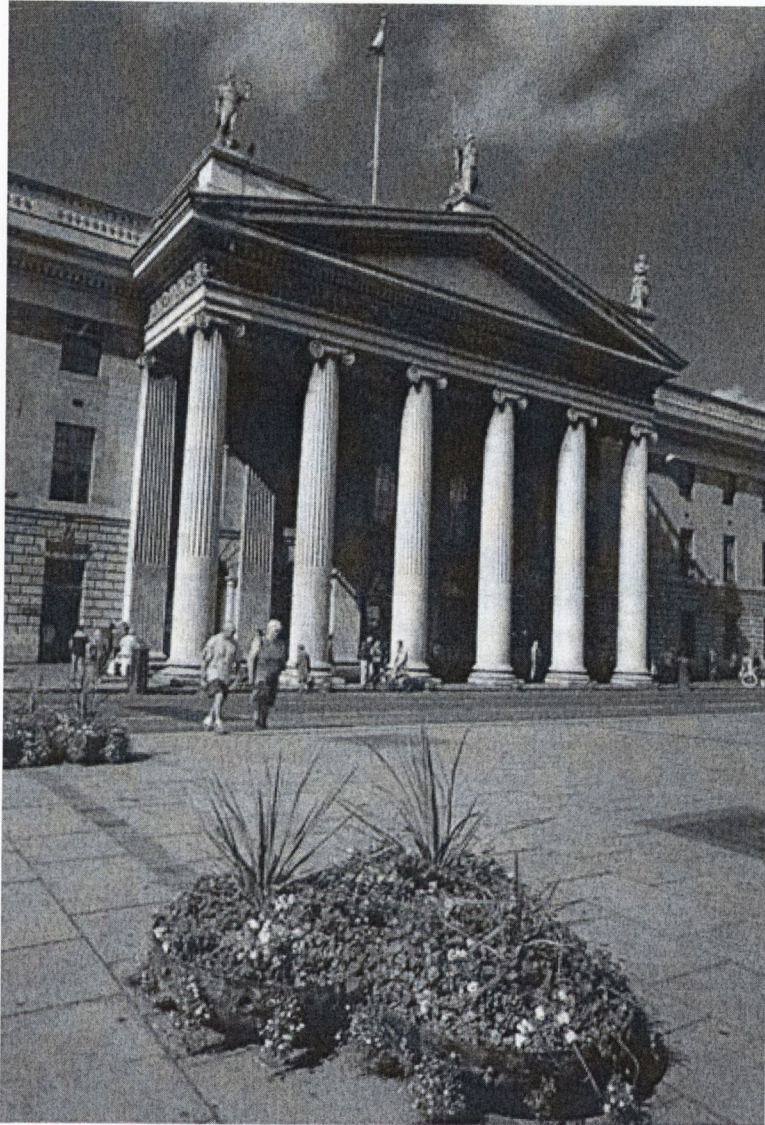




Figure 2.4f: Nelson’s monument in the Phoenix Park.



Figure 2.4g: Parkgate Street Entrance to the Phoenix Park

Figure 2.4h: Dail Eireann



2.10.4 Route Description Task

This task was developed by Mangaoang and O'Mara as a way of measuring the ability of the participants to give an accurate description of the route one would take to get from one place to another using a map of a virtual city.

Materials

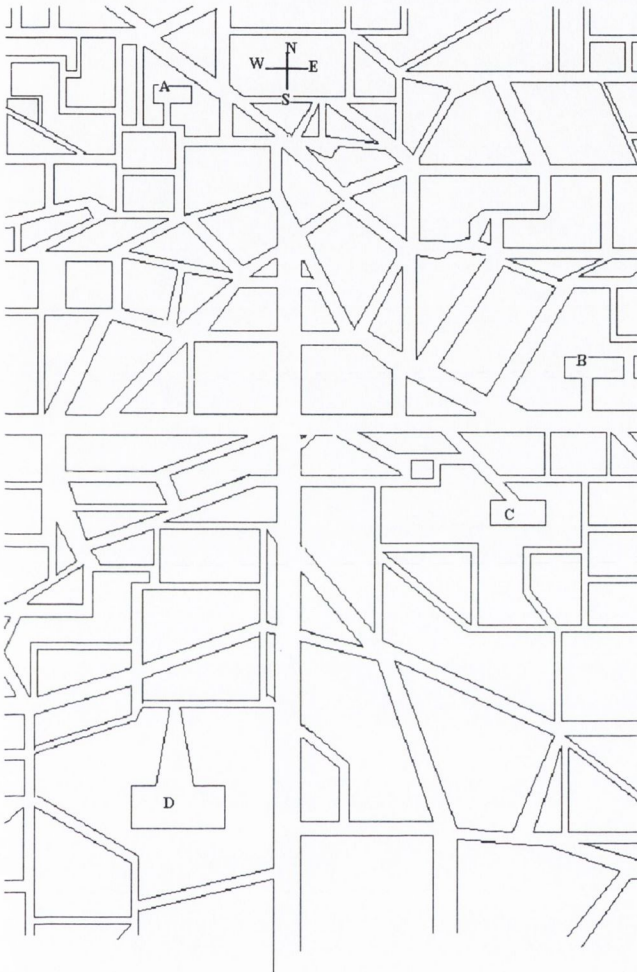
Using bitmap computer software, a two-dimensional map of a 'virtual' city was constructed by the researcher. A copy of this map is shown in Figure 2.6 below. Four letters, A-D were used to signify the location of four landmarks (A – shop, B – cinema, C – monument, D – museum) and the compass points of North, South, East and West were also included. The map contained no other information and was presented to subjects in black and white format on an A4 size sheet of paper.

Procedure

Participants were asked to use this map to answer four questions (see Appendix 2.7). Each question required the participant to describe, in writing, the shortest route they would take to navigate from one landmark to another

e.g. from the cinema at 'B' to the monument at 'C'. Participants were told that they could rotate the map if they wanted to. No time limit was applied. The procedures that were used to score this task are detailed in Appendix 2.3.

Figure 2.6: Virtual map used in the Route Description Task



Scoring procedure

For each of the four questions, the shortest routes and their alternatives were broken down into the requisite steps, generating maximum points of 5, 9, 6 and 7 for routes 1,2,3, and 4, respectively. Longer routes were effectively penalised as were ambiguous or unclear directions. Marks were awarded for each correct step, regardless of whether an incorrect one (e.g. mistaking left for right, or counting 3 turns instead of 4) occurred at any point in the sequence.

A word count was also taken for each set of directions supplied. Whether use was made of the cardinal points in the top half of the map was also recorded.

For a full account of the scoring system that was generated, please see Appendix 2.3.

Measurements

The total number of correct directions written for each of the four questions was summed to give an overall score for the task for each participant. In addition, the number of words used to answer each question was recorded for each participant.

2.11 Demographic details

The demographic details recorded for each participant consisted of the following: gender, age, born in Dublin/not born in Dublin, and years living in Dublin.

2.12 Overall Procedure

The survey was administered to participants in paper format or via e-mail to fill out at their own convenience. Participants read the attached information sheet and signed the consent form. They provided the demographic information listed above and then completed the Dublin Familiarity Scale before proceeding on to the specific tasks. The time taken to complete the entire survey was approximately 15-30 minutes. Upon completion, participants were thanked for their cooperation and invited to take part in the second part of the study described below.

2.13 Part II - Landmark Pointing Task

2.13.1 Participants

A subset of 30 participants who had completed Part I of the study were contacted to take part in a follow-up Pointing Task. This sample comprised 12 males from Dublin, 4 males not from Dublin, 6 females from Dublin, 8 females not from Dublin as shown in Table 2.7 below.

2.13.2 Pointing Task

This task was first used by Nangle (unpublished doctoral thesis) supervised by O'Mara in 1998. It requires participants to point to familiar landmarks from different imagined anchor positions. The rationale for the development of this task and its use in this study stems from the results of imaging studies which have shown that the right hippocampus is activated in similar tasks (Ghaem et al., 1997; Maguire et al., 1997).

Table 2.7: Participants' mean age and years of residence in Dublin.

	N	Age	Years living in Dublin
Born in Dublin	18	Mean (S.D.)	Mean (S.D.)
Males	12	28.33 (12.17)	28.17 (12.26)
Females	6	20.50 (1.38)	16.00 (8.30)
Not born in Dublin	12		
Males	4	24.00 (8.12)	6.08 (8.09)
Females	8	36.68 (15.98)	19.69 (14.40)

The landmarks used in this study were the same as those used by Nangle and consisted of the following: Trinity College Dublin, St. Stephen's Green Shopping Centre, the GPO, the Customs House, Christchurch Cathedral and the Phoenix Park. A subset of four of these landmarks (TCD, GPO, St. Stephen's Green and Customs House) was used as anchor landmarks i.e. the landmarks at which participants were asked to imagine themselves and from which they were asked to point to the locations of the other landmarks.

2.13.3 Apparatus

A circle of radius 1.15m was inscribed on several large pieces of card taped together and marked in intervals of 5 degrees as shown in Figure 2.7 below. A plumbline was used to record the angle at which the participants located the landmarks.

2.13.4 Procedure

Testing took place in a quiet room in the Department of Psychology at TCD. Participants were tested individually after the task requirements were explained to them (Appendix 2.4). Participants stood facing 0 degrees (i.e. straight ahead) and were asked to imagine themselves standing with their back to the first anchor landmark (i.e. TCD).

They were then asked to point to where they imagined the remaining six other landmarks were located relative to their current position. As the participant pointed to each landmark, a plumbline was dropped from the index finger of the participant to the floor and the bearing was calculated using the 5 degree interval markings on the circle on the floor (see Figure 2.7). The same procedure was repeated in turn for each anchor landmark, resulting in twenty-four separate scores.

In some cases, participants preferred to reorient themselves by standing at angles of 90, 180, or 270 degrees according to landmark. Where this occurred note was taken. The tester was blind to the correct angles in order to avoid experimenter error. The task took approximately 10 minutes to complete, following which participants were thanked for their cooperation.

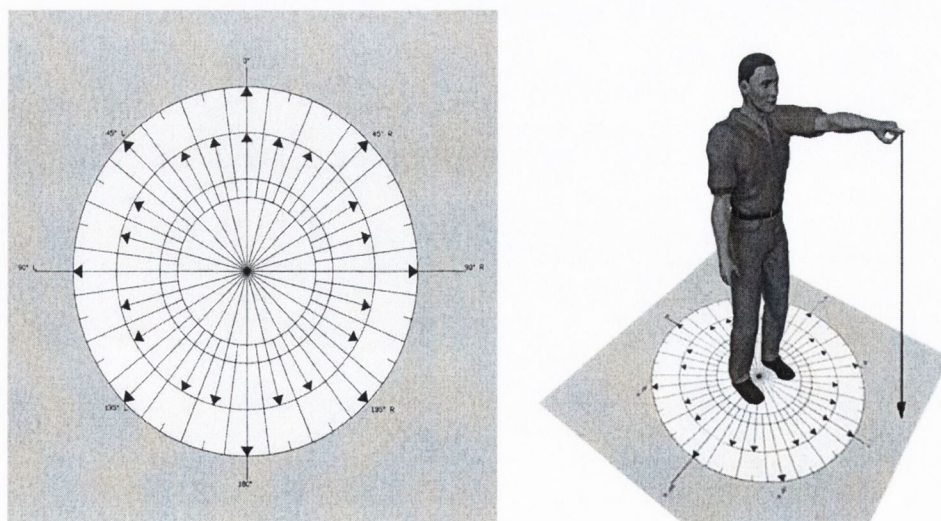


Figure 2.7: Pointing task apparatus

2.13.5 Measurements

In her unpublished doctoral thesis, Nangle calculated the bearing of the six landmarks listed above from each of the four landmarks using a protractor and an Ordnance Survey Map of Dublin (Appendix 2.4). The degree of error for each landmark was obtained by calculating the difference between the true angle and the angle estimated by the participant. This resulted in a total error score over the twenty-four separate landmarks. From this measure, an average error score per landmark was obtained for each participant.

2.13.6 Analysis

The data were analysed using version 10.0 of the SPSS statistical package. Analysis involved the use of both parametric and non-parametric statistics such as multivariate analyses of variance, Pearson correlational analyses and the Kruskal-Wallis test.

2.14 Main Study

2.14.1 Design

The overall design for this study was independent samples, with two experimental groups and one control group.

2.14.2 Participants

The participants were nineteen neurologically normal adults and thirty-three patients of the Epilepsy Surgery Programme at Beaumont Hospital, Dublin. The patients had each undergone a unilateral excision from the temporal lobe for the relief of medically intractable temporal lobe epilepsy and all patients were at least one year post-surgery at the time of testing. Ethical Approval for the Study was applied for and granted by the Beaumont Hospital Ethics Committee prior to data collection.

Selection procedure

Potential participants were identified from hospital records by Dr. Deirdre McMackin, the former Senior Clinical Neuropsychologist at Beaumont

Hospital. Suitable participants were contacted by letter (see Appendix 2.5) and followed up with a phone call. If they were willing to participate, an appointment was arranged at their convenience.

Exclusion criteria

Patients under the age of 18 years were excluded. Patients with any psychiatric contraindications, those who were not seizure free, and any patients with an IQ below 75 were also excluded from the study.

Patient groups

Patients were classified into one of two groups according to the surgeon's operation report. There were 33 patients who had undergone selective amygdalohippocampectomy, 20 in the right hemisphere (RAH) and 13 in the left hemisphere (LAH).

Surgical procedure

Surgery was performed by Professor Jack Phillips, a member of the Epilepsy Neurosurgery Team in Beaumont Hospital. The standard operative approach was through the middle temporal gyrus, which was excised horizontally over a distance of approximately 2.5cm. An image guidance system was then used to identify the depth and direction of the temporal horn, which was exposed and dissected. From there, the medial structures, including most of the amygdaloid nuclei and the anterior 2-3cm of the hippocampal formation including the hippocampus proper and the surrounding structures of the parahippocampal gyrus were removed, while sparing the rest of the lateral and inferior temporal neocortex.

Control Participants

The nineteen age- and gender-matched control participants were recruited from the Psychology Department Participant Panel of Trinity College Dublin. They were paid €5 per hour, plus up to €3 for travel expenses.

Table 2.8: The age and gender of the participants

Participant Group	Gender	N	Mean Age (years) (S.D.)	Age range (years)
RAH	Male	8	36.63 (8.38)	24-47
	Female	12	31.00 (7.58)	21-44
LAH	Male	5	43.00 (14.37)	21-60
	Female	8	32.00 (8.67)	21-41
Control	Male	9	35.89 (10.39)	20-55
	Female	10	31.27 (10.74)	18-49

2.15 Materials

Note: for the materials listed below, it is important to note that although all participants received the same tasks, the experimental groups completed some of these tasks as part of one-year post operative neuropsychological assessment in Beaumont Hospital. Their scores on these tasks were contained in their hospital records. For a list of tasks completed by participants during this session, see Appendix 2.6.

2.15.1 Wechsler Memory Scale – Third Edition (WMS-III)

From this battery of tests, the following subtests were administered to control participants by the researcher and to the experimental participants by a clinical neuropsychologist:

Table 2.9: WMS-III subtests administered to participants.

Immediate Memory	Delayed Memory
Logical Memory I: Story A – Recall Story B – First Recall Story B – Second Recall	Logical Memory II: Story A – Recall Story B – Recall
Verbal Paired Associates I: Recall	Verbal Paired Associates II: Recall Recognition

2.15.2 National Adult Reading Test (NART)

The NART was developed by Nelson and Willison (1982) and consists of a list of 50 words printed in order of increasing difficulty. In administering this test, the list of words is given to the participant and the tester uses the NART answer sheet to record any errors made. The instructions, the answer sheet and the correct pronunciations of the 50 words are included in Appendix 2.7. The NART was administered to the twenty control participants only.

The NART error score is the total number of errors made on the complete NART (i.e. Error score equals 50 minus number of words read correctly). From this error score, the WAIS-R Full Scale, Verbal and Performance IQs can be predicted as shown in Appendix 2.8.

2.15.3 Cognitive Failures Questionnaires (CFQ) as described above

In administering the CFQ, the experimenter read through the instructions with the participant to ensure that they understood what was required. The participants were then asked to continue through the questionnaire themselves at their own pace. The score for each of the twenty-five items was summed to give a total score on the CFQ for each participant (see Appendix 2.1).

2.15.4 Everyday Memory Questionnaire (EMQ)

This questionnaire was developed by Sunderland, Harris, and Gleave (1984) and consists of 28 questions requiring participants to rate how frequently they have had memory lapses over the last three months. The frequency of these lapses is rated on a nine-point scale ranging from 'Not at all in the last three months' to 'More than once a day'. Higher scores indicate greater frequency of reported memory problems. A copy of the EMQ is included in Appendix 2.8.

Procedure and scoring

The EMQ was administered to participants in the same way as the CFQ and no time limit was applied. The score for each of the twenty-eight items was summed to give a total score on the EMQ. The square root of this score was

then calculated as this was the measure used by Sunderland et al. (1984) in their analyses.

2.15.5 Mundane Memory Questionnaire (MMQ) as described above

Procedure and scoring

In administering the MMQ, the experimenter read through the instructions with the participant to ensure that they understood what was required in this task. Participants were then asked to go through the questionnaire and to try to write an answer for each question for each day. If they were unable to recall an event for a specific day, they were told to leave the space blank and to move on to the next item. As with the above questionnaires, no time limit was applied. The scoring procedures for the MMQ have been described in Pilot Study I above and a copy of both forms of the questionnaire is included in Appendix 2.2.

2.15.6 Memory Rating Scale (MRS)

The Memory Rating Scale that was used in the first pilot study was also completed by the participants in this study and scored in the same manner (see Figure 2.1).

2.15.7 Interview Study based on the study by Eldridge et al. (1994).

The interview study used here is a replication of that used in the second part of Pilot Study I described above. The same procedures were used for interviewing participants and the same counterbalancing of the interview formats was applied (as shown in Table 2.10 below). The interview transcripts were scored in the same way as in the pilot study and the total number of basic activities recalled by participants for each day was recorded.

Scoring procedure for Discourse Analysis.

In addition to measuring recall of personally-relevant details, the interview transcripts obtained from participants in this study were subjected to discourse analysis. The aim of this analysis was to quantify the number and type of discourse production errors made by participants and to express this

as a function of overall verbal fluency as measured by the number of words produced.

In accordance with procedures detailed by Haravon et al. (1994), the frequency of the following discourse production errors: repetitions and pauses, verbal tics and pragmatics and the inclusion of ambiguous and irrelevant information (see Appendix 2.9 for a more detailed explanation of discourse production errors). For each participant, the total number of discourse productions errors was recorded.

2.15.8 Rey-Osterrieth Complex Figure Test

The purpose of this test is to assess visuospatial constructional ability and visual memory. It was developed by Rey (1941) and elaborated by Osterrieth (1944).

Procedure and scoring

In administering this task, a plain sheet of A4 size paper was placed on the table in front of the participant in portrait position beside the Rey Figure. The participant is asked to copy the figure as carefully as possible (Copy Condition) – the exact instructions used and a copy of the Rey Figure are included in Appendix 2.10. The Rey Figure was administered to control participants by the researcher and to the experimental participants by a clinical neuropsychologist during a follow-up assessment.

Once the participant has completed this task, the Rey Figure and the copy are removed and another sheet of paper is placed in front of the participant. He/she is then required to draw the figure from memory (Immediate Recall Condition). When this task is completed, the experimenter then waits about thirty minutes after the first administration and then requests the participant to draw the figure from memory once again (Delayed Recall Condition).

The scoring of the Rey Figure in each condition follows the criteria developed by Taylor (1989) and were strictly adhered to. Allowance is made

for the fact that it is difficult to draw a straight line without the use of a ruler, so that if there is a waver in a line or if the line descends or ascends slightly, there is no penalty for these slight inaccuracies. The Taylor Scoring Criteria for the Rey Figure are included in Appendix 2.11.

Table 2.10: Number and mean ages of participants in each interview condition.

Group and Gender	M	Age(S.D.)	F	Age(S.D.)
RSAH	N		N	
Typical, Yesterday, Last Week	2	37.50(2.12)	2	36.50(3.54)
Typical, Last Week, Yesterday	4	35.25(10.44)	3	29.33(7.23)
Yesterday, Last Week, Typical	2	38.50(12.02)	3	32.33(11.06)
Last Week, Yesterday, Typical	0	.	4	28.50(7.55)
LSAH				
Typical, Yesterday, Last Week	1	41.00(.)	3	35.67(6.66)
Typical, Last Week, Yesterday	1	50.00(.)	1	39.00(.)
Yesterday, Last Week, Typical	3	41.33(19.55)	0	.
Last Week, Yesterday, Typical	0	.	4	27.50(9.43)
Control				
Typical, Yesterday, Last Week	2	39.00(1.41)	3	21.00(3.00)
Typical, Last Week, Yesterday	3	28.33(10.41)	2	36.00(12.73)
Yesterday, Last Week, Typical	3	32.00(5.66)	3	34.50(20.51)
Last Week, Yesterday, Typical	2	48.00(9.90)	3	37.33(5.03)

2.15.8 Vividness of Visual Imagery Questionnaire (VVIQ)

The VVIQ was designed to assess visual imagery vividness under conditions which allow for the progressive development of scenes, situations or events as naturally as possible (Marks, 1999). This questionnaire consists of four sets of items giving a total of 16 items and participants rate the vividness of their images separately: with eyes open and eyes closed. A five-point rating scale is used for each item, with a rating of 1 is given for an image that is ‘perfectly clear and vivid as in normal vision’ and a rating of 5 for ‘no image at all, you

only 'know' that you are thinking of an object'. A copy of the VVIQ is shown in Appendix 2.11.

Procedure and scoring

The VVIQ was posted to each participant in March 2003. They were asked to read the instructions accompanying the questionnaire carefully before beginning the questionnaire. Completed questionnaires were returned in the enclosed stamped addressed envelopes and scored by summing the ratings given for each of the 16 items in both conditions i.e. with eyes open and with eyes closed.

2.15.9 Landmark Recognition Task as described above

The Landmark Recognition Task that was used in Pilot Study II was also administered to participants in this study. The same procedures for the administration and scoring of the task were used (see Figures 2.4a-h).

2.15.10 Pointing Task as described above

The Pointing Task that was described in the Pilot Study II was replicated with the participants of this study. The same procedures for the administration and scoring of this task were followed (see Figure 2.6 and Appendix 2.5 for details).

2.15.11 Landmark Location Task

The Landmark Location Task that was used in Pilot Study II was also administered to participants in this study. The same procedures for the administration and scoring of this task were applied (see Figure 2.3).

2.15.12 The Dublin Familiarity Rating Scale as described above

This scale, described in Pilot Study II was also completed by participants in this study and scored in the same way (see Appendix 2.3).

2.15.13 Route Description Task as described above

The Route Description Task that was used in Pilot Study II was also administered to participants in this study following the same procedures.

Scoring

The scoring procedure used in Pilot Study II was modified to generate a more flexible marking system. In this study, participants were awarded one point for each correct direction written in their route descriptions regardless of whether an incorrect/ambiguous one occurred at any point in the sequence. However, repeated or paraphrased directions such as 'go left, or east' were still given one point only. Incorrect or ambiguous directions were not awarded any points. In addition, for each question, three 'correct' possible routes were identified on the virtual map by the researcher (see Appendix 2.12).

Measurements

The total number of correct directions and total number of errors for each route description were recorded for each participant. In addition, the number of words used to answer each question was recorded for each participant. Finally, the route chosen by the participant for each question was noted.

2.16 Spatial Navigation Tasks

This section consists of a variety of path integration tasks where updating of position is achieved by integrating ideothetic sources of information. The three tasks described here are replications of those used by Nangle in her 1998 study of right parietal stroke patients (unpublished doctoral thesis) and they require participants to remember actual routes and distances traversed and to reproduce these routes. For most of these tasks, participants receive no continuous visual feedback, and in order to reduce the likelihood of using compensation strategies, dual-task conditions are employed. The answer-sheets used to record the measurements obtained from these tasks are included in Appendices 2.13-2.15.

2.16.1 Linear Navigation Task

Materials

These included a large room without any potential noise cues, a blindfold, industrial headphones, a stopwatch, a tape measure and some masking tape. Using the masking tape, a straight-line 3.5 metres long was marked on the floor as shown in Figure 2.3 below.

Procedure

The participant was blindfolded to eliminate visual cues and auditory and tactile cues were minimised by using an even ground surface and headphones. On each trial, the participant was hand led using the classic blind person (hand to upper arm) leading technique from the starting point of the 3.5 metre line to the end point.

The participant was then instructed to return to the point of origin unaided. They were required to stop when they thought they had reached this point. Participants were given no feedback about their performance on each trial and were led in a circuitous pathway back to the origin so that they could not directly compute their distance from the correct end point and use this as feedback for the next trial. Subjects were tested in two different conditions using 5 trials each: firstly, without any special instruction (control) and secondly, while performing a dual task such as counting forwards from zero in three's or backwards from 100 in five's.

Measurements

The distance from the true end point to the subjects' end point was recorded for each trial and each condition. The distance from the subjects' end point to the point of intercept with the line was also recorded. This allowed computation of the distance travelled and the degree of error. Time taken to complete the task was recorded.

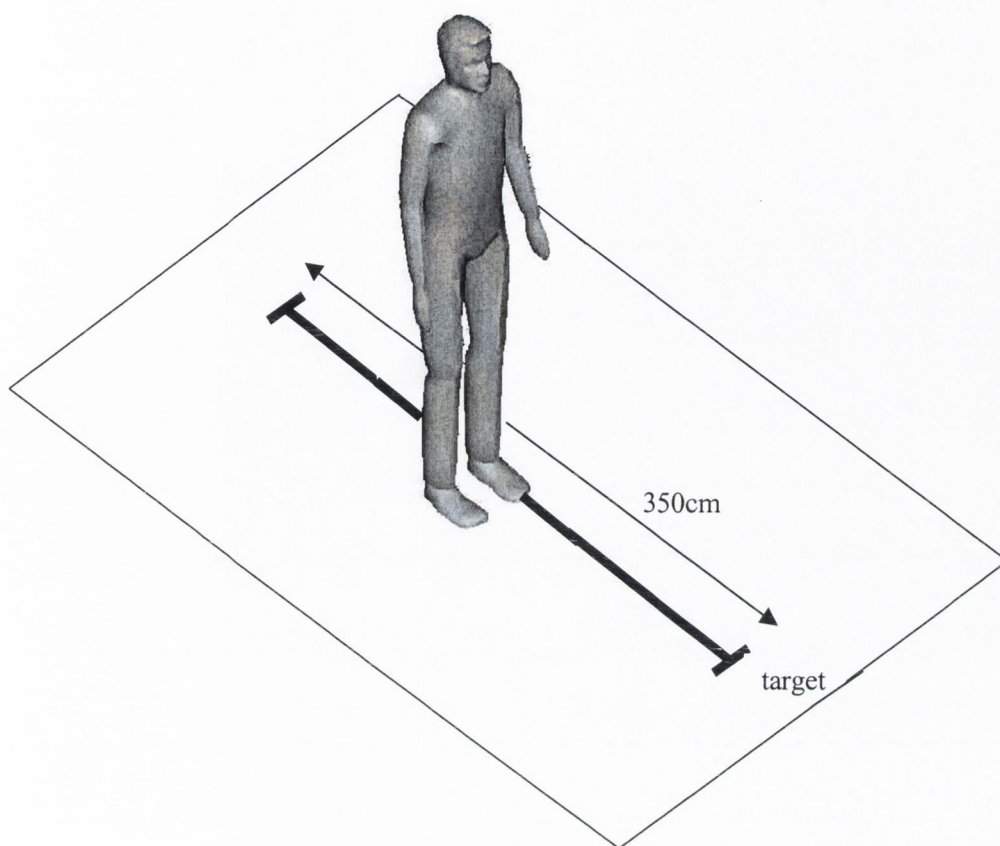


Figure 2.8: A schematic diagram of the line used in the Linear Navigation Task.. The same materials were used in the Backwards Walking Task described below.

2.16.2 Backwards Walking Task

Materials

The materials used for this task were the same as those used for the Linear Navigation Task as shown in Figure 2.8 above.

Procedure

This experiment had four conditions, listed in Table 2.11 below, which were presented in a varied order and intermittently with other tasks to control for practice effects. As with the previous task, participants were given no feedback about their performance on each trial. Furthermore, during the blindfolded tasks, participants were led in a circuitous pathway back to the origin so that they could not directly compute their distance from the correct end point and use this as feedback for the next trial. Each participant completed five trials of each condition. During blindfolded and backward walks, the experimenter walked behind the participant to prevent him/her from falling. In all conditions the participants stopped when they thought they had reached the target position.

Measurements

The distance from the true end point to the subjects' end point was recorded for each trial and each condition. The distance from the subjects' end point to the point of intercept with the line was also recorded. This allowed computation of the distance travelled and the degree of error. Time taken to complete the task was recorded.

2.16.3 Spatial Circular Trajectory Estimation Task

Materials

These included a large room without any potential noise cues, a blindfold, industrial headphones, a stopwatch, a tape measure and twelve white boards of strong card. Using markers, a circle of radius 0.9m was drawn on these boards. Along the circumference of the circle, the angles were marked out at five-degree intervals. At the centre there was a revolving pole with one cord attached, extending to 0.9m. The apparatus was constructed incorporating a cylindrical concrete umbrella base with a central support, which held a vertical pole (height: 5ft.)

Table 2.11: The conditions used in the Backwards Walking Task.

Condition	Description
1	Walking to seen target: the participant was asked to walk to a seen target 3.5m away (i.e. an 'X' marked on the ground).
2	Walking backwards: the participant was asked to look at the target on the floor 3.5m away. The subject was then rotated 180 degrees so that he/she was facing away from the target. The subject was then asked to walk backwards to the previously seen target without looking around.
3	Walking forwards blindfolded: the participant was blindfolded and instructed to walk unguided to a previously seen target 3.5m away.
4	Walking backwards blindfolded: after looking at the target 3.5m away, the participant was rotated 180 degrees so that he/she was facing away from the target. They were then blindfolded and asked to walk backwards, unguided to the previously seen target.

Procedure

During the test the subjects again wore a blindfold and headphones to avoid the influence of visual and auditory cues. Subjects were instructed to walk blindfolded around the circumference of the circle in a clockwise direction while holding the 0.5m cord and stop when they thought they had reached the starting position i.e. when they had completed a 360 degree revolution. Subjects were tested in two different conditions on the circle using 5 trials each. Firstly, without any special instruction (control) and secondly, while performing a dual task such as that outlined above.

Measurements

The time taken to complete this task and the degree of error (i.e. undershoot or overshoot of the complete 360 degrees) were measured on each trial for each condition on the circle.

2.17 Procedure for testing sessions

Patient Participants

Participants from both patient groups were tested in a quiet room in Beaumont Hospital. The same room was used for each participant. At the beginning of the testing session, participants were asked to complete a consent form (shown in Appendix 2.16) and they were reminded that any information given during this session was strictly confidential and for the purposes of this research study only.

All of the materials and scoring sheets described above were collated into separate test booklets for each participant. To ensure that the tasks were presented in the correct, counterbalanced order, the order of presentation of the tasks was listed on the front page of each answer booklet. The testing session was divided into two parts. The first part consisted of all the written and verbal tasks and the second part contained the spatial navigation, pointing and map drawing tasks. Participants were asked if they wanted to take a break between sessions. The time taken to complete both sessions was approximately two hours per participant.

Control participants

Due to the additional length of the assessment battery for control participants, their testing session was spread over two separate occasions. The first session took place in a quiet room in the Psychology Department of Trinity College. As with the experimental groups, the first session for the controls contained the written and verbal tasks. The second session took place on a different date in the same room in Beaumont Hospital that was used with the experimental groups. As with the experimental groups, this session contained the spatial navigation, pointing and map drawing tasks but had the addition of the Rey Figure Task. The time taken for the control participants to complete both parts of the study was approximately two-and-a-half hours.

Table 2.12 below illustrates the order of presentation of the tasks during the testing sessions for experimental groups and control participants. **Note:** The reason why control and experimental groups completed different numbers of tasks was because the experimental groups had already undergone pre- and post-operative neuropsychological testing which included the above tests which were administered to controls. Thus, due to the greater number of tests administered to control subjects, it was sometimes necessary to spread testing over two sessions. In such cases, the first session covered tasks 1-12 and the second session covered tasks 13-23. Testing of experimental participants took on average 2-2.5 hours per participant and for controls, each session took approximately 1.5 hours.

Table 2.12: The order of presentation of the tasks for both groups.

Task number	Controls	Experimental Groups
1	WMS-III: Logical Memory I	CFQ or EMQ (counterbalanced order of presentation)
2	NART	Dublin Familiarity Scale and Landmark Recognition Task
3	WMS-III: Verbal Paired Associates I	MMQ (counterbalanced order of presentation i.e. ordered/random)
4	CFQ or EMQ (counterbalanced order of presentation)	EMQ or CFQ
5	Dublin Familiarity Scale and Landmark Recognition Task	Interview Study (counterbalanced order of interviews)
6	MMQ (counterbalanced order of presentation i.e. ordered/random)	Landmark Location Task
7	EMQ or CFQ	Route Description Task

Task number	Controls	Experimental Groups
8	WMS-III: Logical Memory II Verbal Paired Associates II	Memory Rating Scale End of Session 1
9	Interview Study (with counterbalanced order of interviews)	Session 2 Spatial Navigation tasks presented in the following order: Linear navigation task control condition
10	Landmark Location Task	Backward walking task control condition
11	Route Description Task	Linear navigation task dual condition
12	Memory Rating Scale End of Session 1	Backward walking task, walking backwards condition
13	Session 2 Rey Complex Figure: copy and immediate recall	Spatial circular trajectory task control condition
14	Spatial Navigation tasks: Linear navigation task control condition	Backwards walking, walking blindfolded to target condition
15	Backward walking task control condition	Spatial circular trajectory task dual task condition
16	Linear navigation task dual condition	Backward walking task, walking backwards & blindfolded to target
17	Backward walking task, walking backwards condition	Landmark Pointing Task

Task number	Controls	Experimental Groups
18	Spatial circular trajectory task control condition	VVIQ
19	Backwards walking, walking blindfolded to target condition	
20	Spatial circular trajectory task dual task condition	
21	Backward walking task, walking backwards & blindfolded to target	
22	Landmark Pointing Task	
	Rey Complex Figure – delayed recall	
23	VVIQ	

2.18 Data Analysis

All statistical analyses were carried out using SPSS 10 for PC. In the interests of parsimony, a brief discussion of the different statistical tests used in the analyses of the results of this research is included in the following section.

2.18.1 Reliability analysis

This procedure was used to examine the reliability of the MMQ. An Item analysis was performed on the data from the Memory Questionnaire Validation Study in order to obtain Cronbach’s alpha, which is generally the measure of choice for assessing the reliability of psychological questionnaires.

2.18.2 ANOVA models

Analysis of variance (ANOVA) was the main statistical tool used to examine the differences between the scores obtained by participants in different experimental groups. Univariate ANOVA tests were used when the effects of the between-subjects factors such as Group or Gender are measured on one dependent variable only e.g. CFQ scores. Multivariate procedures were employed when the effects of the between-subjects factors were being measured on two or more dependent variables. When the results of such analyses showed main effects for factors with more than three levels as in the case of the Group factor, the differences between these levels are further investigated using Tukey post hoc multiple comparisons, where alpha was set at $p < .05$.

In certain cases, a repeated measures multivariate mixed-factorial ANOVA was used in order to detect the combined effects of the between subjects and within subjects factors. The repeated measures test was used because all the levels of the within subjects factor were completed by each of the participants. For example, in the Interview Study, each participant recalled basic activities from three particular days, a typical day, yesterday and a day in the previous week.

In such cases, when a main effect of the within subjects factor occurred, Bonferroni paired comparisons were used to show at which levels these effects occurred. When using the multivariate mixed-factorial ANOVA tests, the results of the Mauchly Test of Sphericity were inspected in order to ensure that the assumption of homogeneity of covariance was upheld. If the Mauchly statistic was significant, i.e. χ^2 yielded a significant p-value, then this assumption was violated. In such cases the ANOVA F test was made more conservative by using the Greenhouse Geisser test, which reduced the degrees of freedom of the F ratio, and thus increased the value of F required for significance.

2.18.3 *T*-tests

Independent Samples *t*-tests

These tests were used in order to compare the mean scores obtained by participants from two different groups (e.g. males and females) on the same task.

Paired Samples *t*-tests

The paired samples *t*-test was used to compare the mean scores obtained by one group on two related tasks, for example in the case where participants completed both forms of the VVIQ, this statistical test was used.

2.18.4 Pearson correlations

The Pearson correlation was used to compare the degree of association between scores obtained by subjects on one task and their results on another task. Correlation matrices were used to portray the significant relationships between different tasks. These interactions were then highlighted in a series of Path Models.

2.18.5 Factor Analysis

This statistical procedure was used in the final stage of the analysis as a means of integrating the results obtained from the many different tasks and measures that were administered to participants. Factor analysis is primarily a data reduction method and it was applied in this study in order to explore the connections between the various tasks with a view to providing psychologically meaningful labels to the shared common components.

2.18.6 Non-parametric tests

Kruskal-Wallis test

The Kruskal-Wallis non-parametric equivalent of the one-way ANOVA was used in cases when the data were either ordinal (for example, the ratings on the Memory Rating Scale or Dublin Familiarity Scale), or when the assumptions of the ANOVA were violated to such an extent that it was not appropriate to use parametric statistics.

Mann-Whitney U test

This test was used as an equivalent of the independent samples t -test in order to detect the differences between groups on data which were not amenable to analysis using parametric statistics.

CHAPTER 3 - RESULTS

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3.1 Introduction

In this chapter, the results of this thesis are presented in the following format. Firstly, the findings of the two validation studies, including the results obtained from a reliability analysis, which was performed on the MMQ are presented in this section. The second part of this chapter focuses on the results of the main part of the thesis, and the performance of the two patient groups relative to the control participants on each of the tasks outlined in the previous chapter. For all the graphs contained in this Chapter, the error bars represent the Standard Error of the Mean (SEM). Finally, the results of the neuropsychological assessment data are contained in Appendix 3.1.

3.2 Memory Task Validation Study

3.2.1 Reliability of the MMQ

The reliability of the MMQ was measured by calculating Cronbach’s alpha. The generally accepted value of 0.8 is considered appropriate for cognitive tests (Kline, 1993). An item-analysis of each of the twelve items contained in the MMQ was performed on a total of 422 questionnaires and a summary of the most important results of this procedure are contained in Table 3.1 below. The first point of interest is the overall reliability of the scale, which is expressed by Cronbach’s alpha and is shown to be 0.8475. This result is extremely important in that it indicates that the MMQ is a reliable means of assessing episodic memory over the last four days.

The second important finding concerns the column entitled ‘corrected item-total correlation’ contains the correlations between each item on the MMQ and the participant’s total score on this questionnaire. In order for the scale to be considered reliable, all the items should correlate with the total score. From the data contained in Table 3.1, it is clear that the item with the lowest correlation is Question 3 on the scale concerning the recall of the weather. However, the next column, entitled ‘alpha if item is deleted’, reflects the change in Cronbach’s alpha that would be seen if a particular item were deleted from the questionnaire. If the deletion of an item increases

Cronbach’s alpha, and in doing so improves reliability, then any items that result in substantially greater values of the alpha reported above may need to be deleted in order to improve its reliability. Inspecting the data contained in this column reveals that the deletion of any of the items results in little variation in the overall reliability of the MMQ. Regarding Question 3, which was shown to have the lowest correlation with the overall score, it can be seen that deleting this item results in only a marginal increase in reliability i.e. from 0.8475 to 0.8508. Therefore, from the results of these analyses it was concluded that the twelve-item MMQ did not need to be modified in any way as it contained sufficiently high reliability in its original form.

Table 3.1: Reliability analysis of the MMQ using Cronbach’s alpha

Question no.	Item	Corrected item-total correlation	Alpha if item deleted
1	Get dressed	.3713	.8448
2	Go to work	.4337	.8413
3	Weather	.2596	.8508
4	Coffee break	.6217	.8274
5	Post letters	.6123	.8281
6	Meet friends	.5222	.8353
7	Lunch	.5186	.8359
8	Shopping	.6595	.8240
9	Reading	.5249	.8351
10	Housework	.6307	.8267
11	Watch TV	.5009	.8369
12	Phone calls	.4699	.8392

Alpha = .8475

3.2.2 Analysis of the CFQ and MMQ Scores

Test booklets were completed by 422 participants. The descriptive statistics from the preliminary analysis are shown in Table 3.2 and Figure 3.1 below. The questionnaires were presented in four different counterbalanced orders.

The CFQ and MMQ scores for each order of presentation are shown in Table 3.3 below.

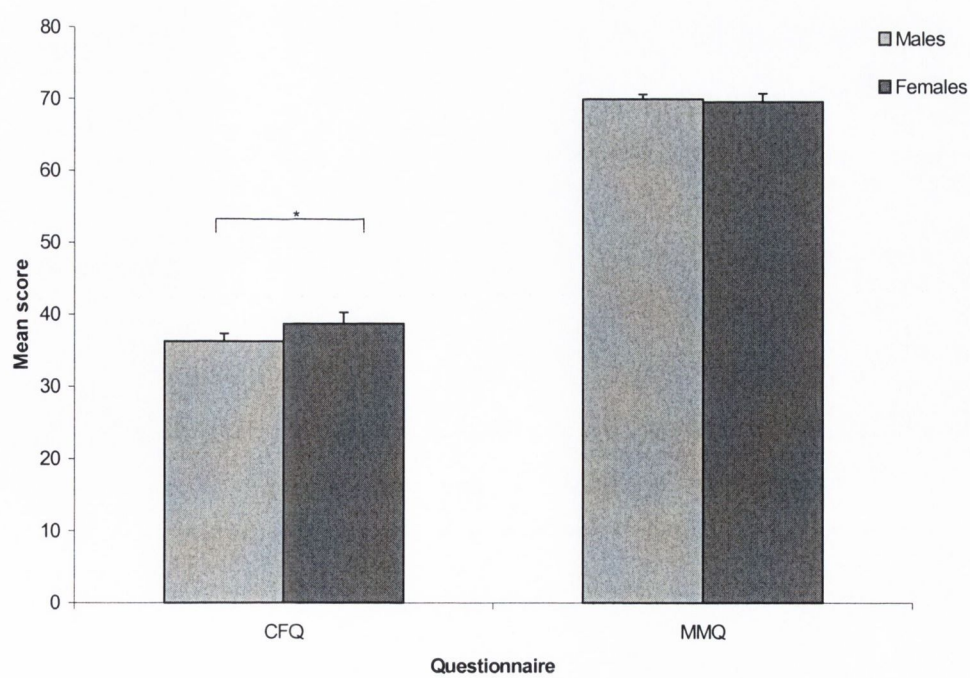
Table 3.2: Participants’ mean scores on the CFQ and MMQ.

Questionnaire scores	Males	N	Females	N
CFQ – mean (S.D.)	36.28 (12.90)	152	38.69 (11.72)	269
MMQ – mean (S.D.)	69.86 (19.00)	152	69.51(18.94)	270

Analyses of the effects of the between-subjects factors.

A two-way ANOVA was used to determine whether the between-subjects factors of Gender and Order (of presentation of booklets) affected participant performance on the MMQ and the CFQ. Regarding the MMQ, the results of this analysis showed no main effects for either factor [Gender: $F(1, 413) = .017, p>.05$; Order: $F(3, 413) = 1.541, p>.05$]. However, a main effect for Gender was found on the CFQ [$F(1,413) = 4.448, p<.05$] but there was no effect of Order of presentation on the CFQ scores [$F(3, 413) = 2.180, p>.05$]. The interaction between the two factors was not significant for either the MMQ or the CFQ [MMQ: $F(3, 413) = .466, p>.05$; CFQ: $F(3, 413) = .804, p>.05$].

Figure 3.1: Mean scores on the CFQ and MMQ



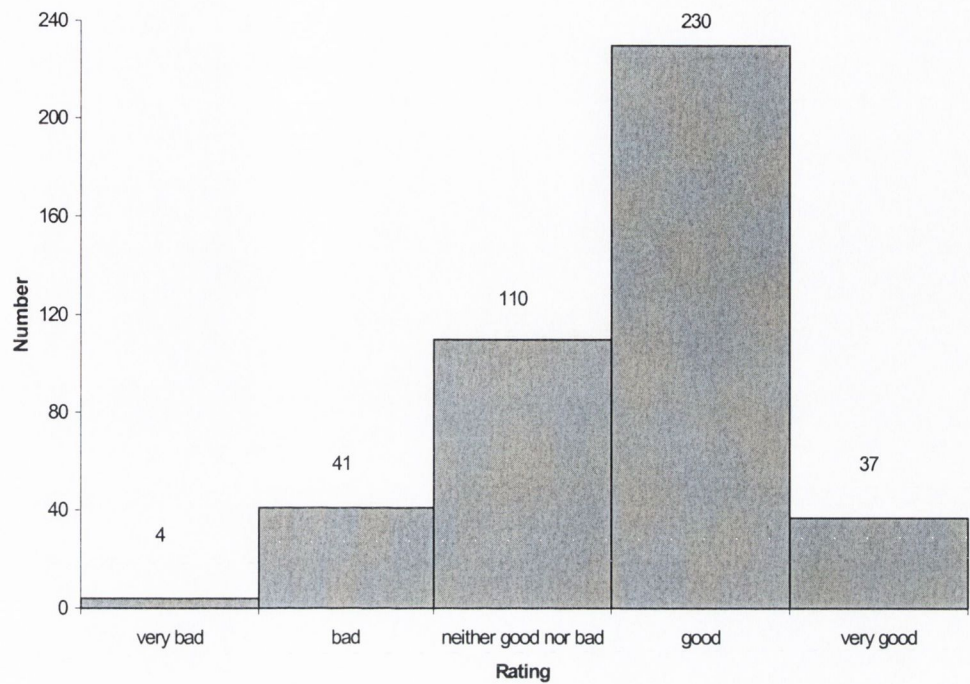
3.3 Analysis of participants’ scores on the Memory Rating Scale.

Figure 3.2 contains a histogram depicting the number of participants in each category on the Memory Rating Scale. From this graph it is clear that most participants rated their overall memory as “good”, while the second most prevalent response was “neither good nor bad”. Few respondents rated their memory as “very bad”. A Kruskal-Wallis non-parametric test was used to determine whether there was a gender difference in self-ratings using this scale. The results showed that the difference in mean ranks between males and females was not significant [$\chi^2(1) = 2.943, p > .05$].

Table 3.3: Participants’ scores in each counterbalanced order.

Order of presentation	Males	N	Females	N
CFQ, MMQ structured n = 103				
CFQ mean (S.D.)	39.04(12.03)	45	39.91(12.41)	58
MMQ mean (S.D.)	72.87(19.73)	45	71.53(20.15)	58
CFQ, MMQ random n = 81				
CFQ mean (S.D.)	37.00(10.25)	25	40.52(11.23)	56
MMQ mean (S.D.)	69.76(18.11)	25	68.14(18.87)	56
MMQ structured, CFQ n = 115				
CFQ mean (S.D.)	33.70(12.62)	40	38.97(10.90)	74
MMQ mean (S.D.)	68.82(20.67)	40	72.73(19.08)	75
MMQ random, CFQ n = 123				
CFQ mean (S.D.)	35.36(15.11)	42	36.28(12.07)	81
MMQ mean (S.D.)	67.69(17.25)	42	66.02(17.57)	81

Figure 3.2: Number of participants in each category on the Memory Rating Scale



3.4 Correlational Analyses

In order to examine the relationships between the different memory tasks and other participant characteristics such as age and gender, a correlation matrix of the scores obtained on the different measures was produced and is shown in Table 3.4 below.

Table 3.4: Correlation matrix between questionnaires, rating scale, age and gender.

Variable	CFQ	MMQ	Age	Gender
Memory Rating Scale	-.507**	.200**	.048	-.086
CFQ		-.082	-.220**	.095
MMQ			.073	-.009
Age				-.080

**p<.01

From this table it is clear that the scores obtained on the CFQ are not significantly correlated with the scores obtained on the MMQ. However, the scores on both questionnaires did correlate significantly with participants’

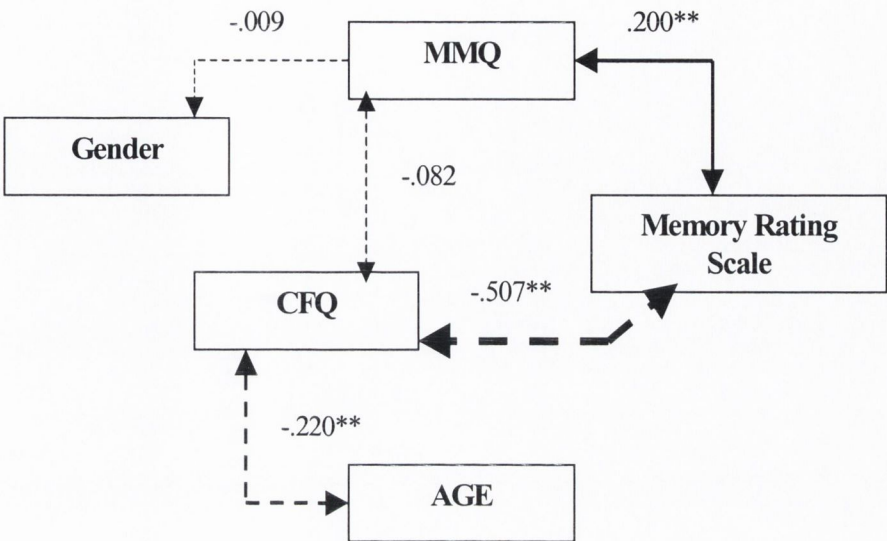
self-rating of memory on the Memory Rating Scale with the correlation between the CFQ and this scale being in the expected negative direction. Finally, the CFQ scores also show a significant negative correlation with age, indicating that younger participants tended to have higher scores on this questionnaire than older participants. A Path Model of the relationship between the significantly correlated tasks and variables is shown in Figure 3.3.

3.5 Specific analyses of MMQ data

Analyses of participants' performance over the four days.

Figure 3.4 below shows the performance of the participants on the MMQ over each of the four days. A repeated-measures mixed factorial ANOVA was used to detect the presence of a main effect of the within-subjects factor Day relative to the between-subjects factors Gender and Order, and to determine whether there was any interaction between the three factors. The results of the Mauchly's Test of Sphericity for homogeneity of covariance showed a significant Mauchly statistic [$\chi^2=746.817$, $p<.01$], providing strong evidence towards heterogeneity of covariance. Since the present data failed the sphericity test, the ANOVA F test was made more conservative by using the Greenhouse-Geisser test, which reduced the degrees of freedom of the F ratio, and thus increasing the value of F required for significance.

Figure 3.3: Path Model of the correlations between age, gender and the memory tasks.



The results of this analysis confirmed the previous findings; neither of the between-subjects factors showed significant main effects [Gender: $F(1, 414) = .073, p > .015$; Order: $F(3, 414) = 2.339, p > .05$], and the interaction between both factors was not significant [$F(3, 414) = .738, p > .05$]. Regarding the within-subjects factor, Day, a significant main effect was observed [$F(1.483, 613.787) = 59.141$]. However there were no interactions between this factor and the between-subjects factors, Gender and Order. Post hoc Bonferroni paired-comparisons for the within-subjects factor, Day are listed in Table 3.4 below. The results of these analyses, which are also contained in Figure 3.5 below, showed that there was a significant difference between the number of details recalled for each of the four days relative to the other days.

Figure 3.4: Participants' scores over the four days on the MMQ

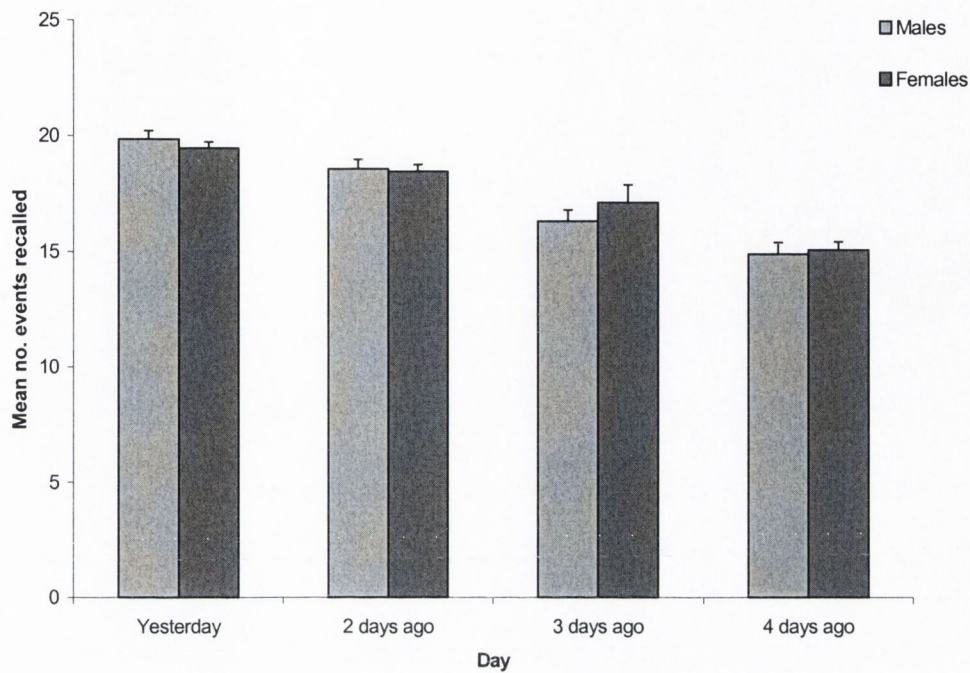
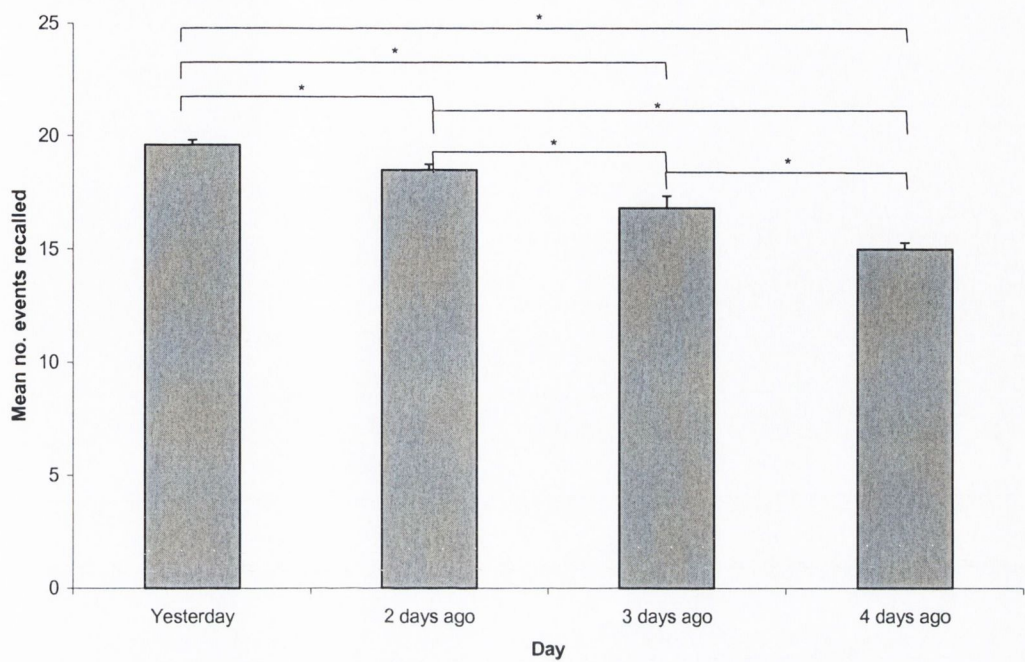


Table 3.4: Bonferroni pairwise comparisons for the within-subjects factor, Day.

Comparisons	Mean difference	Std. Error
Yesterday – 2 Days ago	1.162*	.161
3 Days ago	3.051*	.516
4 Days ago	4.760*	.242
2 Days ago – 3 Days ago	1.889*	.502
4 Days ago	3.598*	.203
3 Days ago – 4 Days ago	1.709*	.494

*p<.05

Figure 3.5: Decline in recall over the four days on the MMQ



The similar performance between males and females on the MMQ is further illustrated in Figures 3.6a and 3.6b below. Figure 3.6a shows the absolute decline in recall for males and females over the four days. This decline is expressed as a percentage of overall retention in Figure 3.6b.

Figure 3.6a: Absolute decline in recall on the MMQ

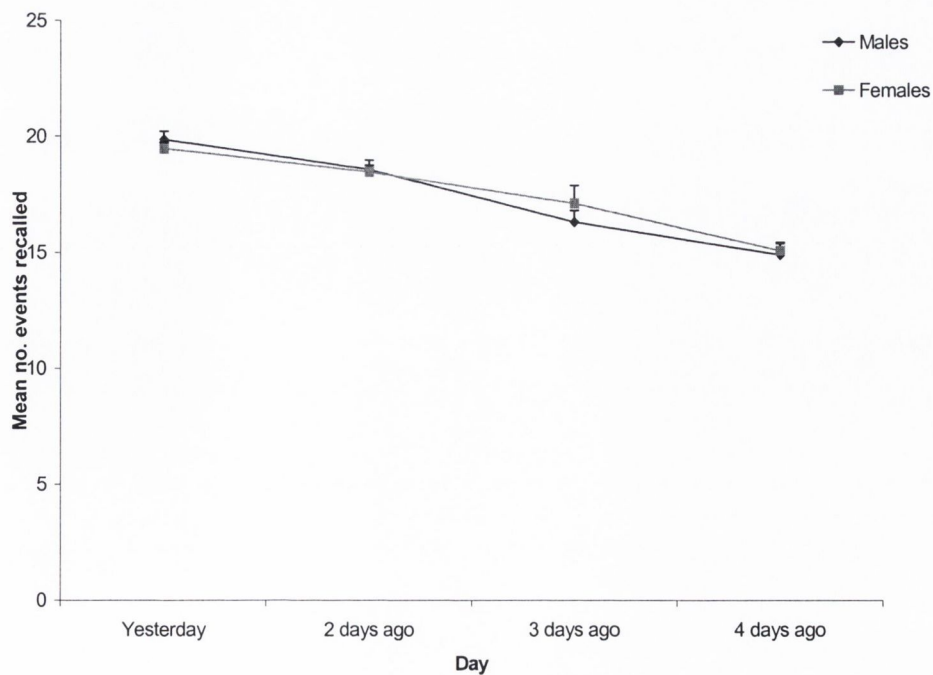
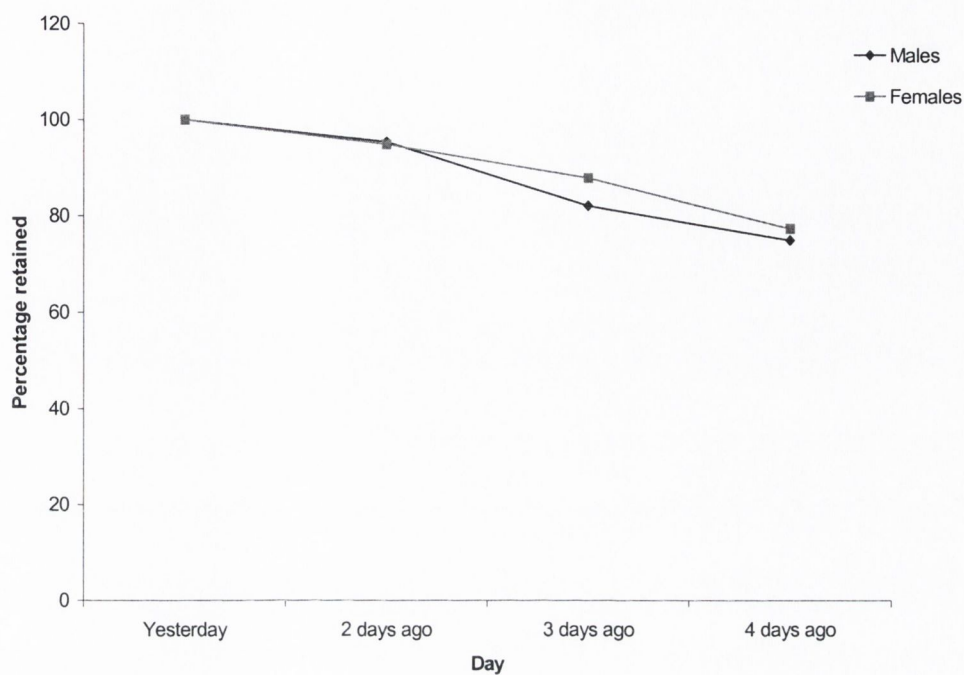


Figure 3.6b: Relative decline in recall on the MMQ



3.6 Correlational Analyses of mean recall over the four days

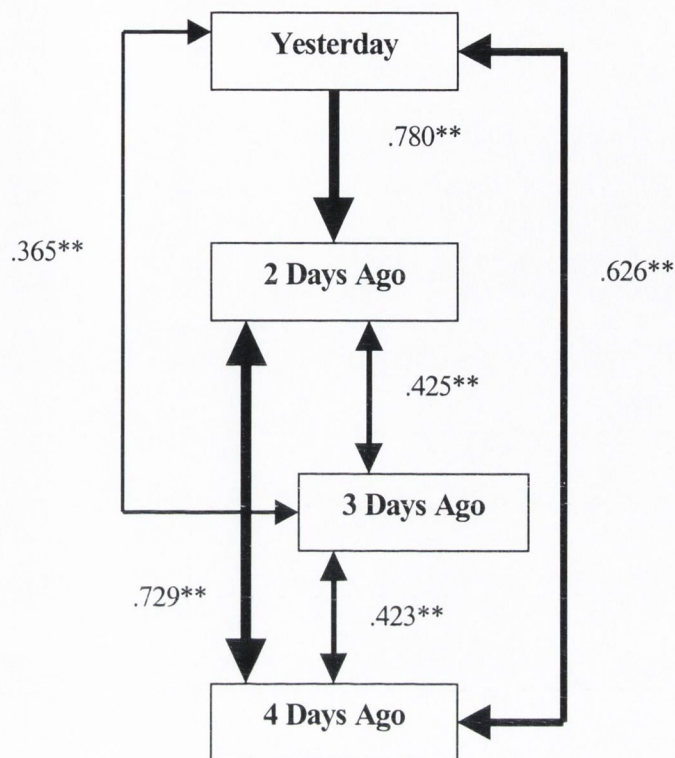
A correlation matrix was produced to illustrate the relationship between the number of details recalled for each day on the MMQ. From Table 3.5 below and the Path Model shown in Figure 3.7, it is clear that there are highly significant correlations between the number of details recalled for each day on the MMQ.

Table 3.5: Correlation matrix of mean number of events recalled each day using the MMQ.

Day	2 Days ago	3 Days ago	4 Days ago
Yesterday	.780**	.365**	.626**
2 Days ago		.425**	.729**
3 Days ago			.463**

**p<0.01

Figure 3.7: Path Model of the correlations between each of the days in the MMQ



3.7 Analysis of the Interview Study

From the main sample of 422 participants, a subset of twenty-one volunteers took part in the interview study. Table 3.6 below shows the mean number of basic activities recalled by participants in the Interview Study. The data are split according to gender and each of the four counterbalanced orders of presentation used.

Analysis of Between-subjects Factors

A multivariate ANOVA was used to test the effects of the between-subjects factors Gender and Order (of recall) on the three dependent variables Typical, Yesterday and Last Week. The results of this analysis showed that there were no main effects of either factor on the any of the dependent variables [Gender – Typical: $F(1,13) = .054, p>.05$; Yesterday: $F(1,13) = .317, p>.05$; Last week: $F(1,13) = .727, p>.05$; Order – Typical: $F(3,13) = 1.595, p>.05$; Yesterday: $F(3,13) = 1.806, p>.05$; Last week: $F(3,13) = 2.006$]. The interaction between Gender and Order was not significant for any of the three

days of recall [Typical: $F(3,13) = .183, p>.05$; Yesterday: $F(3,13) = .829, p>.05$; Last week: $F(3,13) = 1.525, p>.05$]. Figure 3.8 below shows the mean number of activities recalled for males and females for each day in the interview.

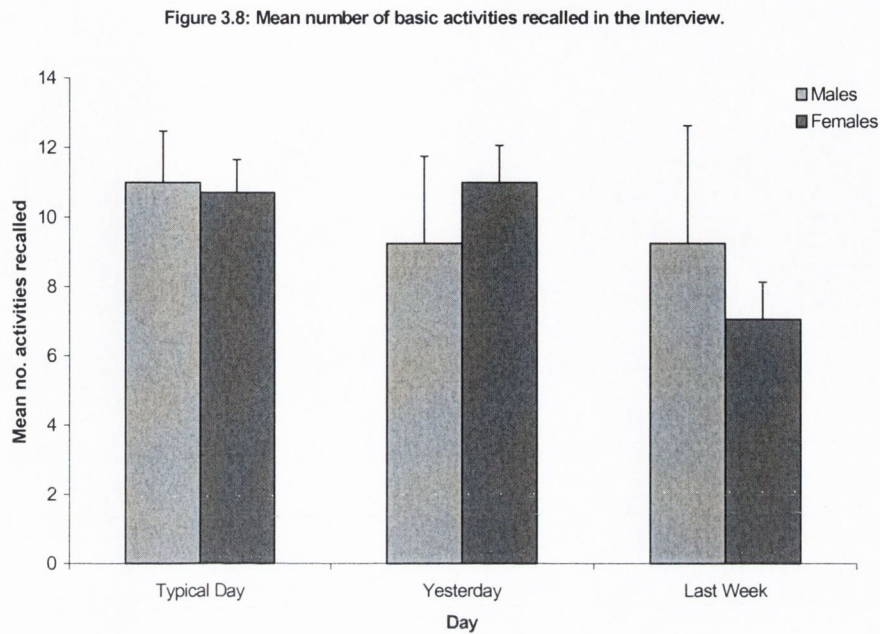
Table 3.6: Mean no. basic activities recalled in the interview study.

Order	N	Males	Females
1. Typical, yesterday, last week	4	n = 1	n = 3
Typical – mean (S.D.)		8.00(.)	16.00(4.00)
Yesterday – mean (S.D.)		10.00(.)	11.00(1.73)
Last week – mean (S.D.)		11.00(.)	8.33(6.66)
Total recalled – mean (S.D.)		29.00(.)	35.33(8.08)
2. Typical, last week, yesterday	7	n = 1	N = 6
Typical – mean (S.D.)		15.00(.)	9.50(2.43)
Yesterday – mean (S.D.)		12.00(.)	9.00(4.86)
Last week – mean (S.D.)		18.00(.)	7.17(3.25)
Total recalled – mean (S.D.)		45.00(.)	25.67(6.31)
3. Yesterday, last week, typical	6	n = 1	n = 5
Typical – mean (S.D.)		11.00 (.)	10.60(4.16)
Yesterday – mean (S.D.)		13.00(.)	12.40(5.59)
Last week – mean (S.D.)		3.00(.)	7.40(5.55)
Total recalled – mean (S.D.)		27.00(.)	30.40(14.21)
4. Last week, yesterday, typical	4	n = 1	n = 3
Typical – mean (S.D.)		10.00(.)	8.00(1.00)
Yesterday – mean (S.D.)		2.00(.)	12.67(2.52)
Last week – mean (S.D.)		5.00(.)	5.00(3.61)
Total recalled – mean (S.D.)		17.00(.)	25.67(3.21)

Analysis of differences in recall over each day

A paired samples *t*-test was then used to test for differences in the mean number of basic activities recalled over the three days. The results revealed a significant difference between the mean number of basic activities recalled for a typical day and for last week [$t(20) = 3.105, p<.01$]. It was also shown

that significantly more activities were recalled for yesterday when compared to last week [$t(20) = -2.816, p<.01$].



3.8 The relationship between the Interview Study, CFQ, MMQ, and Memory Rating Scale.

In order to detect whether there was a correlation between participants’ scores in the Interview Study and their scores on the CFQ, MMQ and Memory Rating Scale, a correlation matrix was produced and is shown in Table 3.7 below.

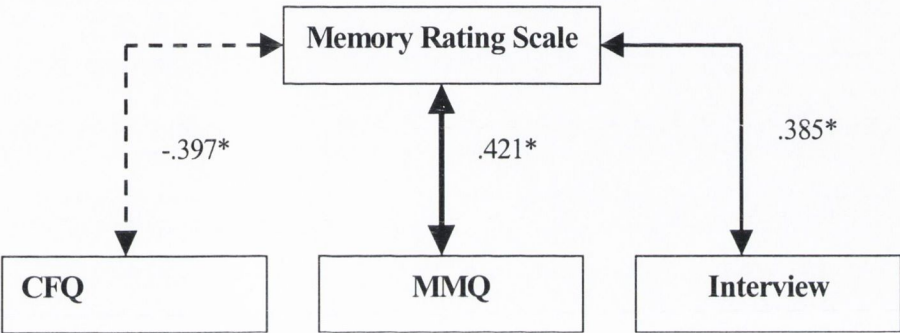
Table 3.7: Correlation Matrix of the relationships between the different tasks.

Variable	CFQ	MMQ	Interview Study
Memory Rating Scale	-.397*	.421*	.385*
CFQ		-.323	.011
MMQ			.348

From the data presented in the above table it is clear that among the subset of participants who completed both parts of the study, their scores in the Interview showed a significant correlation with their self-ratings on the Memory Rating Scale only and not with their CFQ or MMQ scores. What is also worth noting from this table is the finding that the only the Memory

Rating Scale appears to be the only task that is significantly correlated with each of the other tasks. Furthermore, the CFQ and MMQ scores obtained by these participants do not show the same significant negative correlation as was found in Part I of the study. The Path Model contained in Figure 3.9 below illustrates the pattern of correlations found in Part II of the study.

Figure 3.9: Path Model of the correlations between the Memory Rating Scale and the other tasks.



3.9 Landmark Task Validation Study

3.9.1 Analysis of the Landmark Recognition and Landmark Location Tasks.

The survey consisting of the Landmark Recognition Task, Landmark Location Task and Dublin Familiarity Scale was completed by 185 participants. The mean scores for the Landmark Recognition Task and the Landmark Location Task are shown in Table 3.8 and Figures 3.10a-c below.

Analyses of the effects of the between-subjects factors.

A multivariate ANOVA was used to determine the effects of the following between-subjects factors: Gender, Born in Dublin, Age category and Order (of presentation of tasks) on the participants’ scores in the Landmark Recognition and Landmark Location Tasks. The results of this analysis showed that there were no main effects for any of the factors on either of the tasks [Landmark Recognition – Gender: $F(1,169) = .002, p>.05$; Dublin: $F(1,169) = .443, p>.05$; Age: $F(1,169) = 1.754, p>.05$; Order: $F(1,169) =$

.011, $p>.05$; Landmark Location – Gender: $F(1,169) = 2.303$, $p>.05$; Dublin: $F(1,169) = .348$, $p>.05$; Age: $F(1,169) = 1.556$, $p>.05$; Order: $F(1,169) = .690$, $p>.05$]. There was one significant three-way interaction between the factors Gender, Born in Dublin and Age category [$F(1,169) = 4.465$, $p<.05$].

Table 3.8: Mean scores on the Landmark Recognition Task, Landmark Location Task and Dublin Familiarity Scale.

Group	N	Landmark Recognition Score (0-7)	Landmark Location Score (0-5)
Females aged <30yrs		Mean (S.D.)	Mean (S.D.)
Born in Dublin	23	6.61 (0.58)	3.87 (1.52)
Not born in Dublin	38	6.13 (1.32)	4.00 (1.52)
Females aged >30yrs			
Born in Dublin	20	6.50 (1.20)	4.50 (0.79)
Not born in Dublin	23	6.52 (0.67)	4.04 (1.36)
Males aged <30yrs			
Born in Dublin	23	6.13 (0.92)	4.17 (1.11)
Not born in Dublin	22	6.32 (1.32)	4.36 (1.14)
Males aged >30yrs			
Born in Dublin	20	6.85 (0.37)	4.40 (1.10)
Not born in Dublin	18	6.39 (0.61)	4.61 (0.50)

Figure 3.10a: Mean scores for males and females on the Landmark Recognition and Landmark Location Tasks.

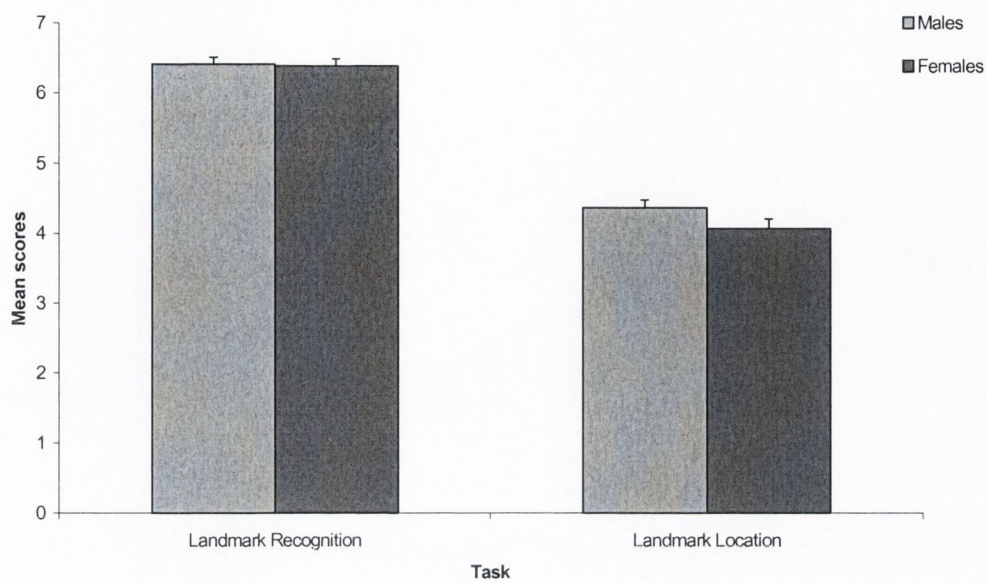


Figure 3.10b: Mean scores for participants born in Dublin/not born in Dublin on the Landmark Recognition and Landmark Location Tasks.

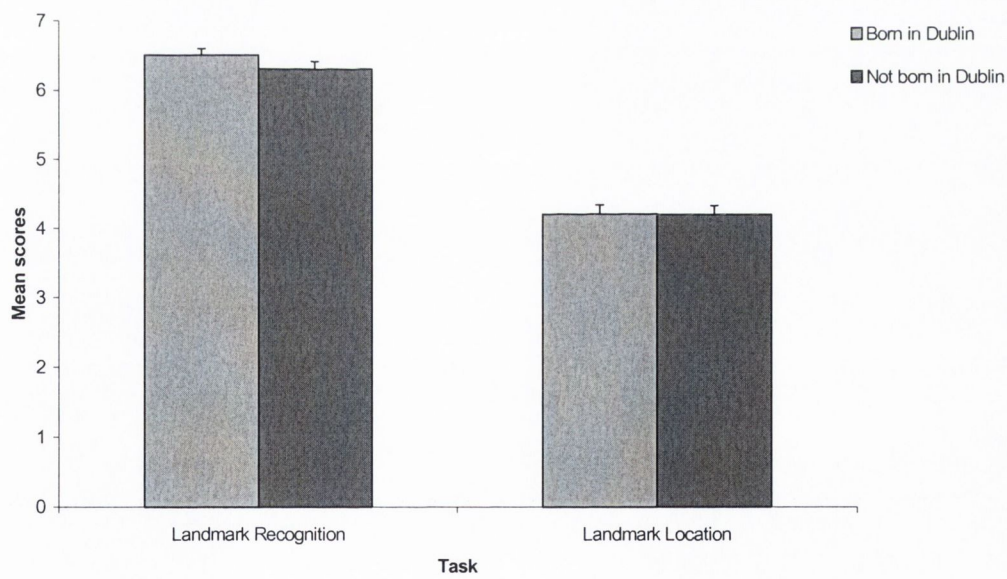


Figure 3.10c: Mean scores for each age category in the Landmark Recognition and Landmark Location Tasks.

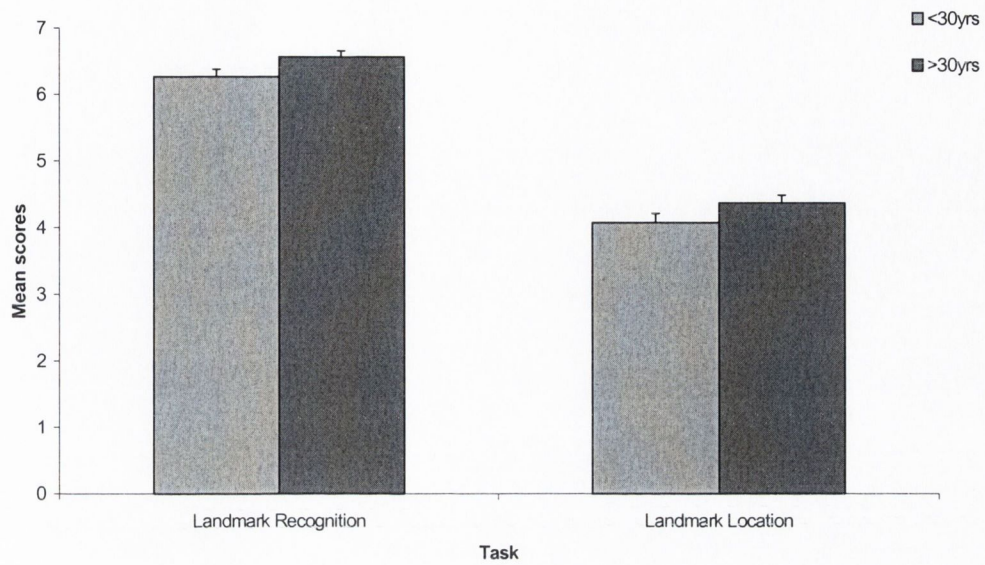
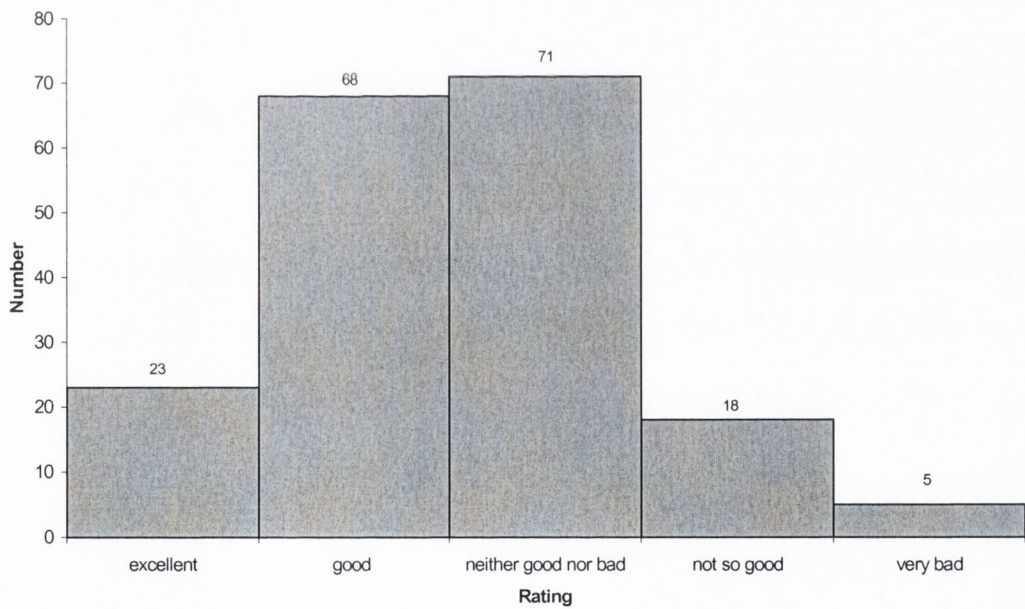


Figure 3.11: Number of participants in each rating category on the Dublin Familiarity Scale.



3.10 Analysis of participants’ ratings on the Dublin Familiarity Scale.

Figure 3.11 above contains a histogram of the frequency of participants’ ratings on the Dublin Familiarity Scale. The Kruskal-Wallis non-parametric test was used to determine whether the factor Gender had an effect on participants’ ratings on the Dublin Familiarity Scale. The results were not

significant [$\chi^2 (1) = .255, p>.05$]. The test was repeated using Born in Dublin/not born in Dublin as the between-subjects factor. This time a significant effect was found in the expected direction as the mean rank score for participants who were born in Dublin was significantly lower than the rank score for those born outside Dublin [$\chi^2 (1) = 8.603, p<.01$].

3.11 Route Description Task

The mean total score mean total word count on the RDT are shown for each participant group in Table 3.9 below. Figures 3.12a and 3.12b contain the mean scores and the number of words written by males and females for each of the four questions in the task.

Figure 3.12a: Mean scores for males and females on the Route Description Task.

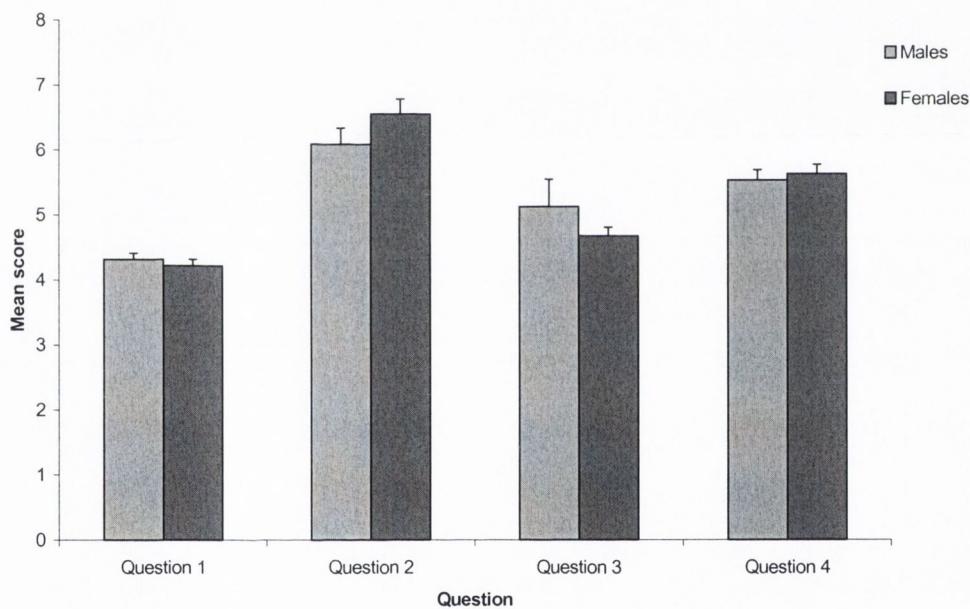
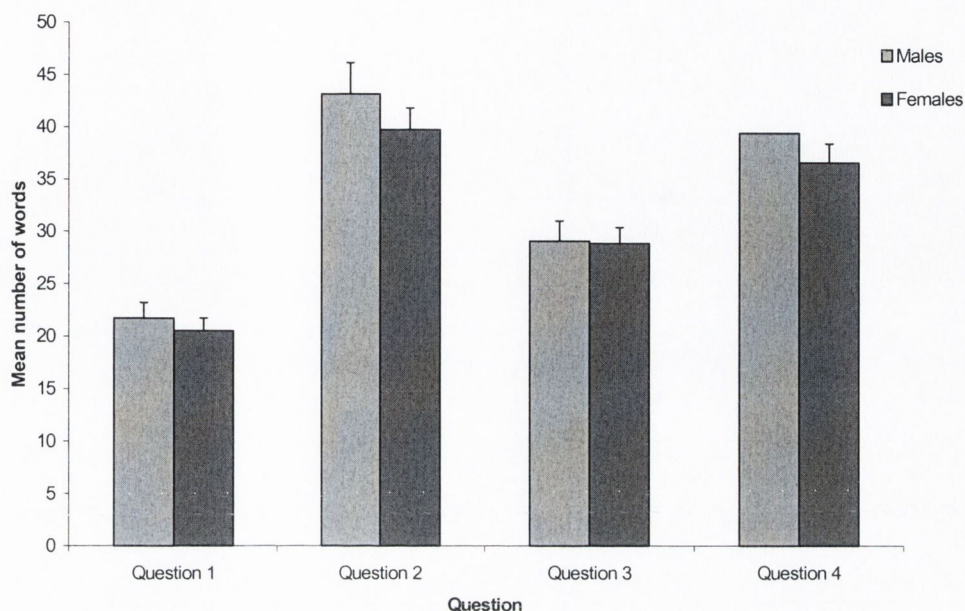


Table 3.9: Mean scores for the Route Description Task

Group	N	Overall Score	Word Count
Females		Mean (S.D.)	Mean (S.D.)
Age <30yrs	58	20.41 (5.00)	129.40 (63.39)
Age >30yrs	40	21.55 (1.39)	124.85 (57.63)
Males			
Age <30yrs	42	19.79 (4.95)	137.90 (68.93)
Age >30yrs	37	20.95 (4.49)	122.97 (67.97)

Figure 3.12b: Mean number of words written by males and females on the Route Description Task.



Analyses of the effects of the between-subjects factors

A multivariate ANOVA was used to measure the effects the between-subjects factors Gender, and Age category on the dependent variables mean overall score and mean word count in the RDT. There were no main effects for Gender on either dependent variable [Overall score: $F(1,165) = .700$, $p > .05$; word count: $F(1,165) = .136$, $p > .05$]. There was a main effect for Age on the overall score, which just reached significance [$F(1,165) = 3.054$, $p = .05$] but not on the word count [$F(1,165) = 1.315$, $p > .05$]. The interaction between the Gender and Age was not significant for either variable [Overall score: $F(1,165) = 1.061$, $p > .05$; word count: $F(1,165) = .619$, $p > .05$].

In order to further explore the main effect of Age on the dependent variable of overall score, a multivariate ANOVA was repeated using Age category as the single between-subjects factor and the mean score for each question on the RDT as the four dependent variables. However, the results of this analysis showed that main effect of Age category did not hold for the mean scores on each of the four questions in the RDT [Question 1: $F(1,172) = 2.022$, $p > .05$; Question 2: $F(1,172) = 2.492$, $p > .05$; Question 3: $F(1,172) = 1.157$, $p > .05$; Question 4: $F(1,172) = 1.405$, $p > .05$].

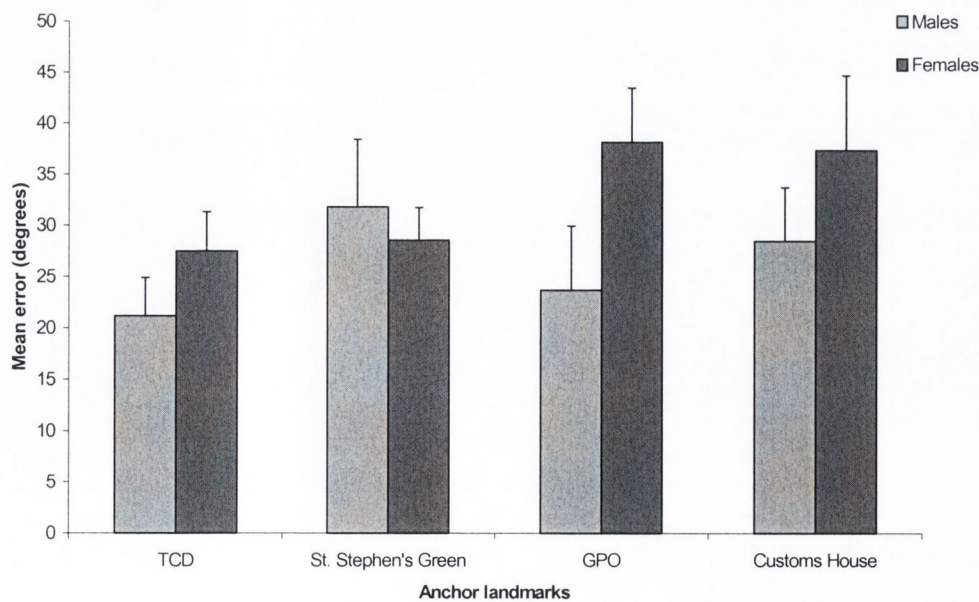
3.12 Analysis of participants’ scores on the Landmark Pointing Task.

A subset of thirty participants from the above sample took part in the Pointing Task, which formed the second part of this study. The mean error scores for each participant when pointing from the four anchor landmarks are shown in Table 3.10 and Figures 3.13a and 3.13b below.

Table 3.10: Mean error scores when pointing from the anchor landmarks in the Pointing Task.

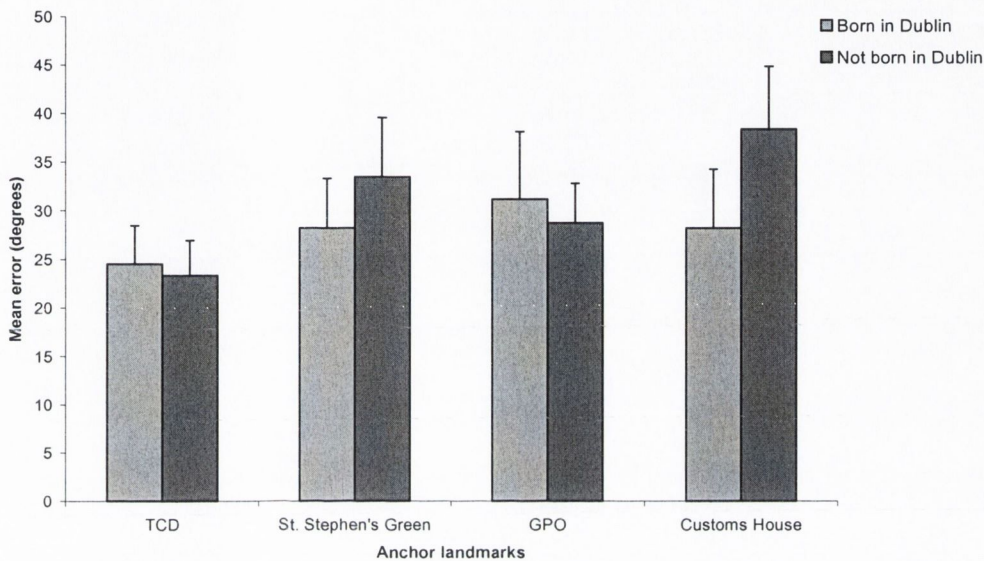
Group	N	TCD	Stephen’s Green	GPO	Customs House
Females		Mean(S.D.)	Mean(S.D.)	Mean(S.D.)	Mean(S.D.)
Dublin born	5	24.17(19.55)	23.33(8.19)	43.67(26.98)	27.83(31.67)
Not born in Dublin	8	29.58(10.03)	31.88(12.47)	34.69(13.36)	43.23(24.95)
Males					
Dublin born	12	24.65(15.62)	30.24(24.49)	25.99(28.64)	28.36(23.26)
Not born in Dublin	4	10.33(4.30)	36.67(35.57)	16.88(5.11)	28.75(14.04)

Figure 3.13a: Mean error scores for males and females when pointing from Anchor Landmarks.



In order to calculate the mean error scores shown in the above table, the errors recorded for participants when pointing to the six landmarks from each of the anchor landmarks were summed to give a total score. This total score was then divided by six, to give an average score for each anchor landmark.

Figure 3.13b: Mean error scores for born in Dublin category when pointing from Anchor Landmarks.



Analyses of the between-subjects and within-subjects factors.

A multivariate mixed factorial ANOVA was used to determine whether the between-subjects factors of Gender, and Born in Dublin, and the within-subjects factor of Landmark affected participants' performance on this task. The results of the Mauchly's Test of Sphericity for homogeneity of covariance showed a significant Mauchly statistic [$\chi^2= 20.525$, $p<.01$], providing strong evidence towards heterogeneity of covariance. Since the present data failed the sphericity test, the ANOVA F test was made more conservative by using the Greenhouse-Geisser test. The results showed that there were no main effects for any of the between-subjects factors [Gender: $F(1, 25) = 1.147$, $p>.05$; Dublin: $F(1,25) = .007$, $p>.05$]. The within-subjects factor, Landmark, also failed to reach significance [$F(2.224, 55.610) = 1.860$, $p>.05$].

3.13 Correlational Analyses

In order to examine the relationship between the different tasks administered to participants in this Validation Study, a correlation matrix was produced and is shown in Table 3.11 below. Figure 3.14 displays the significant correlations as a Path Model. From this diagram it is evident that participants' scores on the Landmark Recognition, Landmark Location, and Pointing Tasks and the Dublin Familiarity Scale are strongly inter-connected. What is also of interest is the significant correlation between the scores obtained on the Route Description Task and those obtained on the Landmark Location Task. Less surprising is the significant association between the Born in Dublin variable and participants' ratings of their knowledge of the city centre on the Dublin Familiarity Scale. The positive direction of this correlation indicates that participants who were not born in Dublin tended to rate themselves as less familiar with the city centre.

Figure 3.14: Path Model of the correlations between the different variables and tasks.

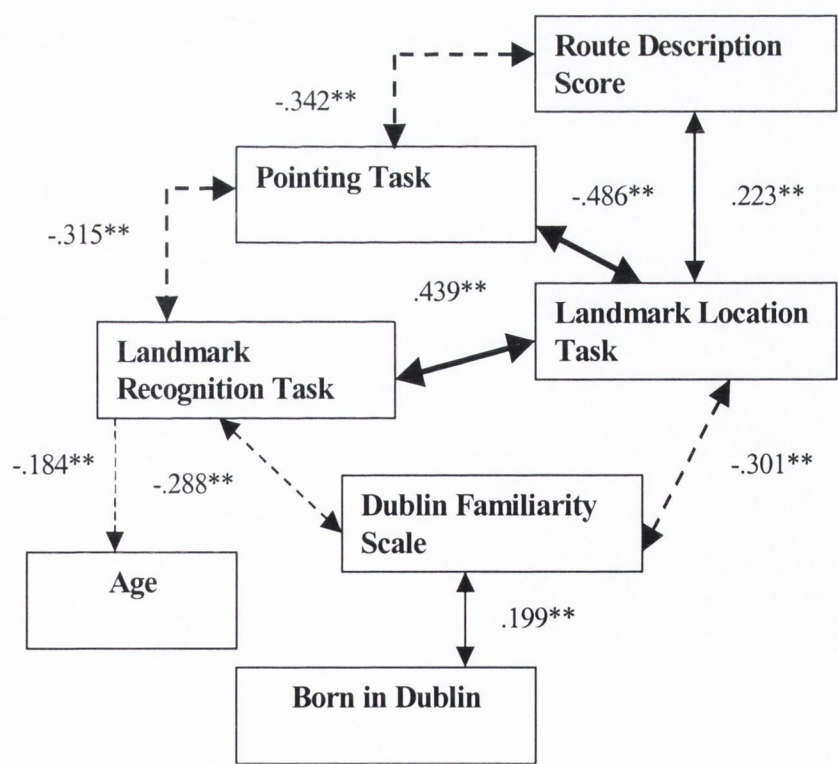


Table 3.11: Correlation matrix of the relationship between the different tasks and variables in the Landmark Task Validation Study.

	Age category	Dublin Familiarity Scale	Landmark Recognition Score	Landmark Location Score	Route Description Score	Route Description Word Count	Pointing Task (average error)
Born in Dublin	-.047	.199**	-.103	-.007	-.075	-.023	-.012
Age category		-.086	.148*	.113	.116	-.070	-.033
Dublin Familiarity Scale			-.288**	-.301**	-.035	-.041	.356*
Landmark Recognition Score				.439**	.060	.065	-.315*
Landmark Location Score					.223**	.107	-.486**
Route Description Score						.549**	-.342*
Route Description Word Count							-.239

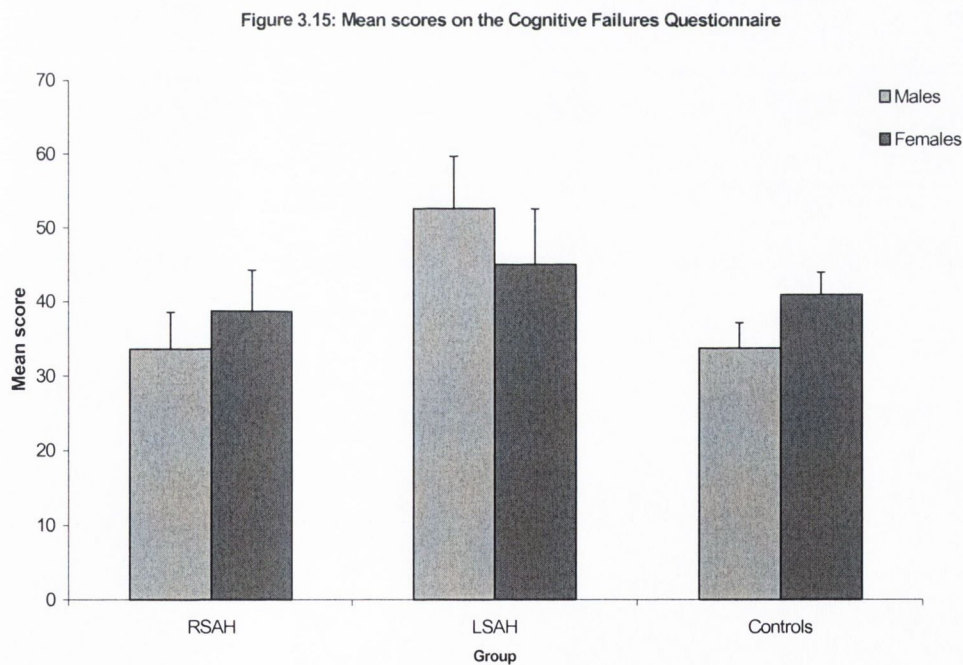
3.14 Main Study

3.14.1 Questionnaire Data

Fifty-two participants including thirty-three patients and nineteen controls completed the CFQ, EMQ, MMQ and the Memory Rating Scale (MRS). Their mean scores on these questionnaires are reported in Table 3.12 below and shown in Figures 3.15-3.17.

Table 3.12: Participants’ mean scores on the CFQ, EMQ, MMQ and MRS.

Questionnaire	RSAH n = 20	LSAH n = 13	Controls n = 19
CFQ – mean (S.D.)	36.7 (17.00)	47.92 (19.05)	37.11 (10.36)
EMQ – mean (S.D.)	6.41 (2.91)	8.30 (2.94)	5.90 (2.14)
MMQ – mean (S.D.)	67.45 (15.94)	63.23 (19.82)	87.00 (6.54)
MRS – mean (S.D.)	3.4(.88)	2.93 (.95)	3.53 (.77)

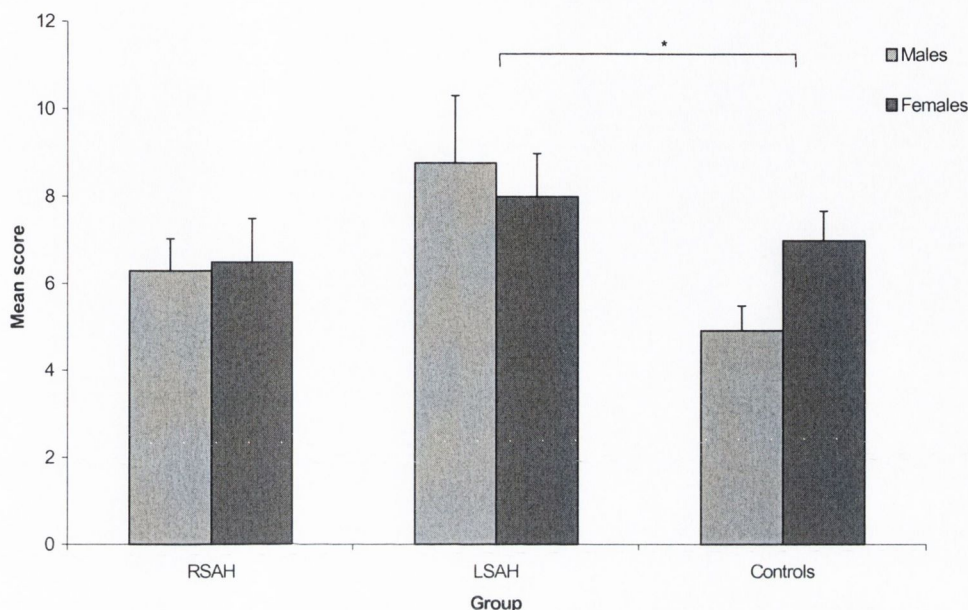


3.14.2 Analysis of CFQ scores

Figure 3.15 above shows the mean scores for male and female participants of each group on the CFQ. A two-way ANOVA was performed on the data, with Group and Gender as the between-subjects factors. The results showed that neither factor had a significant effect on participants’ CFQ scores [Group:

$F(2,46) = 2.797, p>.05$; Gender: $F(1,46) = .122, p>.05$]. The interaction between the two factors was also insignificant [$F(2, 46) = .921, p>.05$].

Figure 3.16: Mean scores on the Everyday Memory Questionnaire.



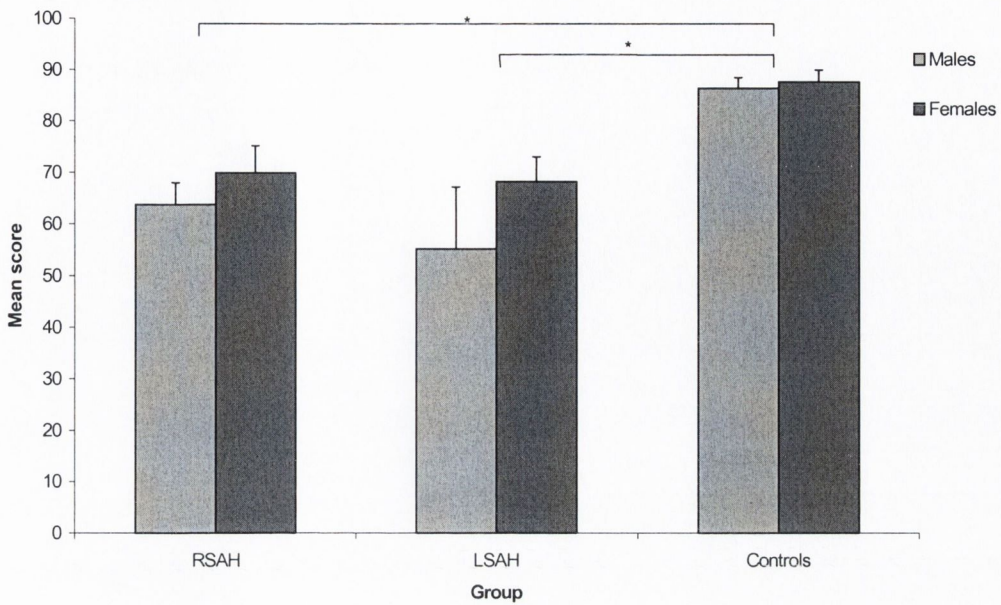
3.14.3 Analysis of EMQ scores

Shown in Figure 3.16 above are the mean scores for males and females in each of the three groups. The results of a two-way ANOVA showed a significant main effect for Group on participants' EMQ scores [$F(2, 46) = 3.336, p<.05$], but no effect for Gender [$F(1, 46) = .427, p>.05$]. Post-hoc multiple comparisons using the Tukey test revealed a significant difference between the LSAH group relative to the normal controls.

3.14.4 Analysis of MMQ scores

The mean scores obtained by males and females in each group are shown in Figure 3.17 below. A three-way ANOVA was performed in order to measure the effects of the following between-subjects factors: Group, Gender and Type of MMQ (structured or random). The results of this analysis showed a main effect for Group only [$F(2,40) = 10.769, p<.01$]: neither Gender nor Type of MMQ had significant effects on participants' MMQ scores [Gender: $F(1, 40) = .808, p>.05$; Order: $F(1,40) = .768, p>.05$]. A more detailed analysis of the MMQ data is reported in section 3.16 below.

Figure 3.17: Mean scores on the Mundane Memory Questionnaire.



3.15 Memory Rating Scale

The frequency of participants' self-ratings of memory using the Memory Rating Scale is shown in Figure 3.18 below. What is interesting about this figure is that it shows that none of the participants from any of the three groups rated their memory as being 'Very Good'. The Kruskal-Wallis non-parametric test was used to determine whether there was a Group effect on participants' ratings on the Memory Rating Scale. The results of this analysis showed that there was no significant difference between the three groups in their self-ratings of memory [$\chi^2 (2) = 4.335, p > .05$].

3.16 Correlational Analysis

A correlation matrix showing the relationships between the different memory questionnaires and the Memory Rating Scale is shown in Table 3.13 below. It is clear from this table and from the Path Model contained in Figure 3.19 that there are highly significant correlations between all four of the tasks.

Figure 3.18: Number of participants in each rating category on the Memory Rating Scale.

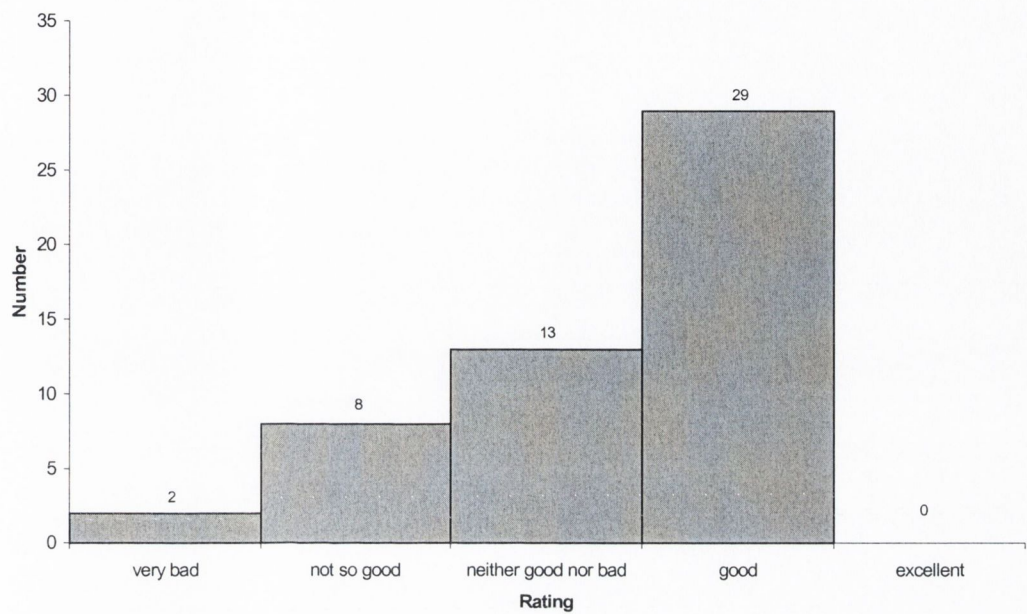


Table 3.13: Correlation matrix of the relationship between the questionnaires and rating scale.

Variable	EMQ	MMQ	Memory Rating Scale
CFQ	.727**	-.473**	-.565*
EMQ		-.440**	-.615**
MMQ			.619**

**p<.01

3.17 Specific analysis of performance on the MMQ over each of the four days.

A more specific analysis of the data recorded from the Mundane Memory Questionnaire is discussed in the following section. Table 3.14 shows the mean number of details recalled by each group over the four days. The data presented in this table and in Figure 3.20 below suggest that there may also be a significant difference between the number of details recalled by each of the patient groups compared to the controls over each of the four days.

Figure 3.19: Path Model of the correlations between the different tasks.

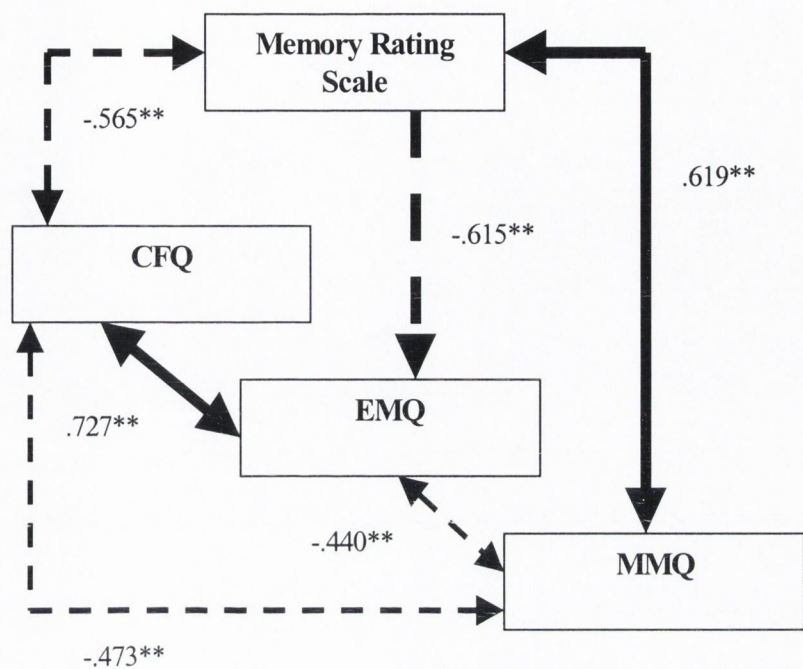


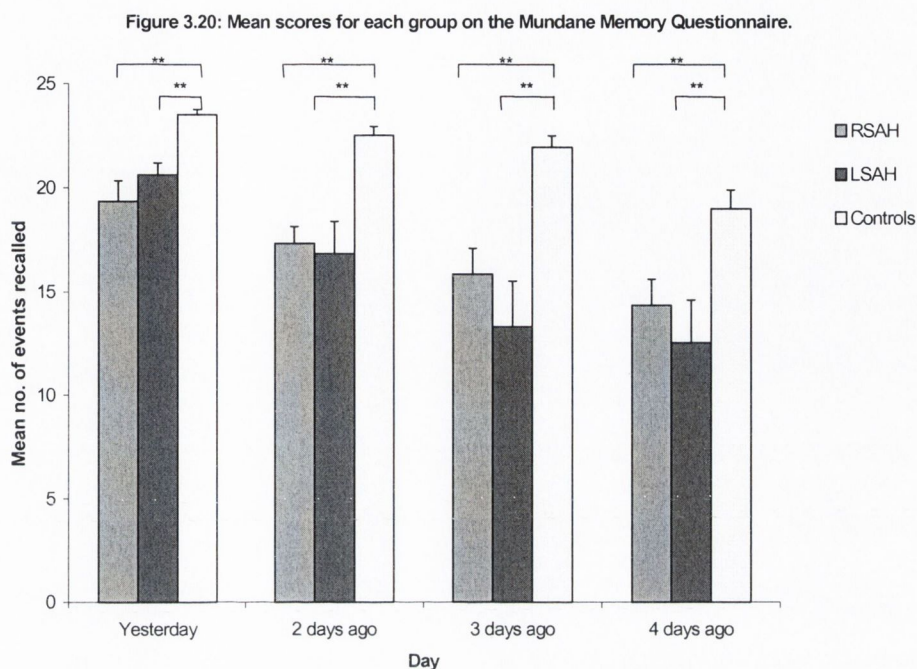
Table 3.14: The mean number of details recalled in the Mundane Memory Questionnaire

Day of recall	RSAH n = 20 mean (S.D.)	LSAH n = 13 Mean (S.D.)	Controls n = 20 mean (S.D.)
Yesterday	19.35 (4.48)	19.62 (2.1)	23.53 (1.02)
2 Days ago	17.35 (3.62)	16.85 (5.58)	22.53 (1.81)
3 Days ago	15.85 (5.56)	13.31 (7.96)	21.95 (2.39)
4 Days ago	14.35 (5.64)	12.54 (7.45)	19.00 (3.90)

Analyses of the between-subjects and within-subjects factors.

Having established a main effect for Group in an earlier section, a repeated-measures multivariate mixed-factorial ANOVA was then performed to measure the effect of the between-subjects factor Group on the within-subjects factor of Day, since recall was measured over four consecutive days. The results of the Mauchly’s Test of Sphericity for homogeneity of covariance showed a significant Mauchly statistic [$\chi^2= 20.277$, $p<.01$], providing strong evidence towards heterogeneity of covariance. Thus, the

ANOVA F test was made more conservative by using the Greenhouse-Geisser test.



The results of this analysis revealed a significant main effect for Group [$F(2,46) = 14.973, p < .01$] only; the factor Gender did not affect performance on this task [$F(1,46) = 2.947, p > .05$]. The interaction between both factors was not significant [$F(2,46) = .621, p > .05$]. The within-subjects factor Day showed a significant main effect [$F(2.286, 105.144) = 34.141, p < .01$]. Post hoc Tukey multiple comparisons of the between subject factor Group revealed significant differences between both patient groups relative to the normal control participants in their performance on the MMQ. Post hoc Bonferroni comparisons of the within-subjects factor Day, shown in Table 3.15 below, showed that there were significant differences between the number of details recalled for each day of recall.

A multivariate ANOVA was then used to determine whether there was a significant effect of the Group factor on performance over each of the four days individually. The results of this analysis showed that there was a significant main effect of Group on each day of recall [Yesterday: $F(2,49) = 9.517, p < .01$; 2 days ago: $F(2,49) = 12.604, p < .01$; 3 days ago: $F(2,49) = 11.125, p < .01$; 4 days ago: $F(2,49) = 5.915, p < .01$].

From the results of post hoc Tukey tests reported above, it was clear that both patient groups were significantly impaired relative to the controls with regard to their recall over each of the four days. Figure 3.21 shows the absolute decline in recall displayed by the three groups and Figure 3.22 shows the relative decline in recall over the four days. In Figure 3.22, the number of details recalled for ‘yesterday’ by each group is set at 100% and the number of details recalled for the remaining three days is expressed relative to this value. From this graph, it is clear that whereas the control group and RSAH group retained over 80% and 70% of the details from four days ago respectively, the rate of retention among the LSAH group was approximately 60%. Furthermore, the LSAH group also showed the most rapid decline in retention with a drop of almost 20% between the retention levels in the interval between ‘yesterday’ and ‘2 days ago’.

Table 3.15: Bonferroni comparisons for the within-subject factor Day.

Day	Mean difference	Std. Error
Yesterday – 2 days ago	2.546*	.513
3 days ago	4.542*	.781
4 days ago	6.247*	.781
2 days ago – 3 days ago	1.995*	.617
4 days ago	3.700*	.603
3 days ago – 4 days ago	1.705*	.559

*p<.05

3. 18 Correlational Analysis

Shown in Table 3.16 below is a correlation matrix of association between recall over the four days on the MMQ. Figure 3.23 displays these correlations as a Path Model.

Figure 3.21: Absolute decline in recall using the MMQ

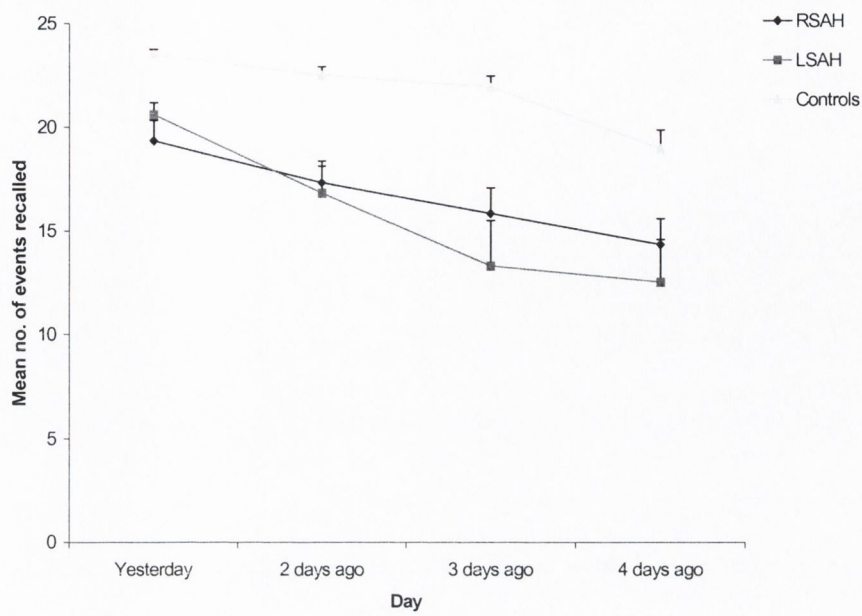


Table 3.16: Correlation Matrix of recall over the four days

Day	2 days ago	3 days ago	4 days ago
Yesterday	.543**	.385**	.395**
2 days ago		.744**	.751**
3 days ago			.817**

**p<.01

Figure 3.22: Relative decline over the four days on the MMQ

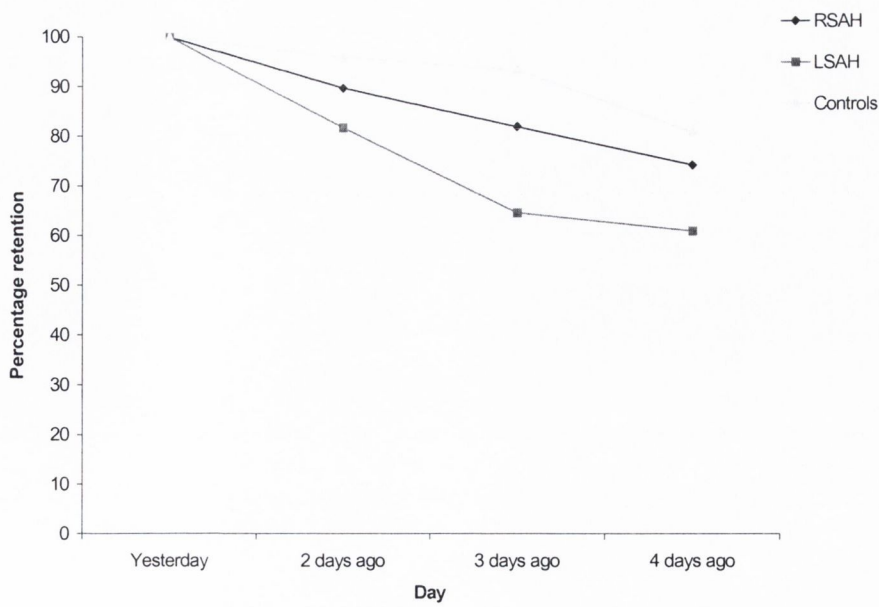
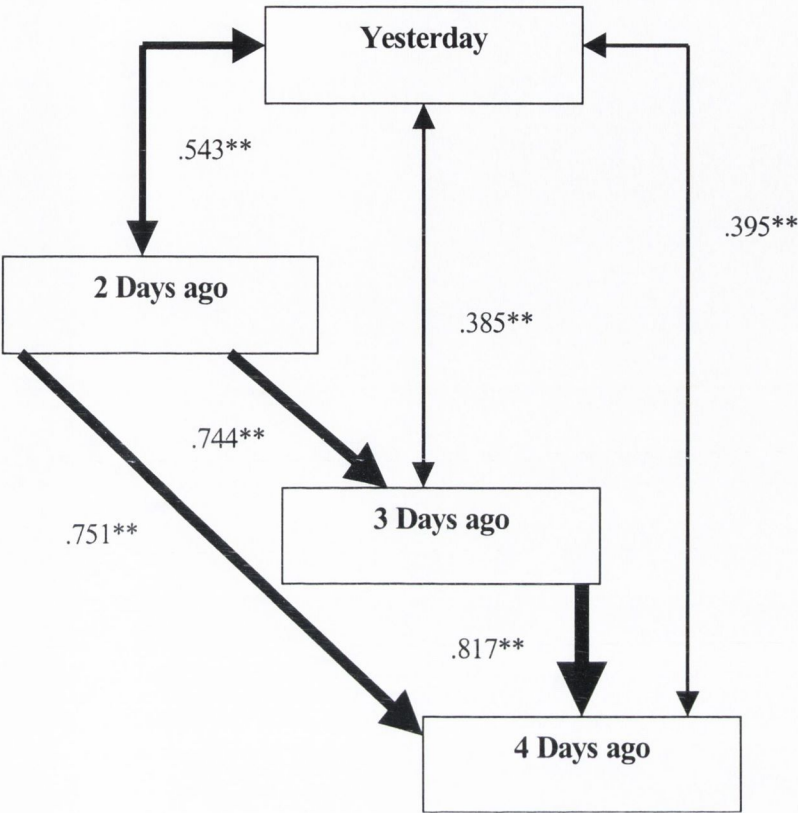


Figure 3.23: Path Model of the correlations between the number of details recalled for each day on the MMQ.



3.19 Interview Study Results

The mean number of basic activities recalled by each group in the Interview Study for the three days of recall is shown in Table 3.17 below. The between-subjects factor Group appears to be significantly affecting participants’ scores on this task, with both patient groups recalling considerable fewer details for each day during the interviews. This difference in performance between the groups is also highlighted in Figure 3.24.

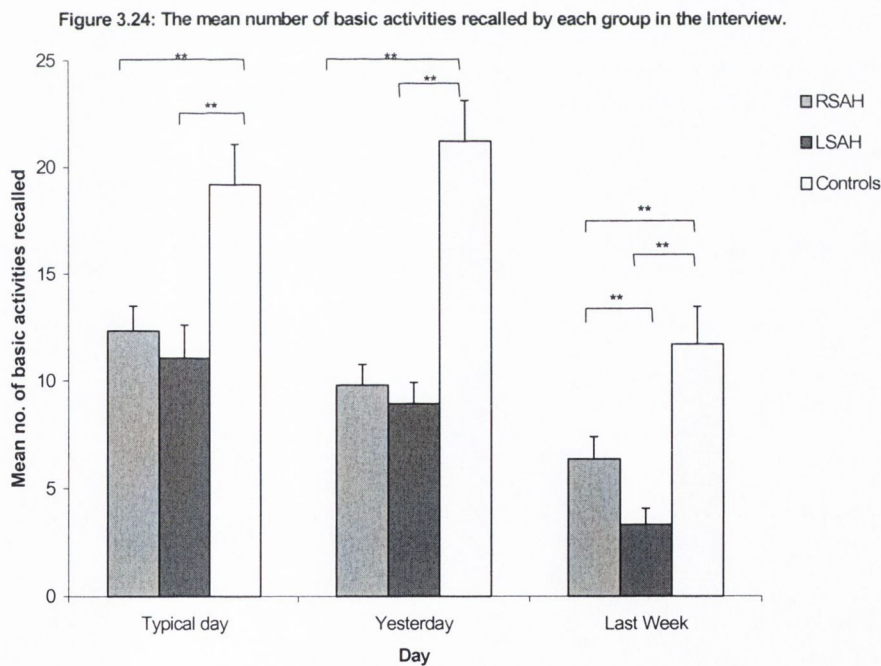
Analysis of the effects of the between-subjects factors on total number of basic activities recalled.

A three-way ANOVA was used to examine the effects of the between-subjects factors Group, Gender and Order (of interview) on the total number of basic activities recalled.

Table 3.17: Mean number of basic activities recalled in the Interview Study

Day of recall	RSAH n = 20 mean (S.D.)	LSAH n = 13 Mean (S.D.)	Controls n = 20 mean (S.D.)
Typical Day	12.35 (5.12)	11.08 (5.56)	19.21 (8.25)
Yesterday	9.80 (4.27)	8.92 (3.57)	21.21 (8.39)
Last week	6.35 (4.58)	3.31 (2.66)	11.68 (7.68)
Total	28.50 (7.63)	23.31 (8.24)	53.11 (15.81)

The results of this analysis showed a main effect for Group [$F(2,31) = 30.794$, $p < .01$] only. Neither Gender nor Order had an effect on recall [Gender: $F(1,31) = 1.449$, $p > .05$; Order: $F(3,31) = .334$, $p > .05$]. Post hoc Tukey comparisons showed both patient groups to recall significantly fewer basic activities when compared with the normal controls.



Analysis of the effect of the within-subjects factor, Day.

The data were then further analysed using a repeated-measures mixed factorial ANOVA to test the effect of the between-subjects factor Group and the within-subjects factor Day (of recall) on performance in the interview. The results of the Mauchly's Test of Sphericity for homogeneity of

covariance were not significant [$\chi^2 = 1.405$, $p > .05$], and therefore it was appropriate to proceed with the usual ANOVA F test. The results of this analysis confirmed the significant main effect for the factor Group [$F(2,49) = 39.705$, $p < .01$] and post hoc Bonferroni paired-comparisons showed that both patient groups were significantly impaired relative to the normal controls.

The results also revealed a significant main effect for the within-subjects factor Day [$F(2,98) = 20.699$, $p < .01$]. Post hoc Bonferroni paired-comparisons showed that there was a significant difference in the number of basic activities recalled for both a Typical day and Yesterday compared to a day in the previous week. However, the difference between the number of basic activities recalled for a Typical day and Yesterday was not significant.

Analysis of the effects of the between-subjects factor, Group on recall over each of the three days.

A multivariate ANOVA was used to determine whether the between-subjects factor, Group affected performance over each of the three days. The results of this analysis showed a main effect for Group on each day of recall [Typical: $F(2,49) = 7.793$, $p < .01$; Yesterday: $F(2,49) = 23.186$, $p < .01$; Last week: $F(2,49) = 9.314$, $p < .01$]. Post hoc Tukey analyses showed that over each of the three days, both patient groups were significantly impaired relative to the control group in the number of basic activities they recalled.

3.20 Correlational analyses

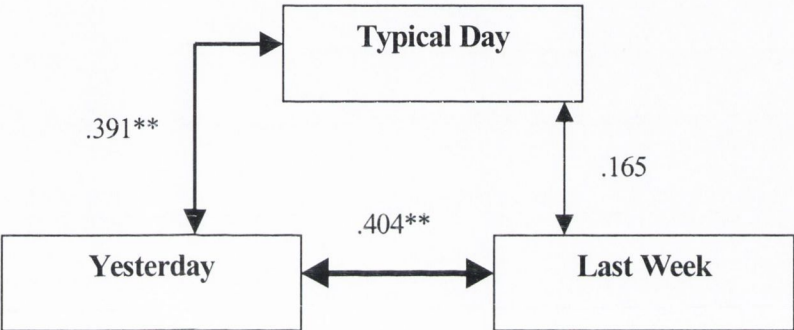
A correlation matrix, shown in Table 3.18 below, was produced to highlight the association between the number of basic activities recalled over each of the three days. Figure 3.25 depicts these significant correlations as a Path Model.

Table 3.18: Correlation matrix of number of basic activities recalled on each day.

Day	Yesterday	Last Week
Typical	.391**	.165
Yesterday		.404**

**p<.01

Figure 3.25: Path Model of correlations between days of recall in the interview.



3.21 Discourse Analysis

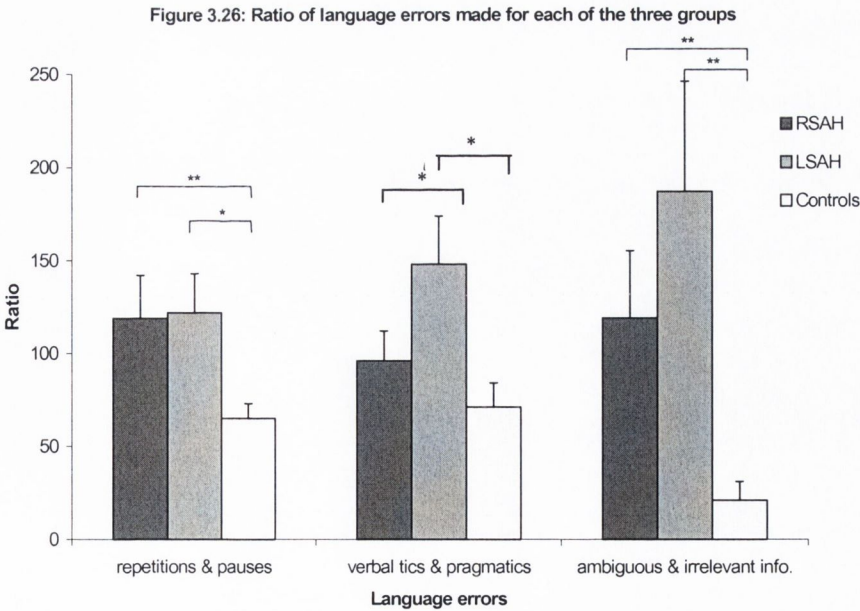
In the following section, the results of the discourse analysis that was performed on the transcripts of the interviews with each participant (contained in Appendix 3.2) are reported. In order to quantitatively analyse discourse production, the language errors made by participants during the interviews were divided into three categories: Repetitions and pauses, verbal tics and pragmatics and the inclusion of ambiguous and/or irrelevant information. For each participant, the total number of errors in each category was calculated. This figure was then expressed as a percentage by dividing it by the total number of words spoken in the interview. This resulted in a percentage of language errors per total word count for each of the three categories as shown in Table 3.19 below. These mean percentage error scores were then compared to the overall mean scores calculated for all participants and expressed as ratios, as shown in Figure 3.26.

Analysis of the effects of the between-subjects factors on discourse production.

A two-way ANOVA was performed to test the effect of the between-subject factors of Group and Gender on the percentage of language errors made. The results showed a main effect for Group only [$F(2,46) = 6.829, p < .01$]; there was no Gender effect [$F(1,46) = .418, p > .05$] and no significant interaction between the factors [$\text{Group} \times \text{Gender } F(2,46) = .489, p > .05$].

Table 3.19: Mean percentage of language errors produced during interviews.

Language errors	RSAH mean(S.D.)	LSAH mean(S.D.)	Controls mean(S.D.)
% repetitions & pauses	3.70(3.23)	3.77(2.34)	2.00(1.05)
% tics & pragmatics	2.67(1.95)	4.11(2.64)	1.98(1.50)
% ambiguous & irrelevant information	0.38(0.51)	0.6(0.69)	0.07(0.14)
Total word count	380.8(193.61)	505(427.94)	590.58(330.51)
% language errors per word count	6.13(3.27)	8.14(4.13)	3.95(1.95)



Post-hoc independent sample *t*-tests showed that the LSAH group generated significantly more repetitions and pauses [$t(15.331) = 2.550, p<.01$], verbal tics and pragmatics [$t(30) = 2.901, p<.01$] and ambiguous and irrelevant information [$t(12.694) = 2.747, p<.01$] compared to the normal control participants. The RSAH group generated significantly more pauses and repetitions [$t(37) = 2.183, p<.05$] and ambiguous and irrelevant information [$t(21.969) = 2.612, p<.01$] compared to the controls. In addition, the LSAH group was significantly impaired relative to the RSAH group in the percentage of verbal tics and pragmatics recorded [$t(31) = -1.800, p<.05$]. A Pearson one-tailed correlation showed a significant negative association between the number of basic activities recalled in the interview and the percentage of language errors made [$r = -.461, p<.01$].

3.22 Analysis of the Landmark Recognition and Landmark Location Tasks

In the following section the results of participants’ performance on the Landmark Recognition and Landmark Location Tasks are reported and analysed. The mean scores obtained by each group on the two tasks can be seen in Table 3.20 and Figure 3.27 below. From these results, there appears to be a strong group influence on participants’ performance on these tasks, with both patient groups, and particularly the RSAH, obtaining lower scores when compared to the control participants.

With regard to the Landmark Recognition Task, however, there also appears to be a significant difference among the patient groups between the scores obtained by participants who were living in Dublin compared to those who were not living in Dublin. Examining the Landmark Location data shows that the effect of living in Dublin does not seem to influence performance in this task.

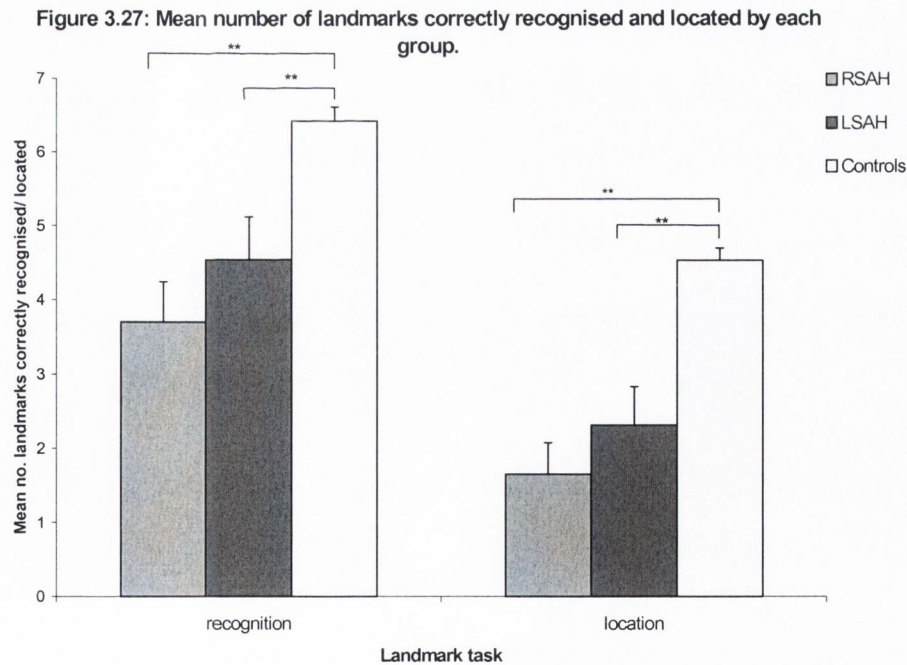
Table 3.20: Participants’ mean scores on the landmark tasks.

Task	RSAH	LSAH	Controls
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	mean(S.D.)	mean(S.D.)	mean(S.D.)
Recognition(overall)	3.70(2.43)	4.54(2.11)	6.42(0.84)
Living in Dublin	5.38(1.30)	6.00(1.00)	6.64(.74)
Not living in Dublin	2.58(2.39)	3.63(2.13)	5.80(.84)
Location (overall)	1.65(1.90)	2.31(1.89)	4.53(0.70)
Living in Dublin	1.88(1.96)	2.40(1.82)	4.50(.76)
Not living in Dublin	1.50(1.93)	2.25(2.05)	4.60(.55)

Analysis of the effects of the between-subjects factors on Landmark Recognition Scores.

A three-way ANOVA was used to measure the effects of the between-subjects factors of Group, Gender and living in Dublin/not living in Dublin on Landmark Recognition scores. Main effects were found for Group [$F(2,40) = 4834, p < .05$] and Dublin [$F(1,40) = 11.539$] but not for Gender [$F(1,40) = .034, p > .05$]. None of the interactions were significant. Post-hoc multiple comparisons using the Tukey test revealed significant differences between both patient groups relative to the control group. However, the difference between the LSAH and RSAH groups was not significant.



Analysis of the effects of the between-subjects factors on Landmark Location Scores.

A three-way ANOVA was used to measure the effects of the between-subjects factors of Group, Gender and living in Dublin/not living in Dublin on the Landmark Location scores. The results showed a main effect for Group only [$F(2,40) = 8.489, p < .01$]; neither Gender nor Dublin had significant effects on performance in this task [Gender: $F(1,40) = .004, p > .05$; Dublin: $F(1,40) = .029, p > .05$]. Post-hoc multiple comparisons using the Tukey test indicated that both patient groups were significantly impaired relative to the normal controls. However, the difference between the LSAH and RSAH groups was not significant.

3.23 Analysis of ratings on the Dublin Familiarity Scale

From the histogram shown in Figure 3.28, it is clear that most participants rated themselves as having a 'very good' knowledge of Dublin's city centre. The Kruskal-Wallis non-parametric test was used to determine whether there was a Group effect on participants' ratings on the Dublin Familiarity Scale. The results showed a significant Group effect. The mean rank scores of both patient groups appeared to be significantly lower than the rank score of the control group [$\chi^2(2) = 6.918, p < .05$]. The results of a Mann-Whitney U test confirmed that there was a significant difference in the ratings made by the RSAH group compared to the controls [$z = -2.414, p < .05$] but not between the LSAH group and controls [$z = -1.901, p > .05$]. The difference between the patient groups in their ratings on the scale was not significant [$z = -.700, p > .05$]. Further analysis using the Kruskal-Wallis revealed a significant effect for the between-subjects factor of living in Dublin/not living in Dublin [$\chi^2(1) = 14.345, p < .01$], with Dubliners achieving higher ratings on this scale compared to non-Dubliners.

3.24 Analysis of participants' scores on the Pointing Task.

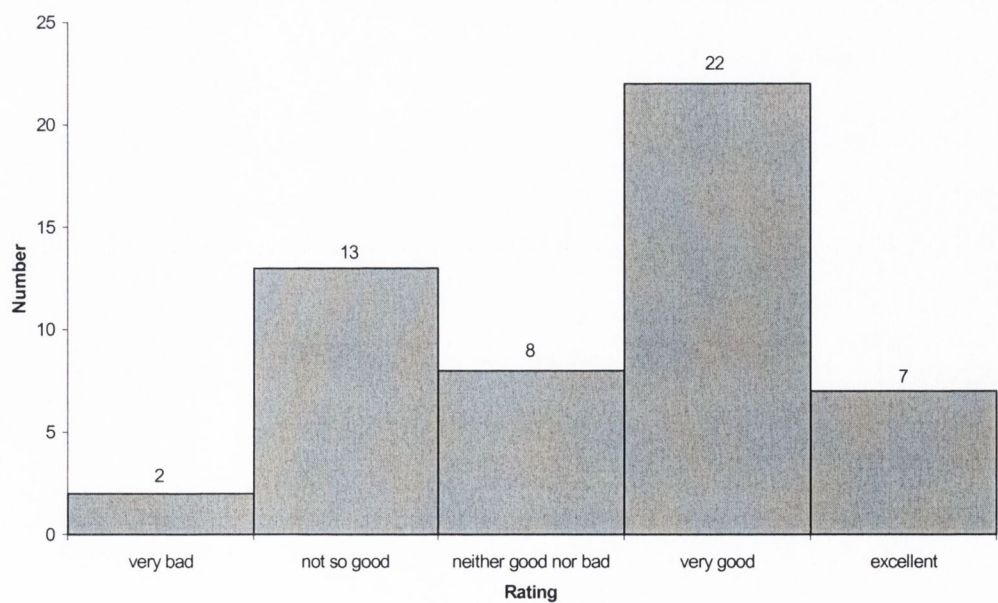
Table 3.21 contains the overall mean error scores obtained by male and female participants of each group in the Pointing Task. This score was calculated by dividing the total error score by the number of landmarks the

participant pointed to. A number of the participants from the patient groups were not able to point to all twenty-four landmarks and therefore calculating an overall average error score based on the number of landmarks that were pointed to was considered to be the most appropriate way to reflect performance in this task. Therefore, it is important to note that analysis of these results is based on scores recorded for a subset of forty-two participants from the total sample. From the data presented in this table, there appears to be a Group influence on performance, with the patient groups having higher error scores on this task compared to the controls. There also appears to be a Gender effect, with the male participants of each group performing better than female participants.

Table 3.21: Participants’ overall mean error scores on the Landmark Pointing Task

Group	RSAH n = 13 mean (S.D.)	LSAH n = 12 Mean (S.D.)	Controls n = 17 mean (S.D.)
Males	48.88(41.45)	41.25(31.55)	23.78(5.33)
Females	65.74(26.03)	75.00(38.32)	27.49(8.55)

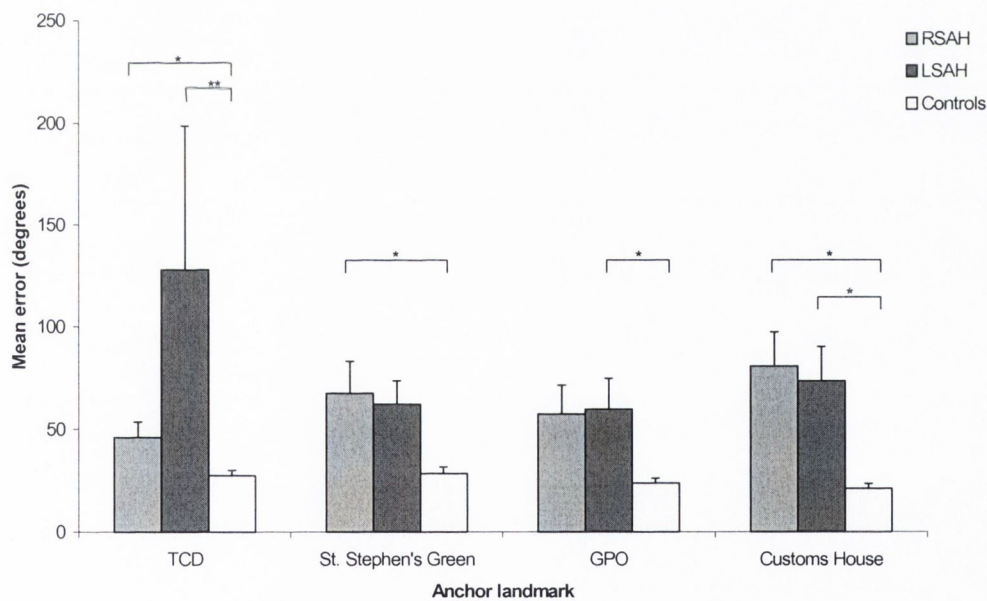
Figure 3.28: Number of participants in each rating category on the Dublin Familiarity Scale.



Analysis of the between-subjects factors on performance on the Pointing Task.

A three-way ANOVA was used to test whether these between-subjects factors of Group and Gender and also the living in Dublin/not living in Dublin factor had significant effects on participants' overall mean error score in the Pointing Task. The results of this analysis showed a main effect for both Group [$F(2,30) = 4.972, p<.05$] and Gender [$F(1,30) = 4.903, p<.05$]; there was no effect for the living in Dublin/not living in Dublin factor [$F(1,30) = .143, p>.05$]. A significant interaction between the three factors was also evident [$F(2,30) = 4.031, p>.05$]. Post-hoc Tukey comparisons revealed significant differences between both patient groups relative to the normal control participants. However, the difference in performance between the LSAH and RSAH groups was not significant.

Figure 3.29a: Mean error scores for each group when pointing from anchor landmarks.



3.25 Analysis of the main effects of Group and Gender in pointing from Anchor Landmarks.

Having established the main effects for Group and Gender, a more detailed analysis of the effects of these factors on task performance was facilitated by examining the mean error scores for each of the participants when pointing from each of the anchor landmarks as shown in Figures 3.29a and 3.29b. As

with the overall mean error score, this anchor landmark score was calculated by dividing the total error scores for each of the anchor landmarks by the total number of landmarks pointed to. This resulted in four separate scores for each participant as shown in Table 3.22.

From the data presented in this table, there appears to be a Group effect in the error scores when pointing for each of the four anchor landmarks. While there also appears to be a Gender effect, this does not seem to be as robust as the effect of Group as it is not evident across each of cases. What is also important to note from this table, and from Figures 3.29a and 3.29b above, is the extremely large standard deviation in the scores for females in the LSAH group when pointing from TCD. The large difference in standard error for this score when compared with the other standard errors meant that the assumption of equal variances, which underlies the ANOVA model, was violated. Therefore it was necessary to analyse this result separately from the other scores using the Kruskal-Wallis and Mann- Whitney U non-parametric tests.

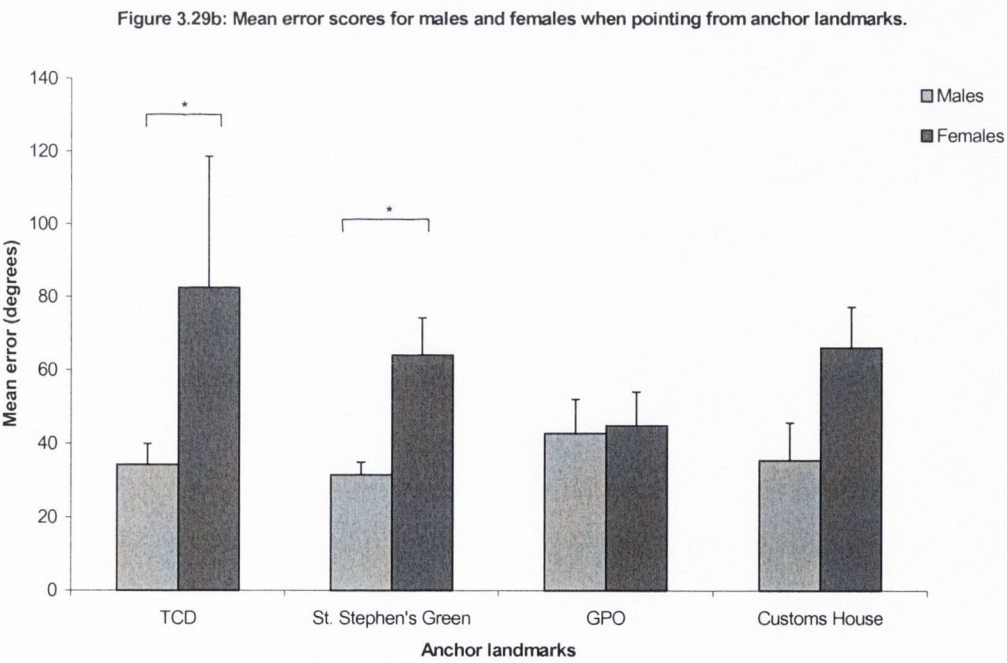


Table 3.22: Mean error scores when pointing from each of the anchor Landmarks.

Group	TCD	St. Stephen's Green S.C.	GPO	Customs House
RSAH	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)
Males	46.47(37.46)	37.70(12.50)	61.20(61.25)	49.13(64.79)
Females	43.90(20.76)	85.84(66.17)	54.77(46.72)	102.76(44.51)
LSAH				
Males	39.52(21.91)	33.19(21.84)	60.42(37.89)	55.84(59.39)
Females	172.06(296.79)	76.50(38.80)	59.14(58.58)	80.71(53.06)
Controls				
Males	23.70(8.24)	27.41(12.03)	24.78(9.82)	21.11(6.95)
Females	31.63(11.12)	29.64(14.42)	22.66(9.90)	21.10(12.03)

Analysis of the effects of Group and Gender on the remaining three anchor landmarks was then performed using a multivariate ANOVA. The results showed significant main effects for Group when pointing from the GPO [$F(2,33) = 4.462, p<.05$] and the Customs House [$F(2,33) = 7.568, p<.01$] but not when pointing from St. Stephen's Green S.C. [$F(2,33) = 2.964, p>.05$]. There was a main effect for Gender when pointing from St. Stephen's Green S.C. [$F(1,33) = 4.430, p<.05$] but not from the GPO [$F(1,33) = .198, p>.05$] or the Customs House [$F(1,33) = 3.567, p>.05$]. There were no significant interactions between the factors for any of the three anchor landmarks. Post hoc Tukey analyses showed significant differences between the RSAH and controls in pointing from St. Stephen's Green S.C., between the LSAH and controls in pointing from the GPO and between both the RSAH and LSAH groups and controls in pointing from the Customs House.

Analysis of the error scores when pointing from TCD was conducted separately as mentioned earlier. The results of a Kruskal-Wallis test showed a significant Group effect on participants' scores [$\chi^2 = 9.754, p<.01$] and post hoc analyses using the Mann-Whitney U test showed that there were significant differences between the RSAH and controls [$z = -2.345, p<.05$] and the LSAH and controls [$z = -2.813, p<.01$]. The differences between the RSAH and LSAH groups was not significant [$z = -.680, p>.05$]. An additional

Mann-Whitney U test was used in order to determine whether the gender difference in error scores when pointing from TCD was significant. The results showed that the difference in male and female scores was significant [$z = -2.187, p < .05$].

3.26 Analysis of participants’ scores on the Vividness of Visual Imagery Questionnaire.

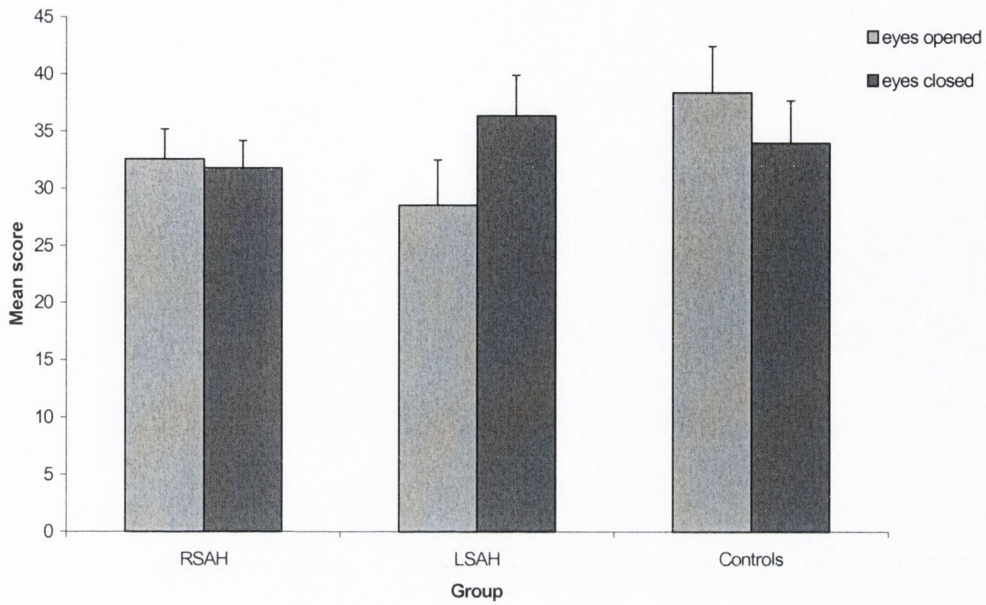
Shown in Table 3.23 below are the scores recorded for participants using the Vividness of Visual Imagery Questionnaires. It is important to note that questionnaires were completed by a subset of forty participants out of the main sample. The VVIQ was administered to participants by way of post some time after they had completed the overall study and this decline in numbers is accounted for by the response rate of 77%.

Table 3.23: Participants’ scores on the Vividness of Visual Imagery Questionnaire.

VVIQ mean(SD)	RSAH n = 16	LSAH n = 9	Controls n = 15
Eyes opened	33.25 (10.77)	28.56 (11.84)	38.40 (15.65)
Eyes closed	31.31 (9.86)	36.38 (9.98)*	34.00 (14.28)

*n = 8 (one participant omitted this part of the questionnaire).

Figure 3.30a: Mean scores for each group on the Vividness of Visual Imagery Questionnaire.



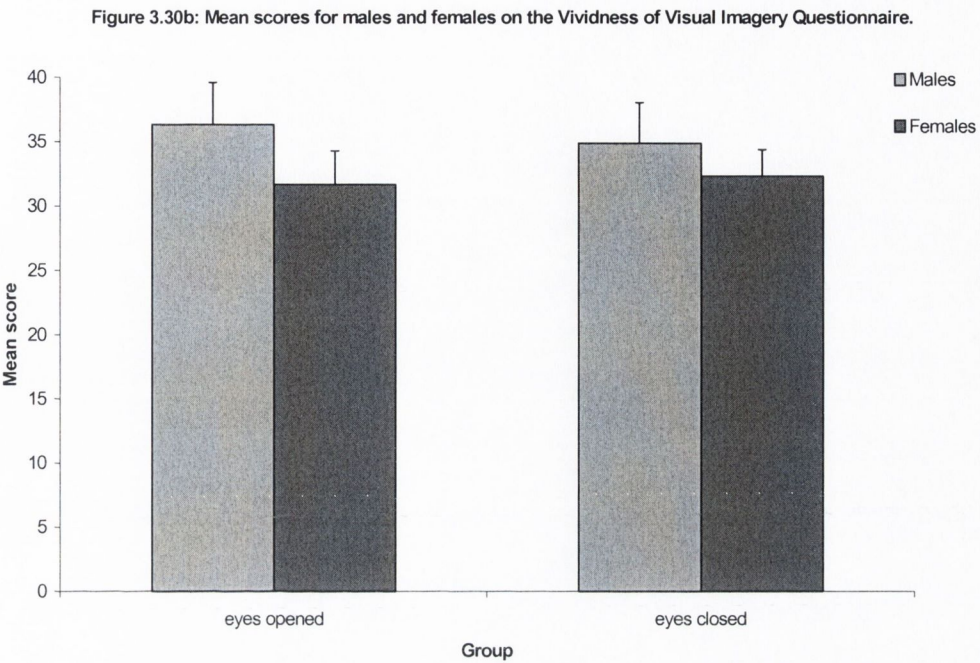
Analysis of the effects of the between-subjects factors.

Figures 3.30a and 3.30b show the mean scores obtained by participants from each group on each format of the VVIQ. A multivariate ANOVA was used to examine the effects of the between-subjects factors Group and Gender on participants' scores on the VVIQ in both conditions. The results of this analysis indicated that participant Group did not significantly affect scores on either condition of this questionnaire [eyes open: $F(2,37) = 1.242, p > .05$; eyes closed: $F(2,37) = .428, p > .05$]. A paired samples two-tailed t -test was used to determine whether there was a significant difference between the eyes-opened and eyes closed conditions of the questionnaire. The results showed that the difference between these conditions was not significant [$t(39) = .532, p > .05$].

3.27 Analysis of the Route Description Task

The results of the Route Description Task are shown in Table 3.24 below. For each of the four questions that participants were required to answer, the total number of correct directions was recorded. This task was completed by forty-eight of the fifty-two participants: the task was only developed after the first four RSAH participants had been tested. From the data contained in this table and in Figures 3.31a and 3.31b below, the influence of the between-subjects factor, Group on participants' scores in this task can be seen. The LSAH

group, in particular, appears to be most impaired relative to the control participants.



Analysis of the effects of the between-subjects and within-subjects factors.

A repeated-measures multivariate mixed factorial ANOVA was used to test the effects of the between-subjects variables Group and Gender and the within-subjects variable of Question on participants’ performance on the Route Description Task. The results of the Mauchly’s Test of Sphericity for homogeneity of covariance yielded a significant Mauchly statistic [$\chi^2=30.323$, $p<.01$]; thus the more conservative Greenhouse-Geisser test was used.

Table 3.24: Mean number of correct directions written by each group for each Question on the Route Description Task.

Question no.	RSAH n = 16 mean (S.D.)	LSAH n = 13 mean (S.D.)	Controls n = 19 Mean (S.D.)
1	4.13 (1.54)	3.31 (1.55)	5.26 (1.05)
2	6.75 (3.99)	5.54 (3.84)	10.79 (2.64)
3	6.19 (1.87)	5.00 (0.91)	7.26 (1.79)
4	6.13 (3.20)	5.85 (2.58)	7.26 (2.42)

Total	23.19 (8.87)	19.69 (7.65)	30.58 (6.34)
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Analysis of the effects of the between-subjects and within-subjects factors.

A repeated-measures multivariate mixed factorial ANOVA was used to test the effects of the between-subjects variables Group and Gender and the within-subjects variable of Question on participants’ performance on the Route Description Task. The results of the Mauchly’s Test of Sphericity for homogeneity of covariance yielded a significant Mauchly statistic [$\chi^2=30.323, p<.01$], thus the more conservative Greenhouse-Geisser test was used. The analysis of the between-subjects factors showed a significant main effect for Group [$F(2,42) = 7.629, p<.01$] but there was no effect for Gender [$F(1,42) = .266, p>.05$]. The interaction between the two factors was not significant [$F(2,42) = .437, p>.05$]. Post hoc Bonferroni paired-comparisons revealed both patient groups to be significantly impaired relative to the control participants in their performance on this task.

Analysis of the effects of the within-subjects factor.

The results of the within-subjects analysis showed a significant main effect for Question [$F(2.214,92.982) = 4.542, p<.01$]. The post hoc Bonferroni paired-comparisons are shown in Table 3.25 below. From this table it is clear that the score for Question 1 differs significantly from the scores for each of the other three questions. The score for Question 2 differs from the scores for Questions 1 and 3; the score for Question 3 differs from the scores for Question 1 and 2 and finally, the score for Question 4 differs from the score for Question 1 only.

Figure 3.31a: Mean scores for each group on the Route Description Task

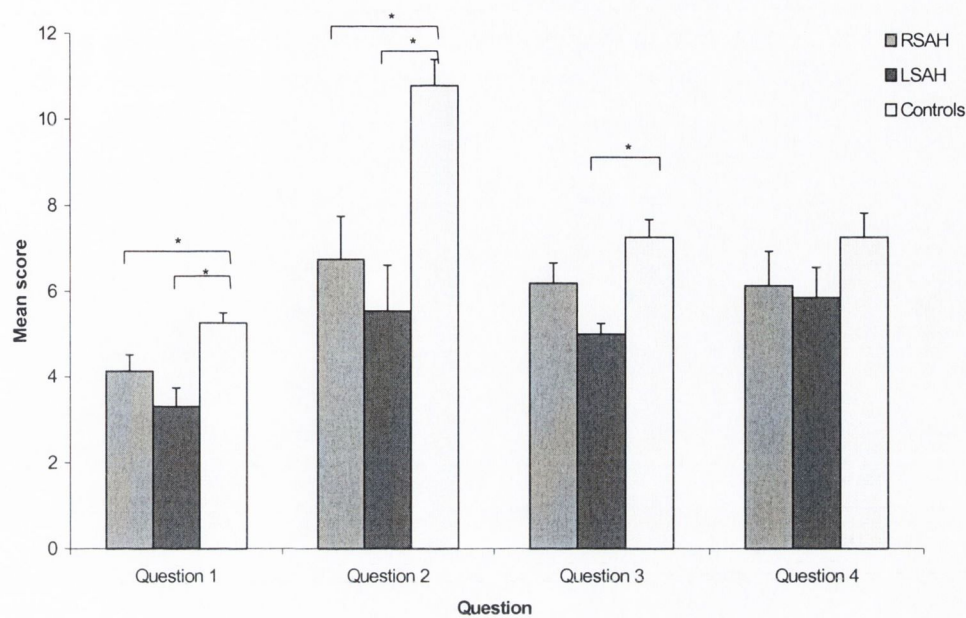


Figure 3.31b: Mean scores for males and females on the Route Description Task

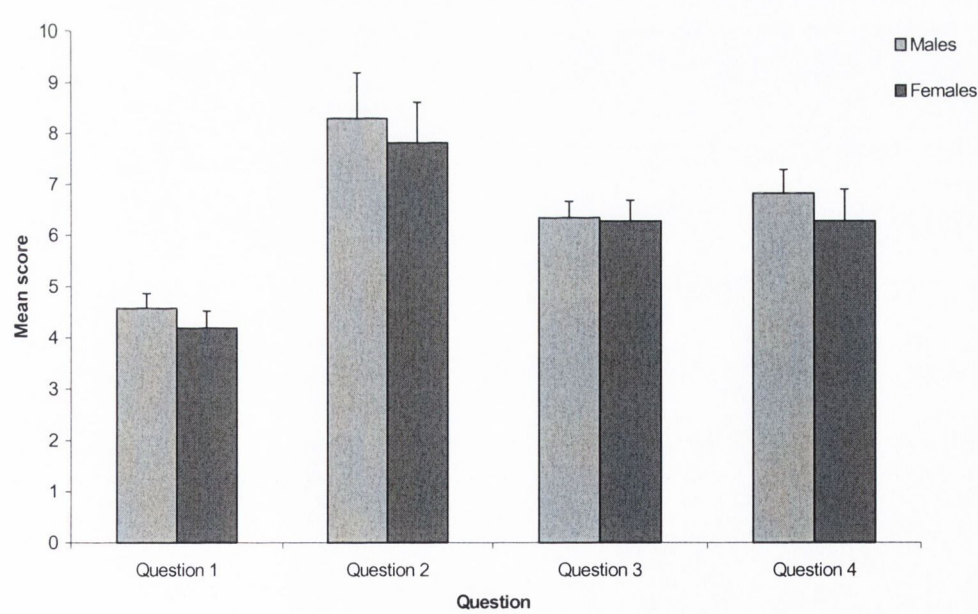


Table 3.25: Bonferroni paired-comparisons for the within-subjects factor Question.

Comparisons	Mean Difference	Std. Error
Question 1 – Question 2	-3.431*	.458
Question 3	-1.870*	.223
Question 4	-2.226*	.373
Question 2 – Question 1	3.431*	.458
Question 3	1.561*	.421
Question 4	1.204	.465
Question 3 – Question 1	1.870*	.223
Question 2	-1.561*	.421
Question 4	-.357	.301
Question 4 – Question 1	2.226*	.373
Question 2	-1.204	.465
Question 3	.357	.301

*p<.05

Analysis of the main effects of the between-subjects factor Group for each of the four questions.

The differences between the scores obtained by the three groups on each question were detected by using a multivariate ANOVA with the scores obtained on each of the four questions as the dependent variables. The results of these analyses confirmed the main effect of Group for three of the four questions [Question 1: $F(2,45) = 8.224, p<.01$; Question 2: $F(2,45) = 10.456, p<.01$; Question 3 : $F(2,45) = 7.454, p<.01$]; there was no effect of Group on the scores obtained for Question 4 [$F(2,45) = 1.252, p>.05$]. Post hoc analyses using the Tukey test showed that for Questions 1and 2, both patient groups scored significantly lower than controls and for Question 3, the difference in scores was between the LSAH and controls only.

3.28 Correlational analyses of the scores obtained on each of the four questions.

In order to determine whether there was a significant relationship between the scores obtained on each of the four questions, a correlation matrix was produced and is shown in Table 3.26 below. It is clear from the data presented in this table that the scores on each of the four questions are significantly correlated with each other.

Table 3.26: Correlation matrix of the association between the scores on each Question.

Question	Question 2	Question 3	Question 4
Question 1	.651**	.627**	.485**
Question 2		.715**	.553**
Question 3			.660**

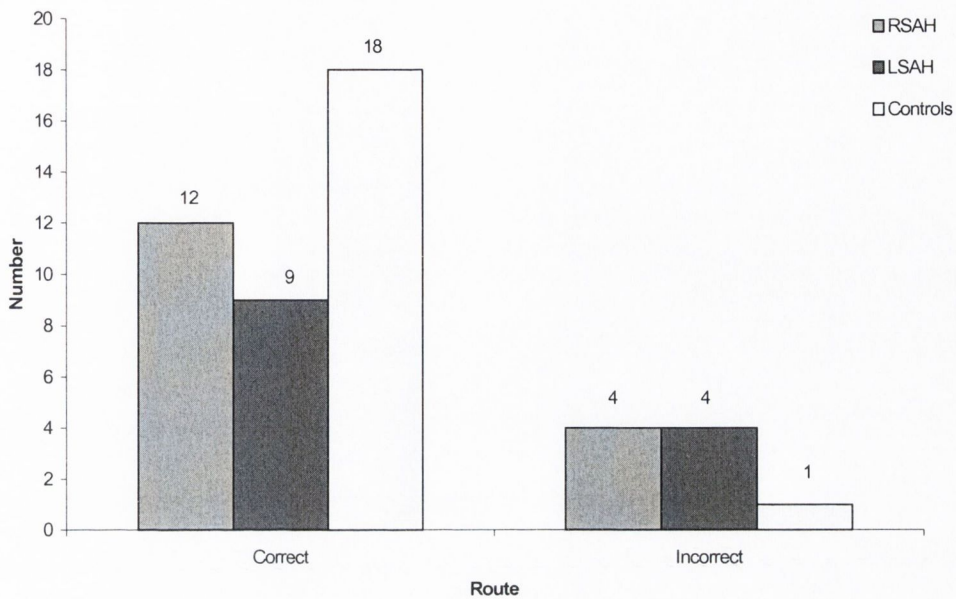
**p<.01

3.29 Analysis of the routes chosen by participants for each question.

Another measure that was recorded in the Route Description Task was the route chosen by each participant for each question. As explained in Chapter 2, for each of the four questions, a number of correct routes were identified on the map. From this guide, the route chosen by the participant for each question was noted. Ambiguous or incorrect route descriptions were also assigned a value. This variable was then recoded as a dichotomous variable with a value of 1 for ‘correct’ routes and 2 for ‘incorrect’ routes.

The frequency with which correct and incorrect routes were chosen for each question is shown in Figures 3.32a-3.32d below. From these graphs, it is evident that a greater number of participants from the both patient groups compared to control participants tended to choose incorrect routes. A Kruskal-Wallis non-parametric test was used to determine whether there was a Group difference in the frequency with which correct or incorrect routes were chosen for each question.

Figure 3.32a: Number of correct and incorrect routes chosen for Question 1.



The results of the analysis for Question 1 showed that there was no difference between the groups [$\chi^2(2)=3.830$, $p>.05$]. This analysis was repeated for each of the remaining three questions and showed a significant difference between the groups in the routes chosen for Question 2 [$\chi^2(2)=10.545$, $p<.01$], with the both patient groups, particularly the LSAH group, having significantly higher mean ranks. This indicates that more patients than controls were assigned a '2' for their choice of route meaning that it was incorrect.

A Mann-Whitney U test was used to specify which groups were significantly different from each other. The results of these comparisons showed that for Question 2, both the RSAH [$z = -2.079$, $p<.05$] and LSAH [$z = -2.633$, $p<.01$] groups tended to choose incorrect routes more frequently than controls. For Questions 3 and 4, the difference between groups was not significant with regard to the frequency of correct and incorrect routes chosen [Question 3: $\chi^2(2)=5.276$, $p>.05$; Question 4: $\chi^2(2)=2.873$, $p>.05$].

Figure 3.32b: Number of correct and incorrect routes chosen for Question 2.

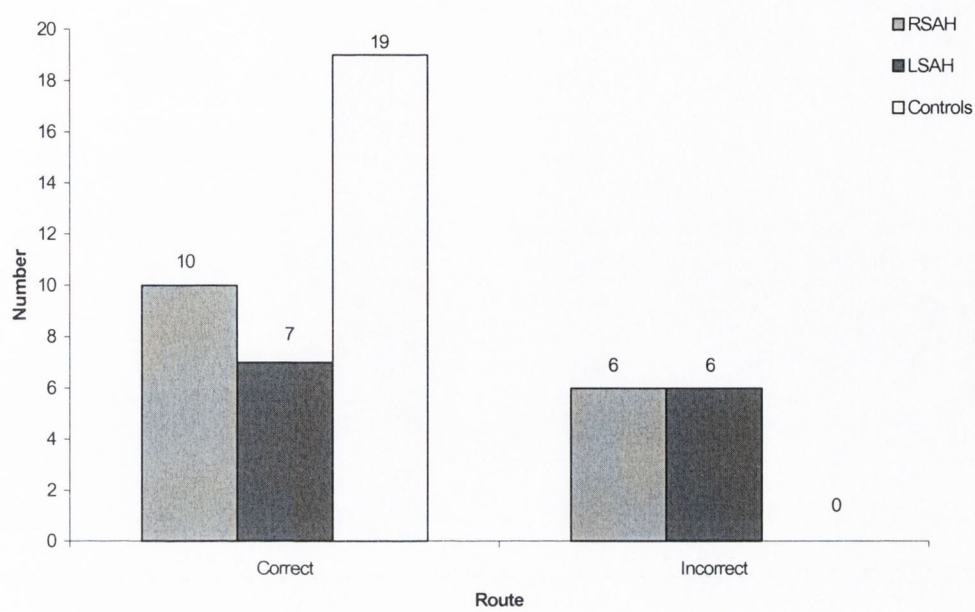


Figure 3.32c: Number of correct and incorrect routes chosen for Question 3.

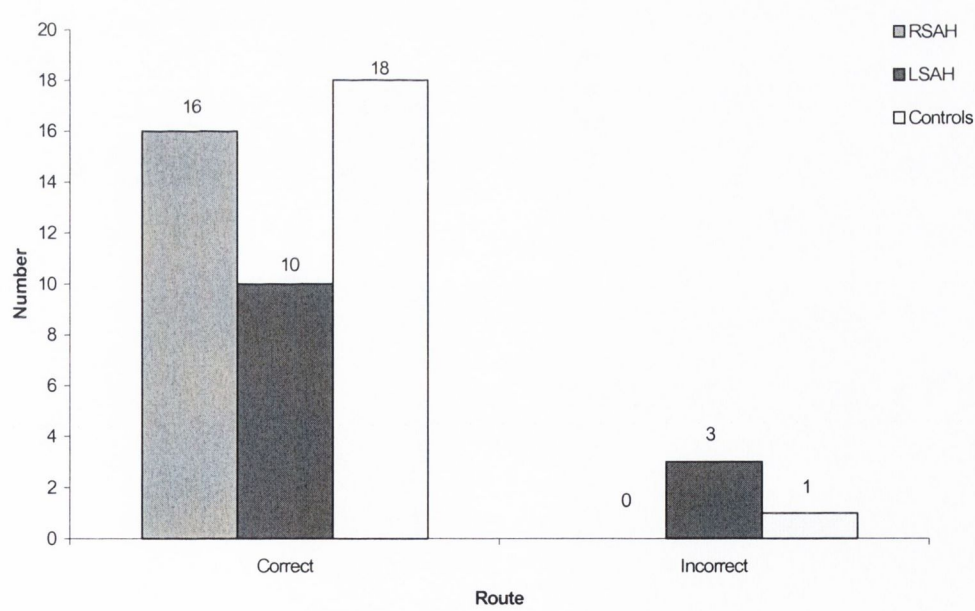
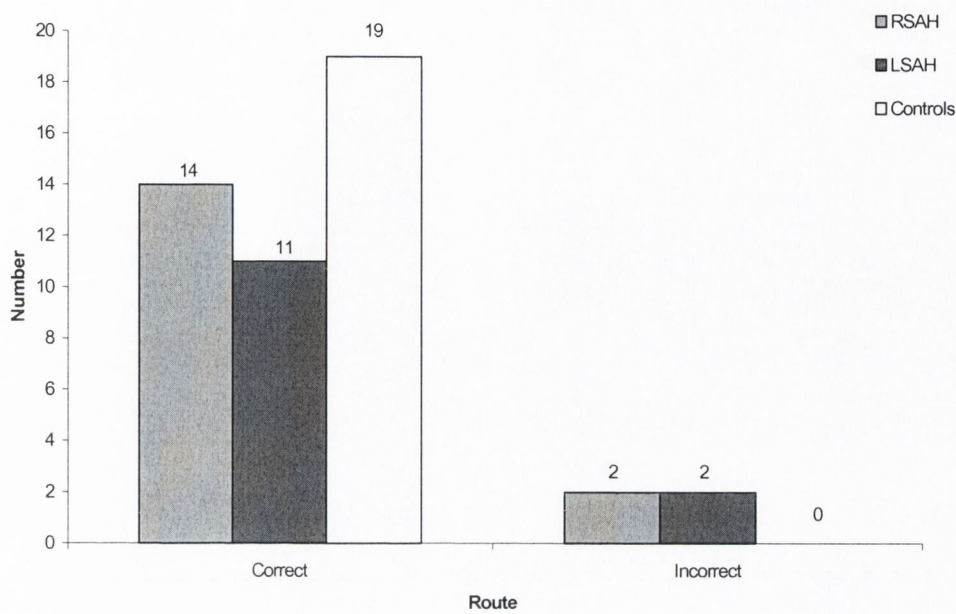


Figure 3.32d: Number of correct and incorrect routes chosen for Question 4.



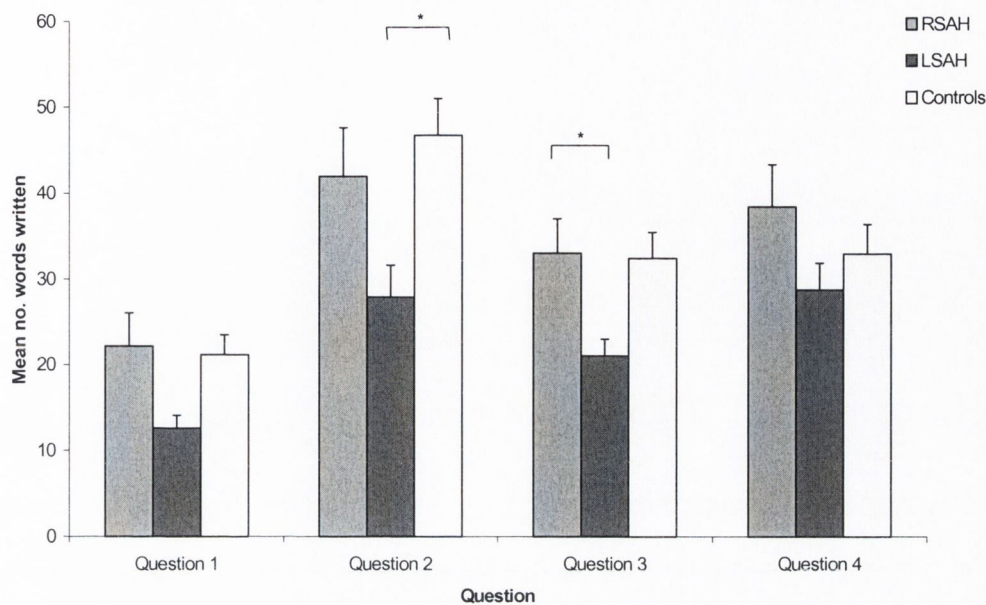
3.30 Analysis of the mean number of words written for each question on the Route Description Task.

Shown in Table 3.27 and Figures 3.33a and 3.33b below are the mean word counts for participants from each group for each of the four questions. The data presented here imply that there is a group influence on the number of words written in the Route Description Task, with the LSAH group writing seemingly fewer words than either the RSAH or the control groups.

Table 3.27: Mean number of words written for each question.

No. words	RSAH n = 16 Mean (S.D.)	LSAH n = 13 mean (S.D.)	Controls n = 19 mean (S.D.)
Question 1	22.19 (15.48)	12.62 (5.44)	21.21 (10.08)
Question 2	42.00 (22.62)	27.92 (13.33)	46.79 (18.56)
Question 3	33.06 (15.96)	21.08 (7.01)	32.47 (13.13)
Question 4	38.50 (19.52)	28.77 (11.37)	33.00 (14.97)
Total	135.75 (67.69)	88.15 (28.37)	132.63 (50.28)

Figure 3.33a: Mean number of words written by each group on the Route Description Task.



Analysis of the effects of the between-subjects factors on word count.

A multivariate ANOVA was used to determine the effects of the between-subjects factors Group and Gender on the four dependent variables i.e. the mean number of words written by each participant for each question. The results of the analysis showed a main effect for Group on the word count for Questions 2 and 3 [Question 2: $F(3,42) = 3.723, p < .05$; Question 3: $F(3,42) = 3.541, p < .05$] but not for Questions 1 and 4. The between-subjects factor Gender did not have a significant effect on word count in any of the questions [Question 1: $F(1,42) = .070, p > .05$; Question 2: $F(1,42) = .059, p > .05$; Question 3: $F(1,42) = .328, p > .05$; Question 4: $F(1,42) = .173, p > .05$]. Post hoc multiple comparisons using the Tukey test showed that for Question 2, the word count for the LSAH group differed significant from the word count for the control participants [$t(42) = -18.87, p < .05$]. Interestingly, for Question 3, the difference in word count was between the LSAH and RSAH groups [$t(42) = -11.99, p < .05$].

3.31 Correlational analysis of the number of words written for each question.

A correlation matrix of the associations between the word counts for each of the four questions was produced and is shown in Table 3.28 below. It is clear

from the above data that there are highly significant correlations between the word counts for each of the questions in this task.

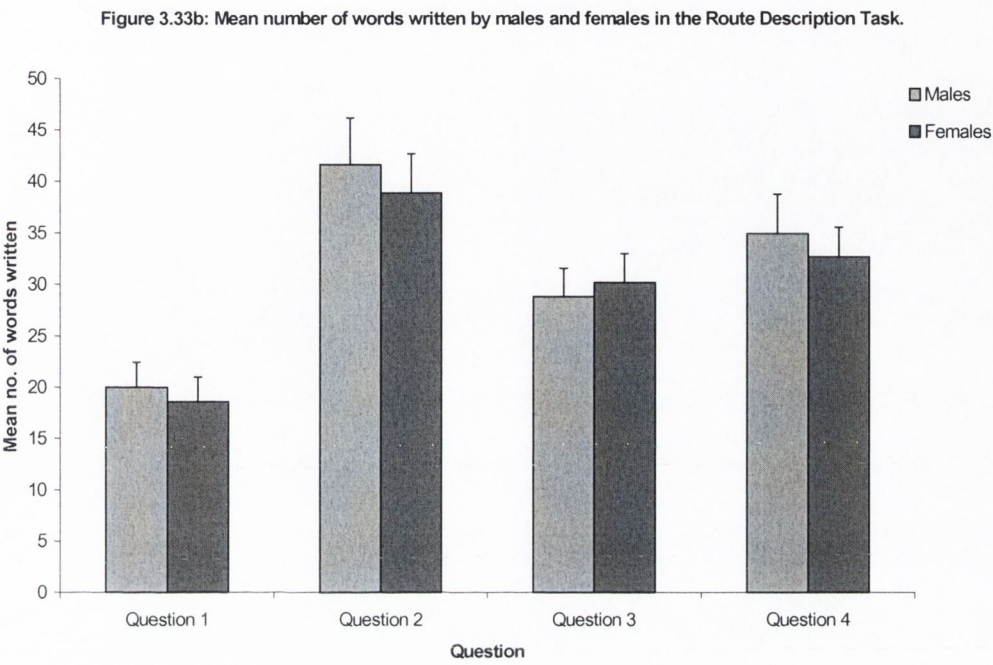


Table 3.28: Correlation matrix of the association between the number of words written for each question on the Route Description Task.

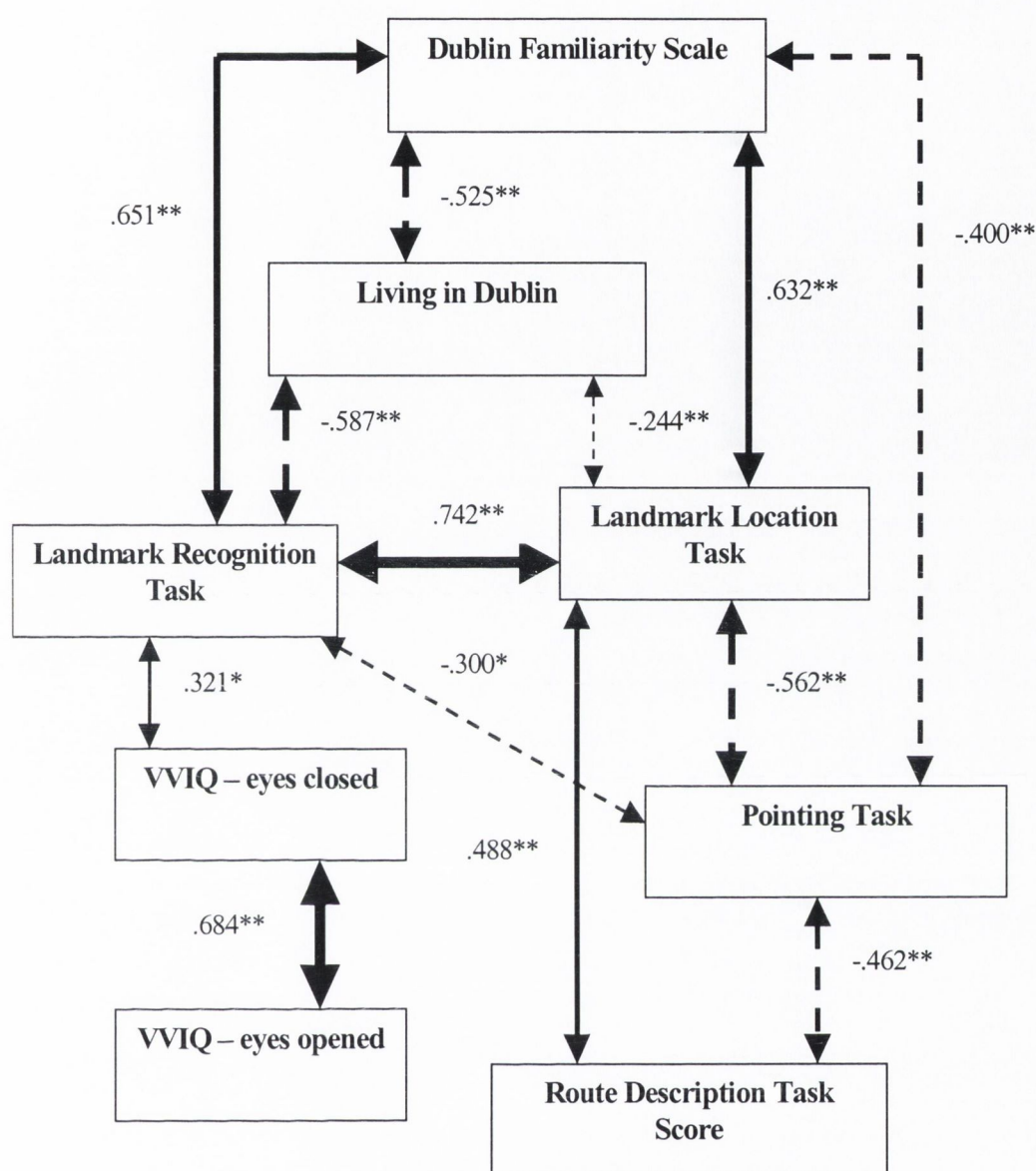
Question	Question 2	Question 3	Question 4
Question 1	.702**	.704**	.634**
Question 2		.797**	.747**
Question 3			.857**

**p<.01

3.32 Correlational Analyses of the landmark tasks

In order to examine any significant relationships between the landmark tasks, a correlation matrix was constructed and is reproduced in Table 3.29. From there, a Path Model, highlighting the significant links between the different tasks, was created. This can be seen in Figure 3.34 below.

Figure 3.34: Path Model of the correlations between the landmark tasks



3.33 Analysis of the Spatial Navigation Tasks

In the following section of this chapter, the focus of the analyses is now directed towards the results obtained from the Spatial Navigation Tasks completed by the participants. A subset of sixteen of the nineteen controls took part in these tasks: three of the control participants were unable to complete this part of the study due to time constraints. Therefore, the analyses reported below are based on results taken from forty-nine participants. The measures contained in Figures 35-39 are in centimetres unless otherwise indicated.

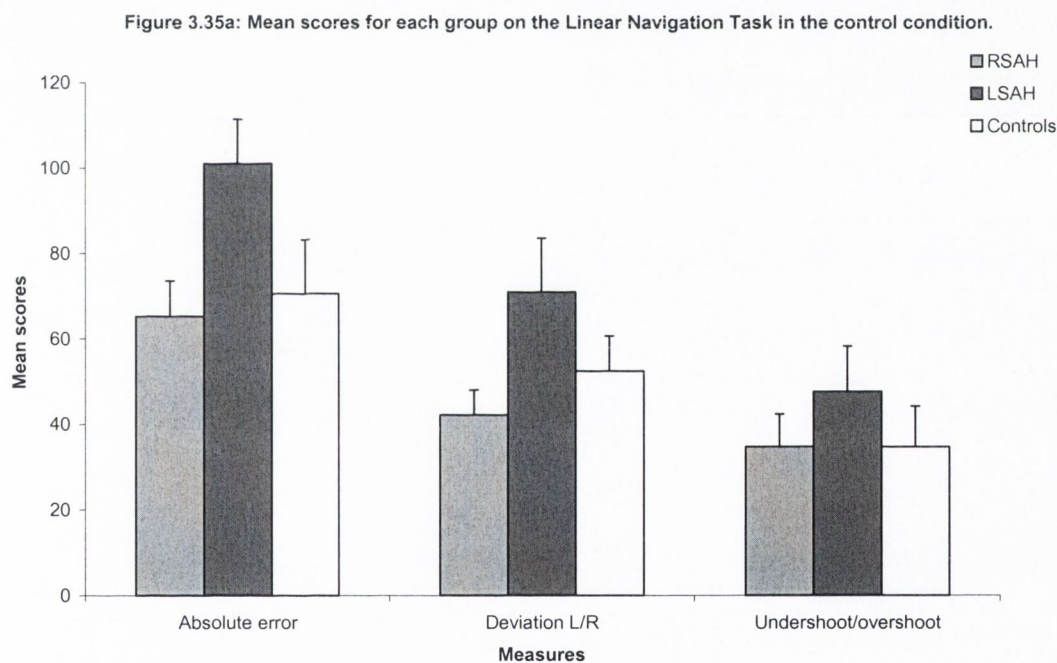
Table 3.29: Correlation matrix of the relationships between the Landmark Tasks and Route Description Task.

Variables	Dublin Familiarity Score	Landmark Recognition Score	Landmark Location Score	Route Description Score	Pointing Task (ave. error)	VVIQ eyes opened	VVIQ eyes closed
Living in Dublin	-.525**	-.587**	-.244*	.084	.061	.036	.103
Dublin Familiarity Scale		.651**	.632**	.076	-.400**	.134	.206
Landmark Recognition			.742**	.239	-.300*	.232	.321*
Landmark Location				.488**	-.562**	.204	.226
Route Description Score					-.462**	.155	.003
Pointing Task (ave. error)						-.127	.086
VVIQ eyes opened							.684**

*p<.05; **p<.01

3.33.1 Linear Navigation Task

Table 3.30 below contains the results of the Linear Navigation Task for each of the participant groups. For each of the two conditions in this task, a number of different measures were taken: Absolute error, deviation to the left or right of the line, the distance the participant overshoot or undershot the line, the time taken and the total distance walked by the participant. Each participant completed five trials of each condition; thus the data presented in Table 3.31 consists of the mean scores for each of the measures. Figures 3.35a and 3.35c contain the scores obtained by participants in each group on both conditions of the task and the scores for male and female participants are shown in Figures 3.35b and 3.35d. Figure 3.37 shows the distance walked by participants in both conditions.



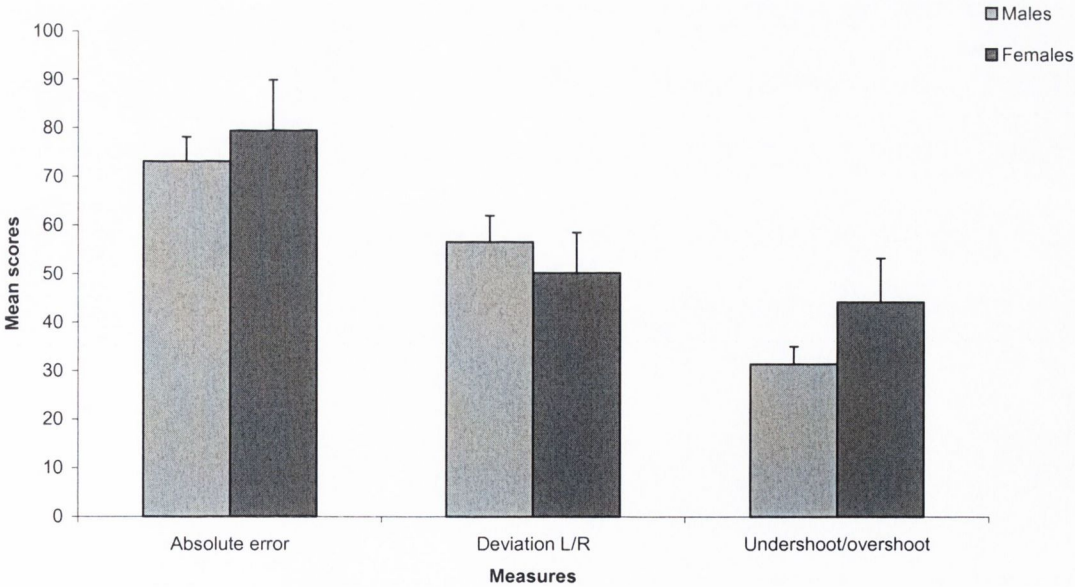
Analysis of the effects of the between-subjects factors on each of the dependent measures.

Multivariate ANOVAs were used to test the effect of the between-subjects factors Group and Gender on the following dependent variables in both the control and dual task conditions: absolute error, deviation the left/right of the line, total distance walked, undershoot/overshoot and time taken. The results of these analyses are reported below.

Table 3.30: Participants’ mean scores on the Linear Navigation Task.

Condition (measurements in cm)	RSAH n = 20 mean (S.D.)	LSAH n = 13 mean (S.D.)	Controls n = 16 Mean (S.D.)
Control Condition			
Absolute error	65.28(37.40)	100.92(37.57)	70.57(43.45)
Deviation to L/R	42.17(25.80)	70.88(45.56)	52.34(32.77)
Undershoot/overshoot	335.02(50.93)	320.66(54.56)	347.68(51.01)
Time taken(sec)	8.78(3.35)	9.86(7.26)	7.44(2.18)
Total distance walked	335.02(50.93)	320.65(54.56)	347.68(51.02)
Dual Task Condition			
Absolute error	60.97(41.69)	77.59(30.05)	63.78(31.86)
Deviation to L/R	46.47(38.47)	58.03(28.61)	49.50(23.70)
Undershoot/overshoot	362.43(29.62)	358.96(43.83)	362.49(39.82)
Time taken(sec)	7.40(3.42)	10.20(6.85)	6.51(2.07)
Total distance walked(cm)	362.43(29.62)	358.96(43.83)	362.49(39.82)

Figure 3.35b: Mean scores for males and females on the Linear Navigation Task in the control condition.



3.35c: Mean scores for each group in the dual task condition.

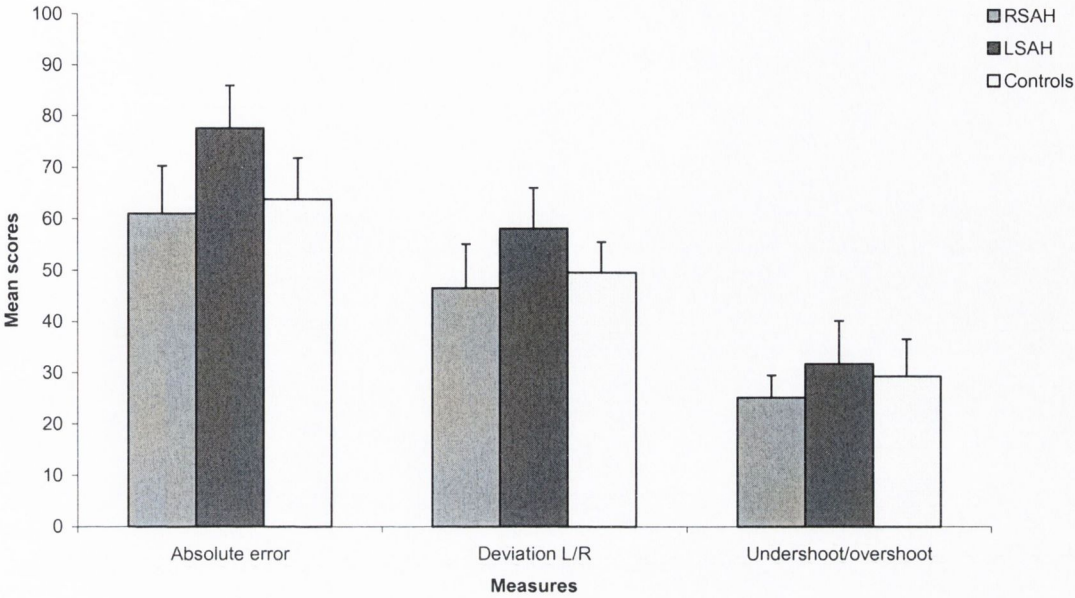
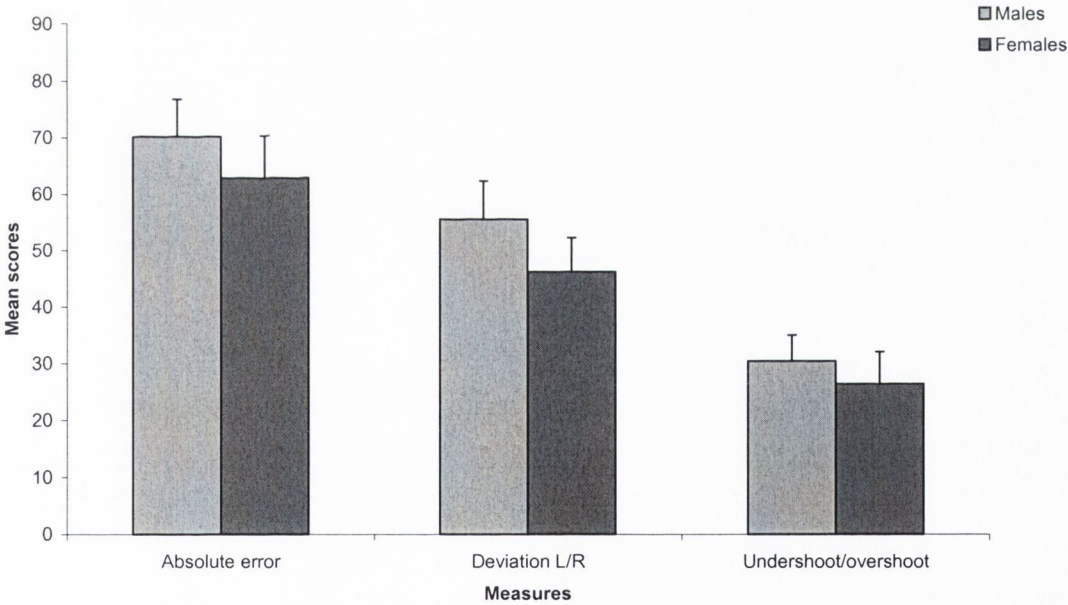


Figure 3.35d: Mean scores for males and females in the dual task condition.



Absolute error

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = .371, p > .05$; Group dual task condition: $F(2,43) = 2.478, p > .05$; Gender control condition: $F(1,43) = .493, p > .05$; Gender dual task condition: $F(1,43) = .770, p > .05$]. The interaction between the factors

was not significant in either condition [Control: $F(2,43) = .889, p>.05$; dual task: $F(2,43) = .264, p>.05$].

Deviation to Left/Right of the line

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = 2.059, p>.05$; Group dual task condition: $F(2,43) = .637, p>.05$; Gender control condition: $F(1,43) = .216, p>.05$; Gender dual task condition: $F(1,43) = 1.256, p>.05$]. The interaction between the factors was not significant in either condition [Control: $F(2, 43) = .931, p>.05$; dual task: $F(2,43) = .756, p>.05$].

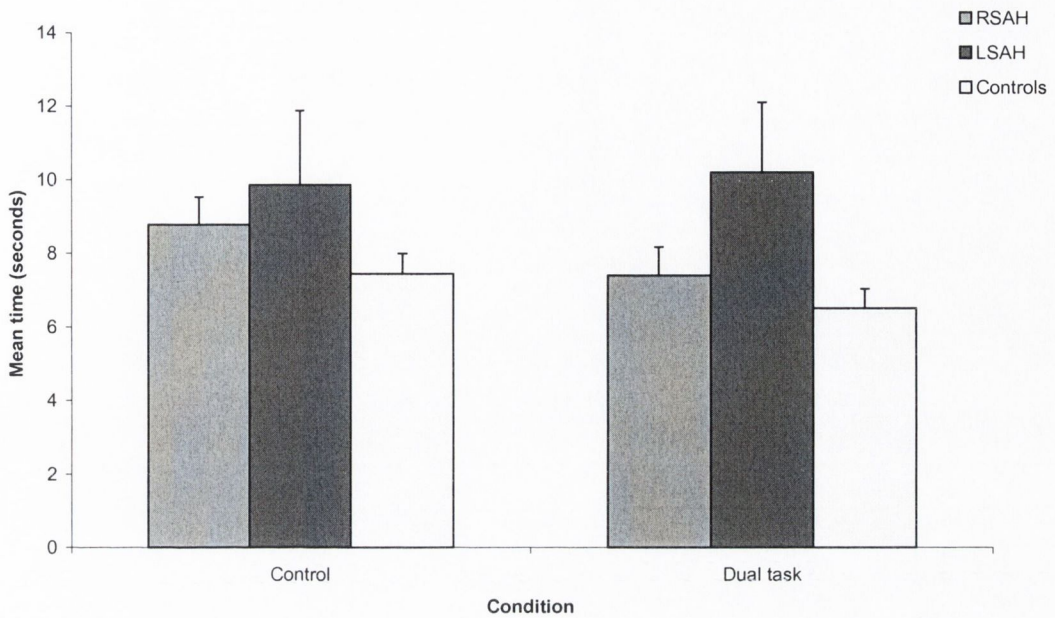
Total Distance Walked

Figures 3.36a and 3.36b below show the mean total distance walked by participants in the Linear Navigation Task. There were no main effects for Group in either condition [Control: $F(2,43) = .559, p>.05$; dual task: $F(2,43) = .246, p>.05$] or for Gender in the dual task condition [$F(1,43) = .088, p>.05$]. However, there was a significant main effect for Gender in the control condition with regard to the total distance walked [$F(1,43) = 6.077, p<.05$]. There was a significant interaction between the two factors in the dual task condition only [$F(2,43) = 4.950, p<.05$].

Undershoot/Overshoot

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = .338, p>.05$; Group dual task condition: $F(2,43) = .027, p>.05$; Gender control condition: $F(1,43) = 1.498, p>.05$; Gender dual task condition: $F(1,43) = .023, p>.05$]. The interaction between the factors was not significant in either condition [Control: $F(2, 43) = .228, p>.05$; dual task: $F(2,43) = 2.578, p>.05$].

Figure 3.35e: Mean time taken for each group in each condition.



Time taken

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = .814$, $p > .05$; Group dual task condition: $F(2,43) = 2.106$, $p > .05$; Gender control condition: $F(1,43) = .537$, $p > .05$; Gender dual task condition: $F(1,43) = 2.232$, $p > .05$]. The interaction between the factors was not significant in either condition [Control: $F(2, 43) = 2.409$, $p > .05$; dual task: $F(2,43) = 3.153$, $p > .05$].

Figure 3.35f: Mean time taken for males and females in each condition.

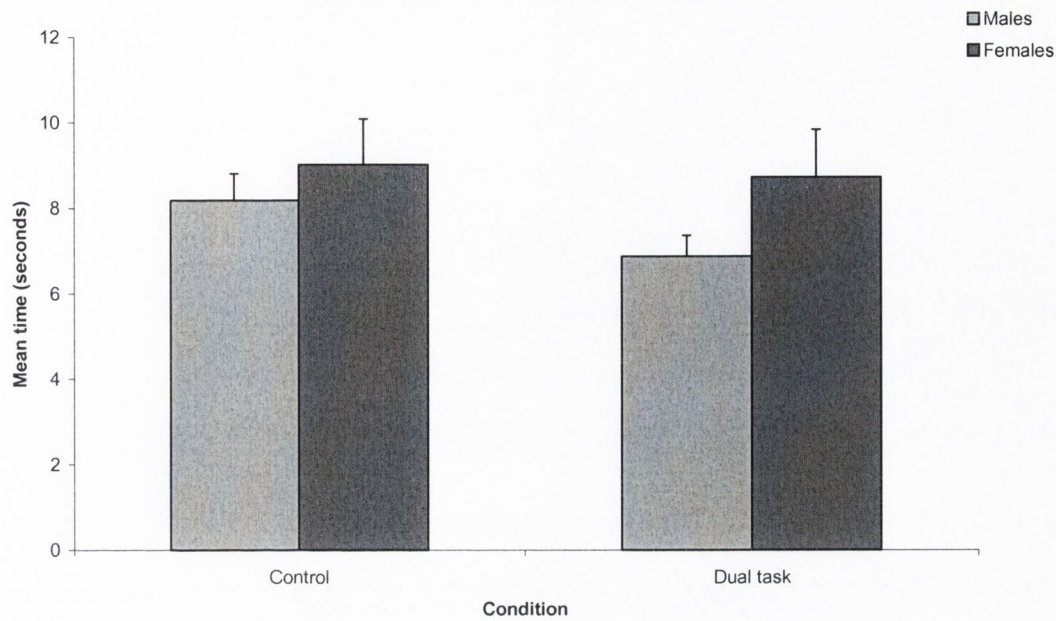
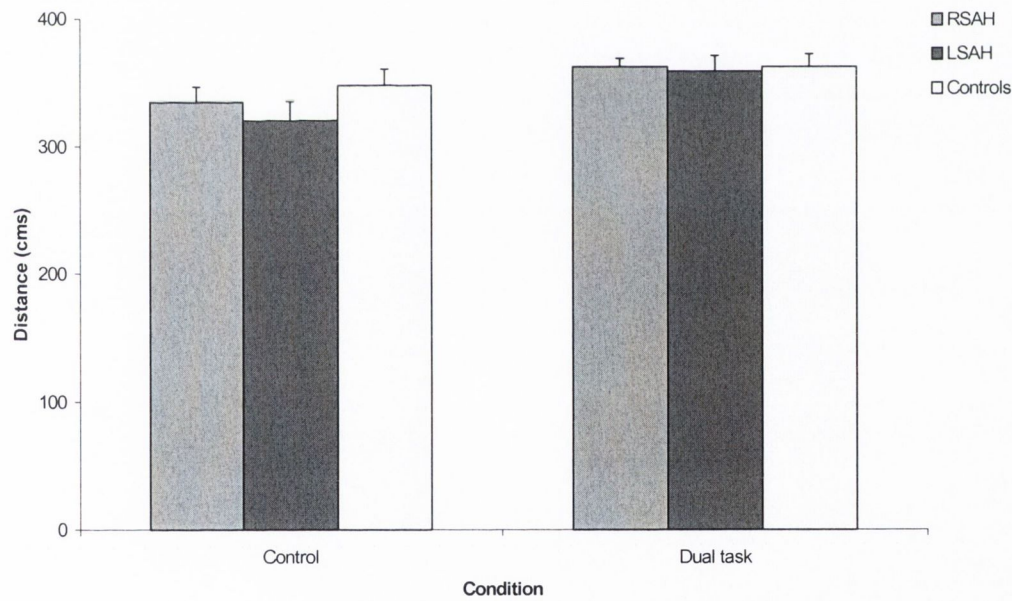


Figure 3.36a: Mean total distance walked by each group in the Linear Navigation Task.



3.33.2 Backward Walking Task

The Backward Walking Task consisted of four conditions, with each participant completing five trials of each condition. The measures taken on this task were the same as those recorded in the Linear Navigation Task, and the data presented in Table 3.31 below depicts the mean scores obtained by each group for each measure.

Figures 3.37a-h show the performance of participants from each group on each condition of the Backward Walking Task and also depict the performance of males and females on this task. The total distance walked by participants can be seen in Figures 3.39a and 3.39b.

Figure 3.36b: Mean total distance walked by males and females in the Linear Navigation Task.

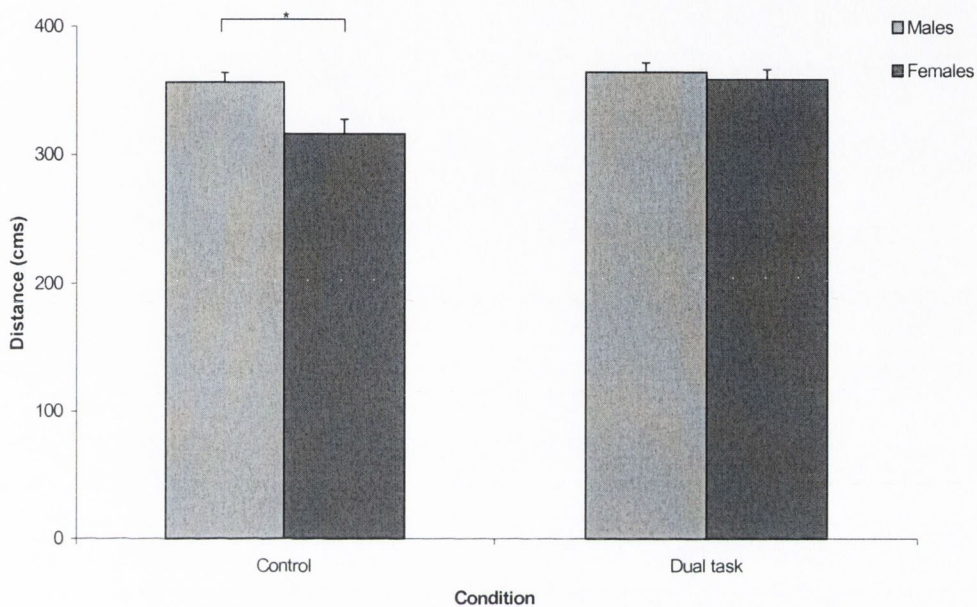
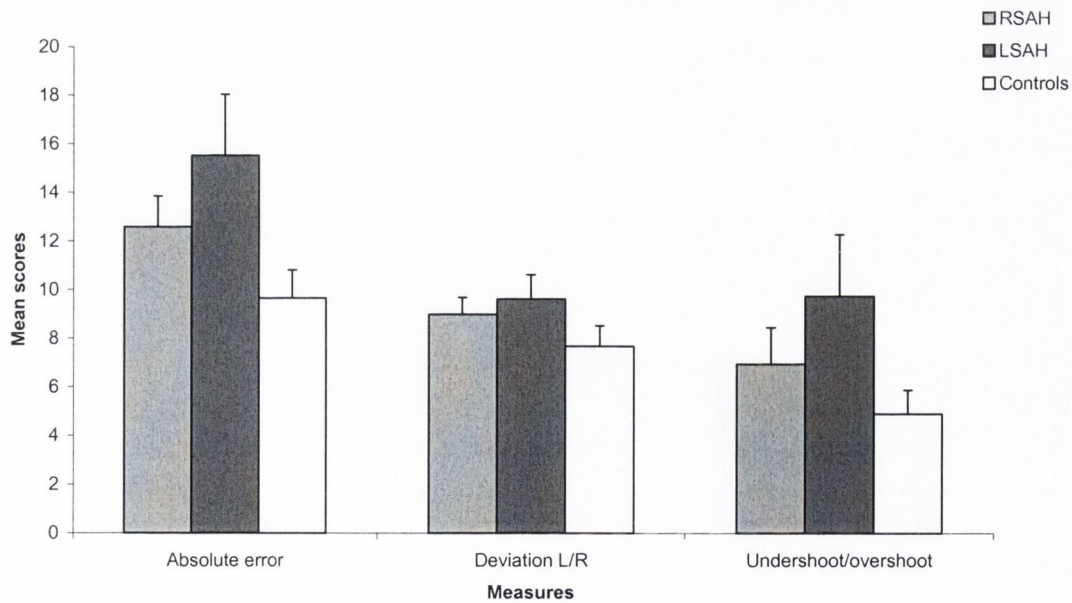


Figure 3.37a: Mean scores for each group on the Backward Walking Task in the walking to seen target condition.



Analyses of the effects of the between-subjects factors on each of the dependent measures.

Multivariate ANOVAs were used to test the effect of the between-subjects factors Group and Gender on the following dependent variables in each of the four conditions: absolute error, deviation the left/right of the line, total distance walked, undershoot/overshoot and time taken. The results of these analyses are reported below.

Absolute error

There were no main effects for either Group or Gender in any of the four conditions [Walking to seen target – Group: $F(2,43) = 2.880$, $p > .05$; Gender: $F(1,43) = .048$, $p > .05$; Walking backwards – Group: $F(2,43) = .078$, $p > .05$; Gender: $F(1,43) = .517$, $p > .05$; Walking forwards blindfolded – Group: $F(2,43) = 2.564$, $p > .05$; Gender: $F(1,43) = .470$, $p > .05$; Walking backwards blindfolded – Group: $F(2,43) = 2.019$, $p > .05$; Gender: $F(1,43) = .191$, $p > .05$]. The interaction between the factors was not significant in any of the four conditions [Walking to seen target: $F(2,43) = 1.025$, $p > .05$; Walking backwards: $F(2,43) = .066$, $p > .05$; Walking forwards blindfolded: $F(2,43) = 1.025$, $p > .05$; Walking backwards blindfolded: $F(2,43) = .265$, $p > .05$].

Deviation to the Left/Right of the line

There was a main effect of Gender in the Walking to seen target condition only [$F(1,43) = 6.630$, $p < .05$]. There were no effects of either factor in any of the other conditions [Walking to seen target – Group: $F(2,43) = 2.955$, $p > .05$; Walking backwards – Group: $F(2,43) = .347$, $p > .05$; Gender: $F(1,43) = .215$, $p > .05$; Walking forwards blindfolded – Group: $F(2,43) = 1.825$, $p > .05$; Gender: $F(1,43) = 1.090$, $p > .05$; Walking backwards blindfolded – Group: $F(2,43) = .800$, $p > .05$; Gender: $F(1,43) = .008$, $p > .05$]. The interaction between the factors was not significant in any of the four conditions [Walking to seen target: $F(2,43) = 1.818$, $p > .05$; Walking backwards: $F(2,43) = 2.482$, $p > .05$; Walking forwards blindfolded: $F(2,43) = 1.784$, $p > .05$; Walking backwards blindfolded: $F(2,43) = .540$, $p > .05$].

Table 3.31: Participants' mean scores on the Backward Walking Task

Condition (measurements in cm)	RSAH n = 20 Mean (S.D.)	LSAH n = 13 mean (S.D.)	Controls n = 16 Mean (S.D.)
Walking to seen target			
Absolute error	12.58(5.62)	15.52(9.06)	9.64(4.66)
Deviation to L/R	8.98(3.08)	9.61(3.57)	7.66(3.35)
Undershoot/overshoot	355.34(7.89)	357.89(10.88)	353.35(5.33)
Time taken	4.10(1.18)	4.49(1.59)	3.26(1.14)
Distance walked	355.34(7.89)	357.89(10.88)	353.35(5.33)
Walking backwards			
Absolute error	31.52(17.62)	33.91(21.94)	35.08(24.42)
Deviation to L/R	17.37(6.37)	15.68(6.87)	17.58(6.39)
Undershoot/overshoot	333.14(23.10)	332.25(29.59)	328.21(28.56)
Time taken (sec)	6.60(2.62)	7.57(5.47)	4.33(1.23)
Distance walked	333.14(23.10)	332.25(29.59)	328.21(28.56)
Walking blindfolded			
Absolute error	42.50(26.89)	61.54(26.59)	52.90(23.46)
Deviation to L/R	34.78(26.87)	48.31(29.03)	39.85(18.55)
Undershoot/overshoot	358.60(21.92)	342.51(30.45)	367.56(29.31)
Time taken (sec)	6.76(2.04)	7.48(3.67)	5.84(1.13)
Distance walked	358.60(21.92)	342.51(30.45)	367.56(29.31)
Walking backwards Blindfolded			
Absolute error	67.88(45.19)	95.80(48.57)	64.41(25.69)
Deviation to L/R	36.51(25.38)	49.36(30.06)	40.76(23.14)
Undershoot/overshoot	307.79(49.90)	290.39(66.80)	304.1(26.00)
Time taken (sec)	8.87(3.72)	10.06(7.00)	7.14(1.85)
Distance walked	307.79(49.90)	290.39(66.80)	304.10(26.00)

Figure 3.37b: Mean scores for males and females on the Backward Walking Task in the Walking to seen target condition.

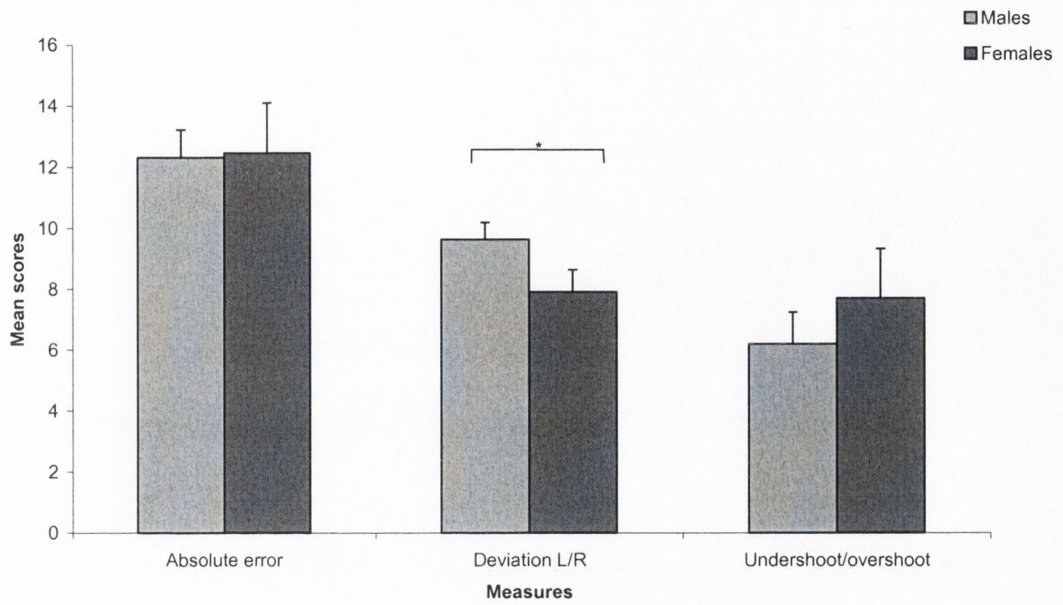


Figure 3.37c: Mean scores for each group on the Backwards Walking Task in the walking backwards condition.

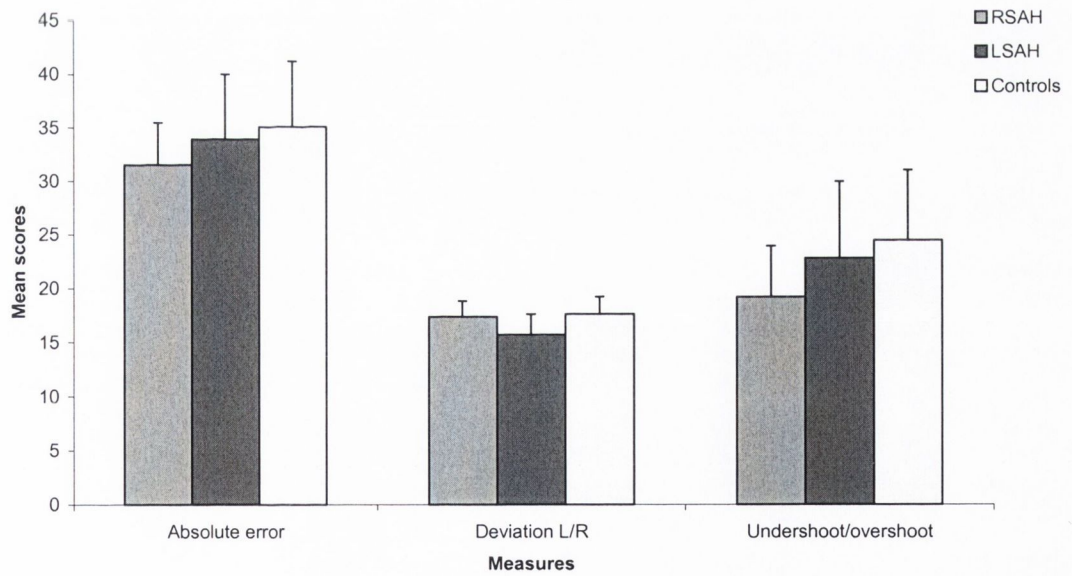
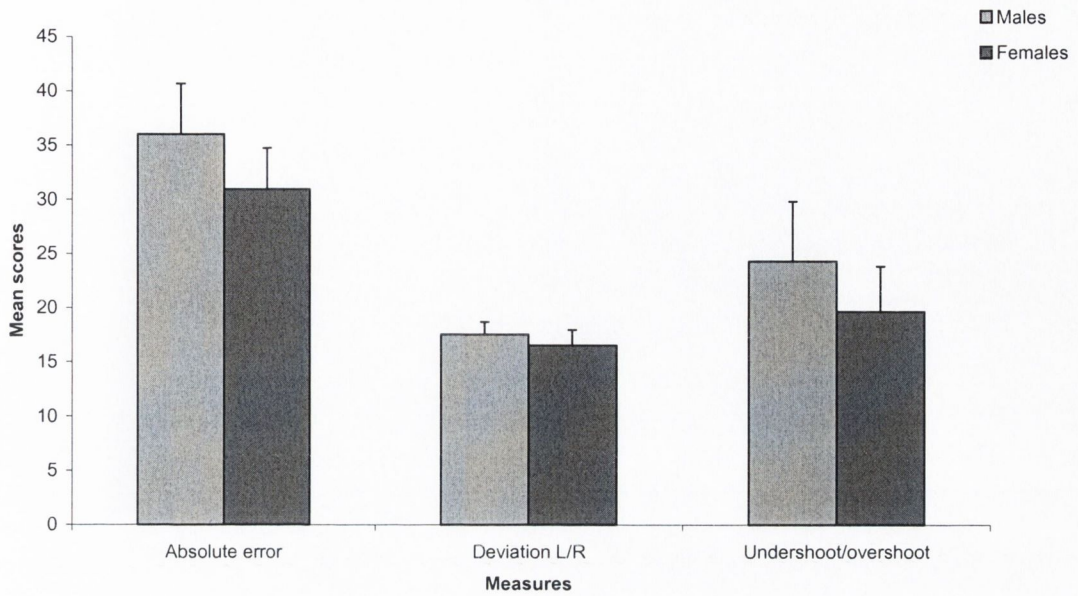


Figure 3.37d: Mean scores for males and females on the Backwards Walking Task in the walking backwards condition.



Total Distance Walked

There were no main effects for either Group or Gender in any of the four conditions [Walking to seen target – Group: $F(2,43) = .701$, $p > .05$; Gender: $F(1,43) = .596$, $p > .05$; Walking backwards – Group: $F(2,43) = .076$, $p > .05$; Gender: $F(1,43) = .363$, $p > .05$; Walking forwards blindfolded – Group: $F(2,43) = 2.722$, $p > .05$; Gender: $F(1,43) = .197$, $p > .05$; Walking backwards blindfolded – Group: $F(2,43) = .418$, $p > .05$; Gender: $F(1,43) = .028$, $p > .05$]. The interaction between the factors was not significant in any of the four conditions [Walking to seen target: $F(2,43) = .444$, $p > .05$; Walking backwards: $F(2,43) = .022$, $p > .05$; Walking forwards blindfolded: $F(2,43) = 1.138$, $p > .05$; Walking backwards blindfolded: $F(2,43) = .173$, $p > .05$].

Figure 3.37e: Mean scores for each group on the Backwards Walking Task when walking forwards blindfolded.

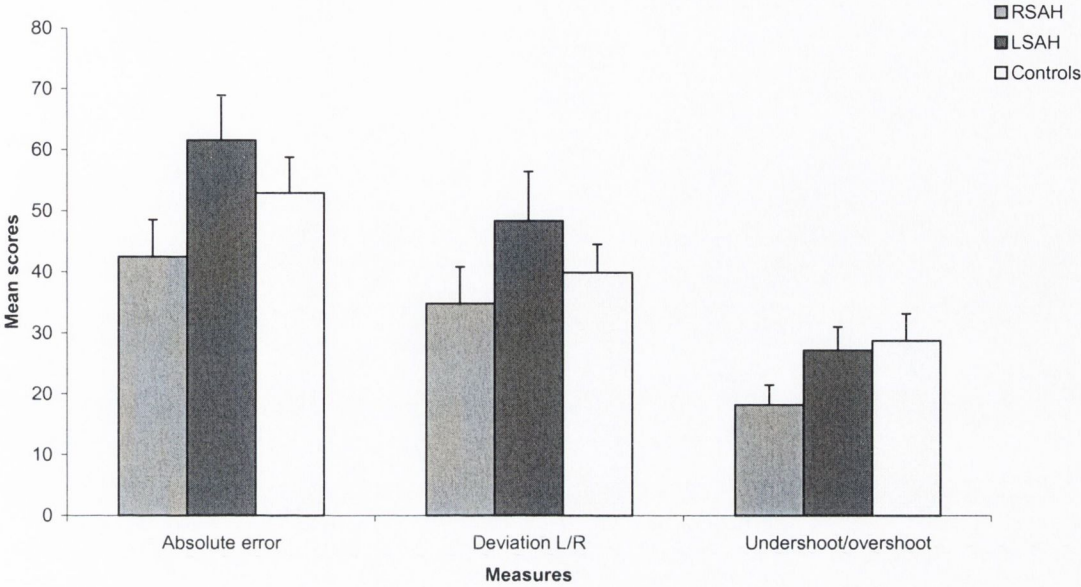


Figure 3.37f: Mean scores for males and females on the Backwards Walking Task when walking forward blindfolded.

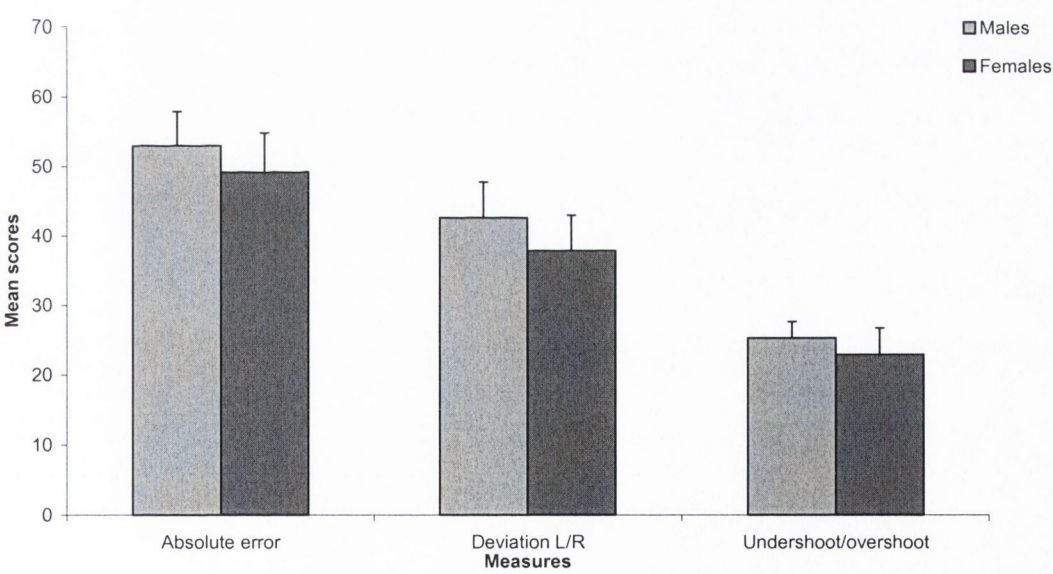


Figure 3.37g: Mean scores for each group on the Backwards Walking Task when walking backwards blindfolded.

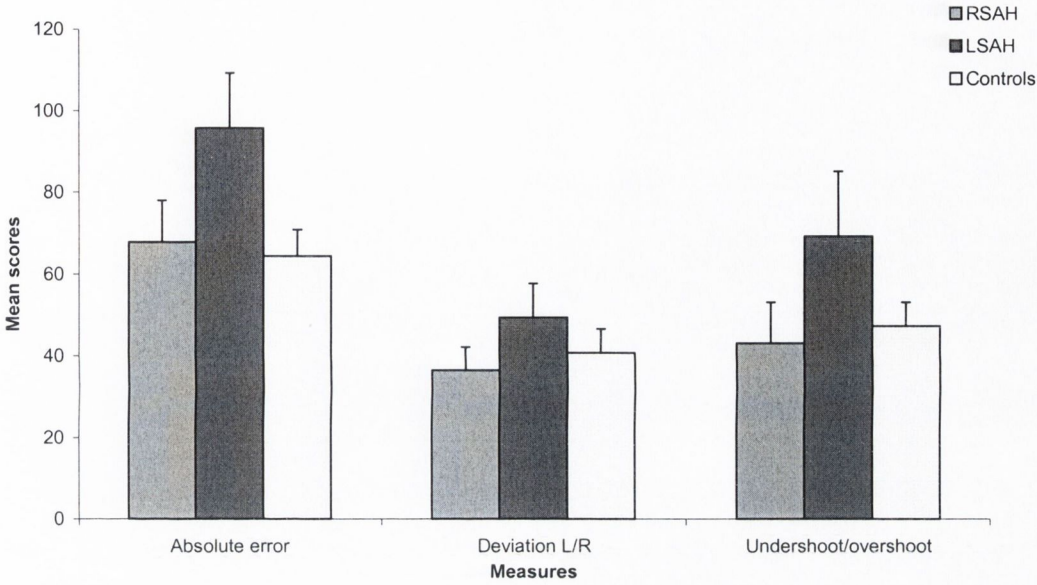


Figure 3.37h: Mean scores for males and females on the Backwards Walking Task when walking blindfolded backwards.

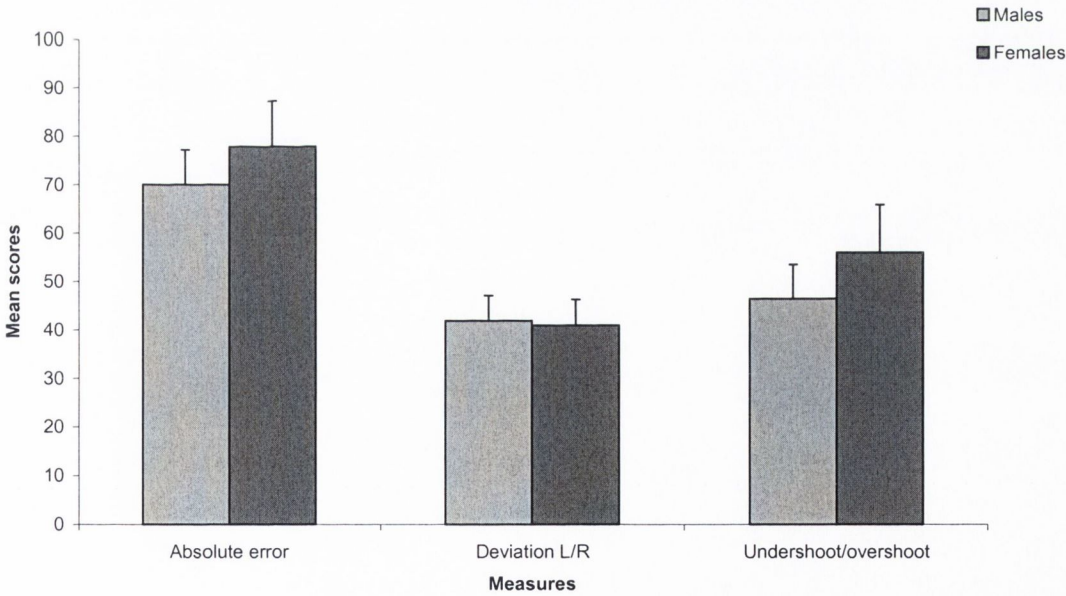


Figure 3.37i: Mean time taken for each group on each condition of the Backward Walking Task.

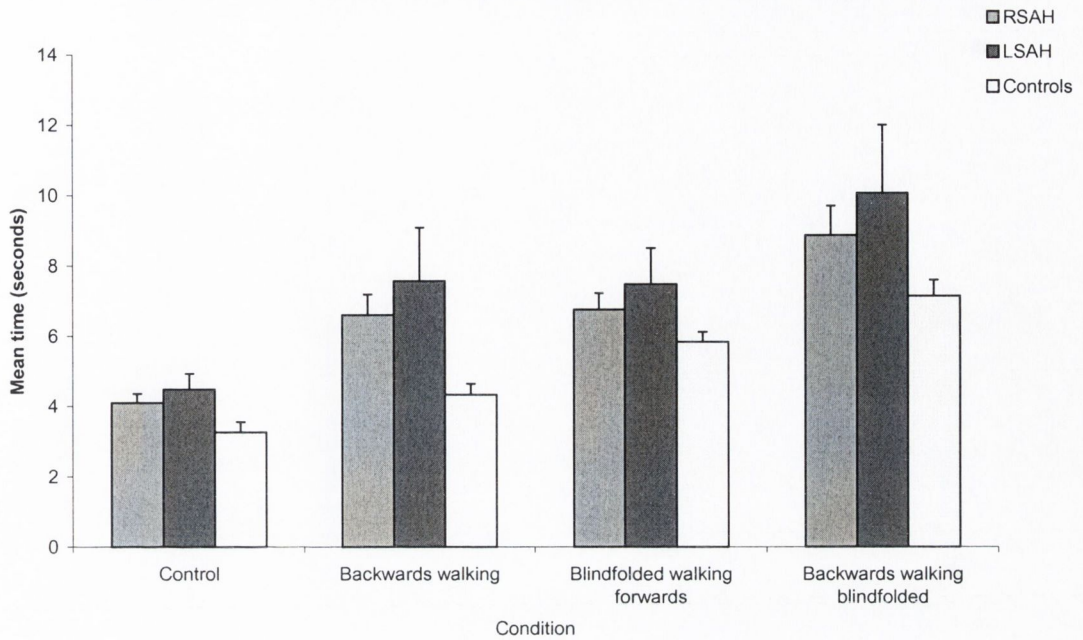
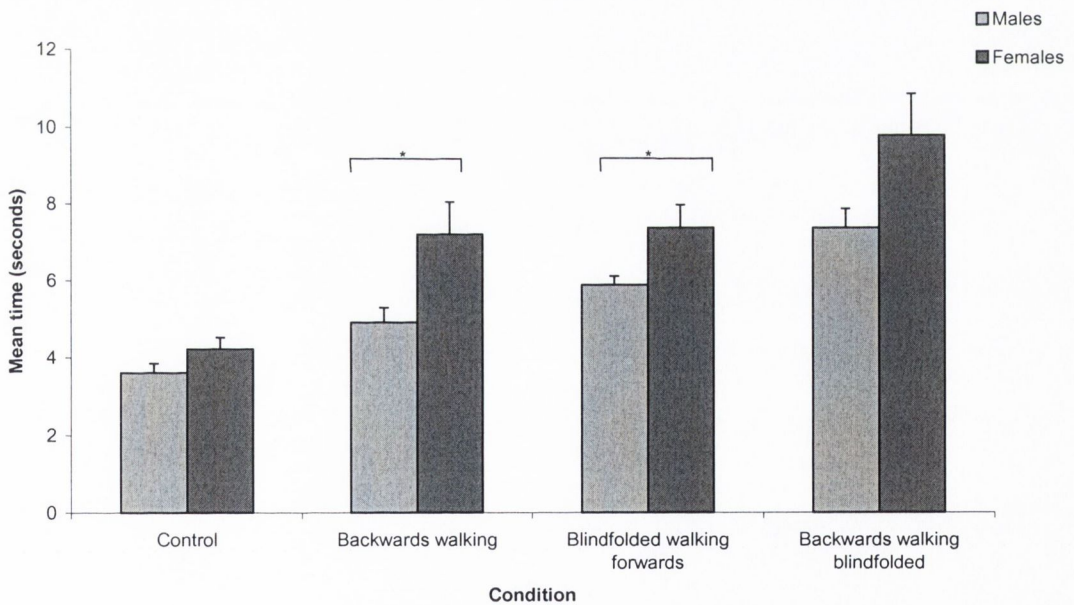


Figure 3.37j: Mean time taken for males and females on each condition of the Backwards Walking Task.

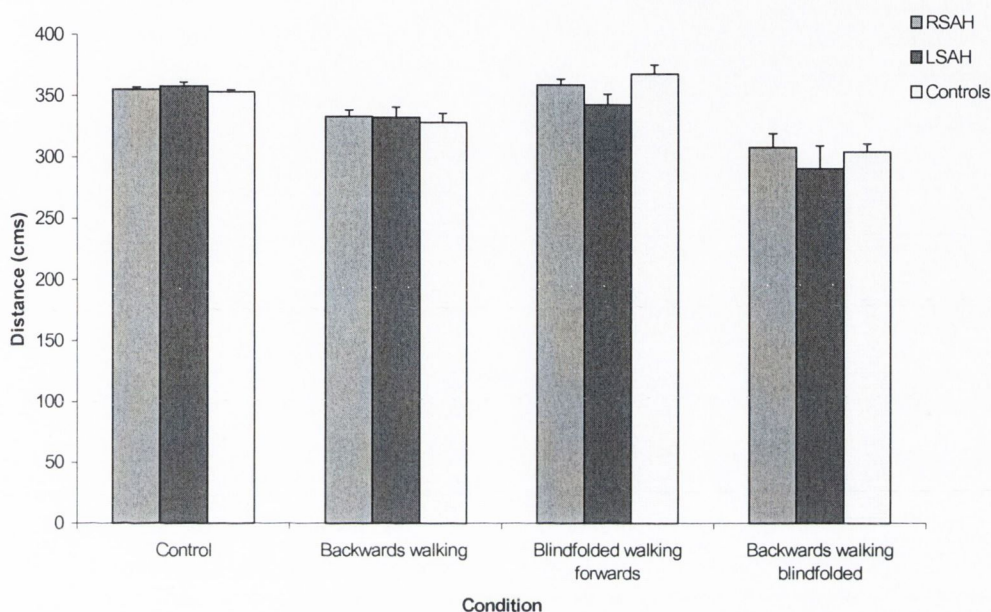


Undershoot/overshoot

There were no main effects for either Group or Gender in any of the four conditions [Walking to seen target – Group: $F(2,43) = 1.325$, $p > .05$; Gender: $F(1,43) = .450$, $p > .05$; Walking backwards – Group: $F(2,43) = .087$, $p > .05$; Gender: $F(1,43) = .209$, $p > .05$; Walking forwards blindfolded – Group: $F(2,43) = 1.777$, $p > .05$; Gender: $F(1,43) = .007$, $p > .05$; Walking backwards

blindfolded – Group: $F(2,43) = 1.358, p > .05$; Gender: $F(1,43) = .392, p > .05$]. The interaction between the factors was not significant in any of the four conditions [Walking to seen target: $F(2,43) = 1.040, p > .05$; Walking backwards: $F(2,43) = .367, p > .05$; Walking forwards blindfolded: $F(2,43) = .726, p > .05$; Walking backwards blindfolded: $F(2,43) = .020, p > .05$].

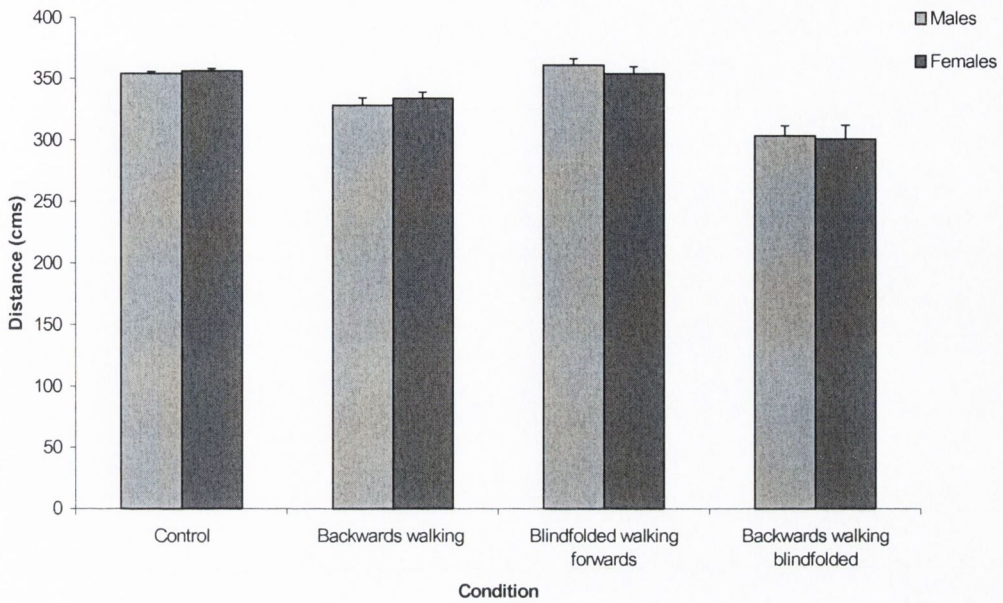
Figure 3.38a: Mean total distance walked by each group in the Backwards Walking Task.



Time taken

There were main effects for Gender in the walking backwards condition [$F(1,43) = 4.150, p < .05$] and the walking forwards blindfolded condition [$F(1,43) = 4.143, p < .05$]. However, no Gender effects were found in the remaining two conditions [Walking to seen target: $F(1,43) = 1.444, p > .05$; Backwards walking blindfolded: $F(1,43) = 3.109, p > .05$]. There were no main effects for Group in any of the conditions [Walking to seen target: $F(2,43) = 2.928, p > .05$; Walking backwards: $F(2,43) = 2.675, p > .05$; Walking forwards blindfolded: $F(2,43) = 1.349, p > .05$; Walking backwards blindfolded: $F(2,43) = 1.185, p > .05$]. The interaction between the factors was not significant in any of the four conditions [Walking to seen target: $F(2,43) = .794, p > .05$; Walking backwards: $F(2,43) = .792, p > .05$; Walking forwards blindfolded: $F(2,43) = 2.637, p > .05$; Walking backwards blindfolded: $F(2,43) = 2.022, p > .05$].

Figure 3.38b: Mean total distance walked by males and females in the Backward Walking Task.



3.33.3 Analysis of the Circular Trajectory Task

The results of participants' performance on the Circular Trajectory Task are shown in Table 3.32 below. As with Tables 3.30 and 3.31 above, this table contains the mean scores obtained by participants across the five trials on each of the two conditions. Figures 3.39 and 3.40 show the results obtained for each group and for males and females on both conditions of the Circular Trajectory Task.

Analysis of the effects of the between-subjects factors on the dependent measures.

Multivariate ANOVAs were used to test the effect of the between-subjects factors Group and Gender on the following dependent variables in both the control and dual task conditions: absolute error, total distance walked, undershoot/overshoot and time taken. The results of these analyses are reported below.

Absolute error

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = 1.003, p > .05$; Group dual task condition: $F(2,43) = 1.218, p > .05$; Gender control condition: $F(1,43) = .346, p > .05$; Gender dual task condition: $F(1,43) = .454, p > .05$].

Table 3.32: Participants’ mean scores on the Circular Trajectory Task.

Condition	RSAH n = 20	LSAH n = 13	Controls n = 16
	mean(S.D.)	mean(S.D.)	Mean(S.D.)
Control			
Absolute error(degrees)	32.14(25.48)	26.94(16.87)	22.43(14.35)
Total distance(degrees)	349.58(32.93)	354.2(27.46)	363.73(20.63)
Time taken(sec)	13.40(4.66)	14.04(5.48)	12.41(3.54)
Overshoot/undershoot (cm)	23.64(24.71)	20.95(16.21)	12.91(16.20)
Dual Task			
Absolute error(degrees)	42.72(30.81)	47.20(28.67)	25.99(16.95)
Total distance(degrees)	338.42(43.26)	331.88(40.36)	351.44(26.79)
Time taken(sec)	14.69(6.08)	17.69(10.41)	13.38(3.55)
Overshoot/undershoot (cm)	34.86(32.91)	36.83(31.88)	19.31(17.54)

Figure 3.39a: Mean scores for each group on the Circular Trajectory Task in the control condition.

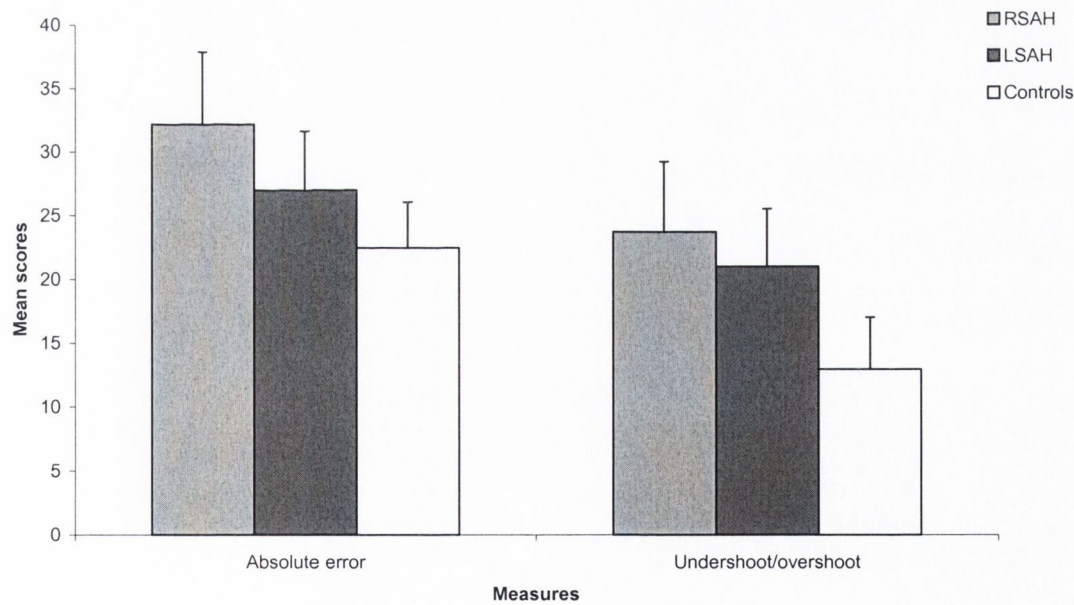


Figure 3.39b: Mean scores for males and females on the Circular Trajectory Task in the control condition.

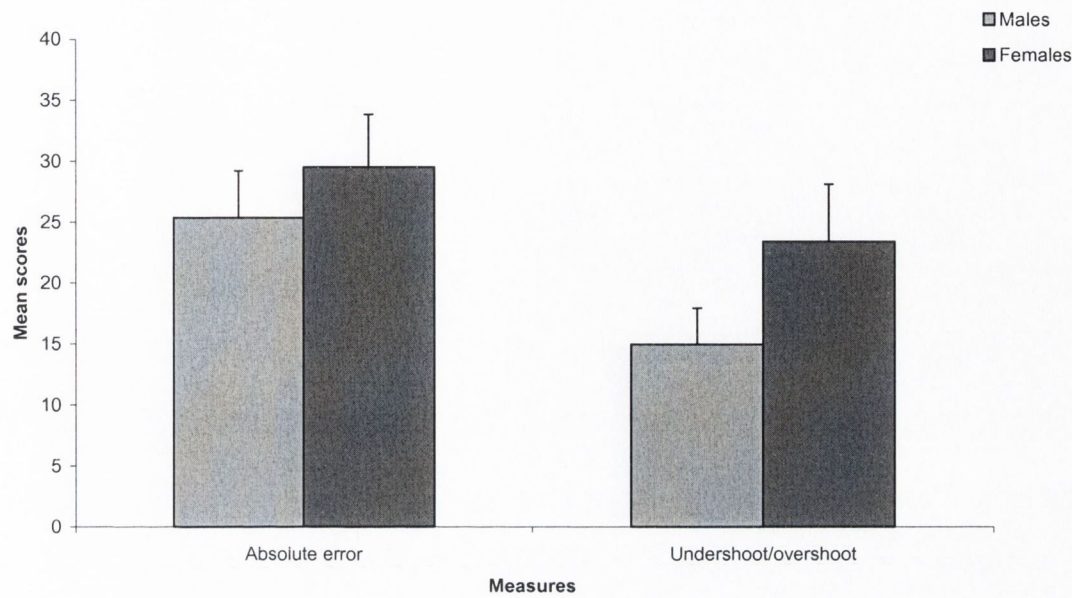


Figure 3.39c: Mean scores for each group on the Circular Trajectory Task in the dual task condition.

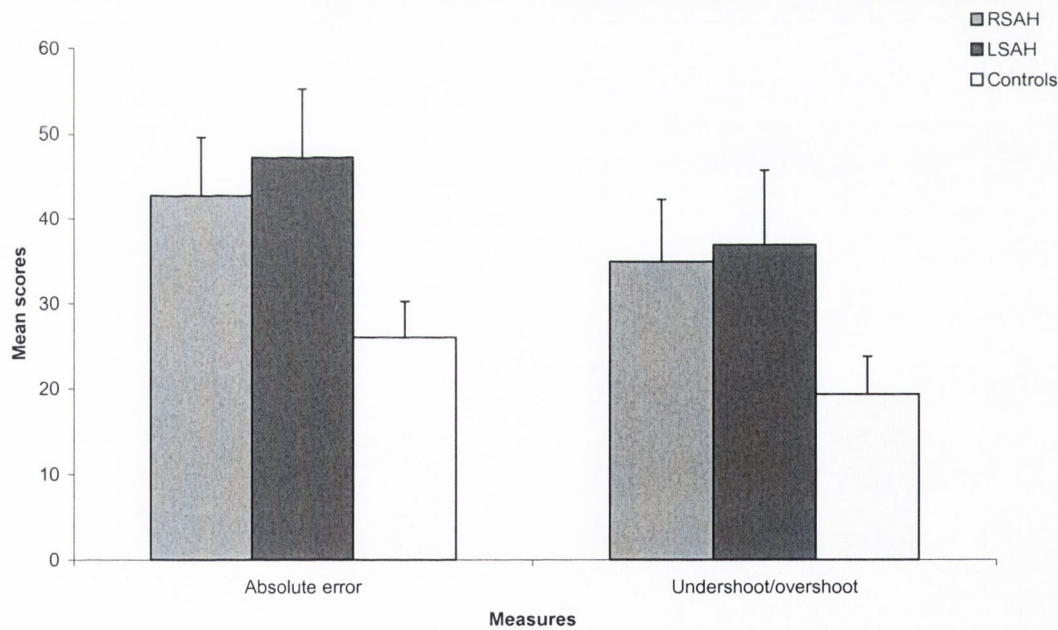
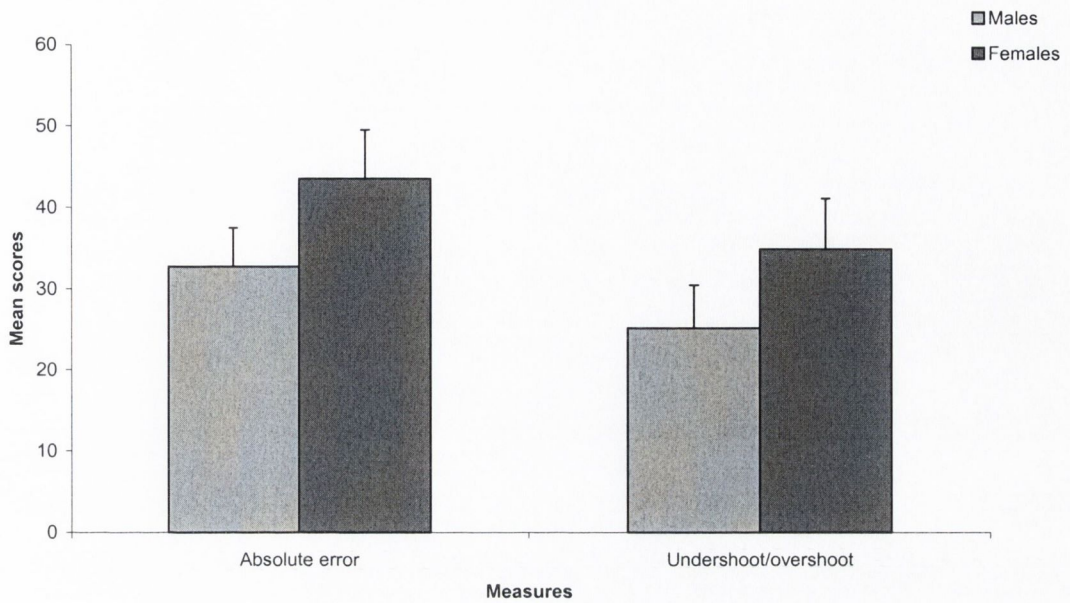


Figure 3.39d: Mean scores for males and females on the Circular Trajectory Task in the dual task condition.



The interaction between the factors was not significant in either condition [Control: $F(2,43) = .397$, $p > .05$; dual task: $F(2,43) = 1.308$, $p > .05$].

Total Distance Walked

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = 1.118$, $p > .05$; Group dual task condition: $F(2,43) = .728$, $p > .05$; Gender control condition: $F(1,43) = .006$, $p > .05$; Gender dual task condition: $F(1,43) = .157$, $p > .05$]. The interaction between the factors was not significant in either condition [Control: $F(2,43) = .501$, $p > .05$; dual task: $F(2,43) = .262$, $p > .05$].

Figure 3.39e: Mean time taken for each group on each condition of the Circular Trajectory Task

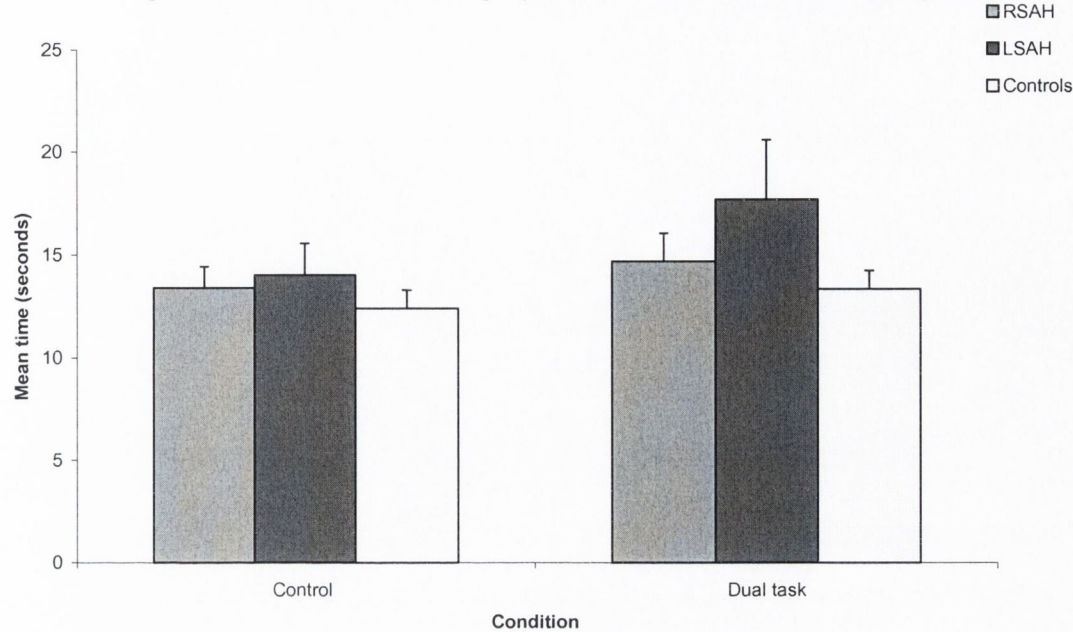


Figure 3.39f: Mean time taken for males and females on each condition of the Circular Trajectory Task.

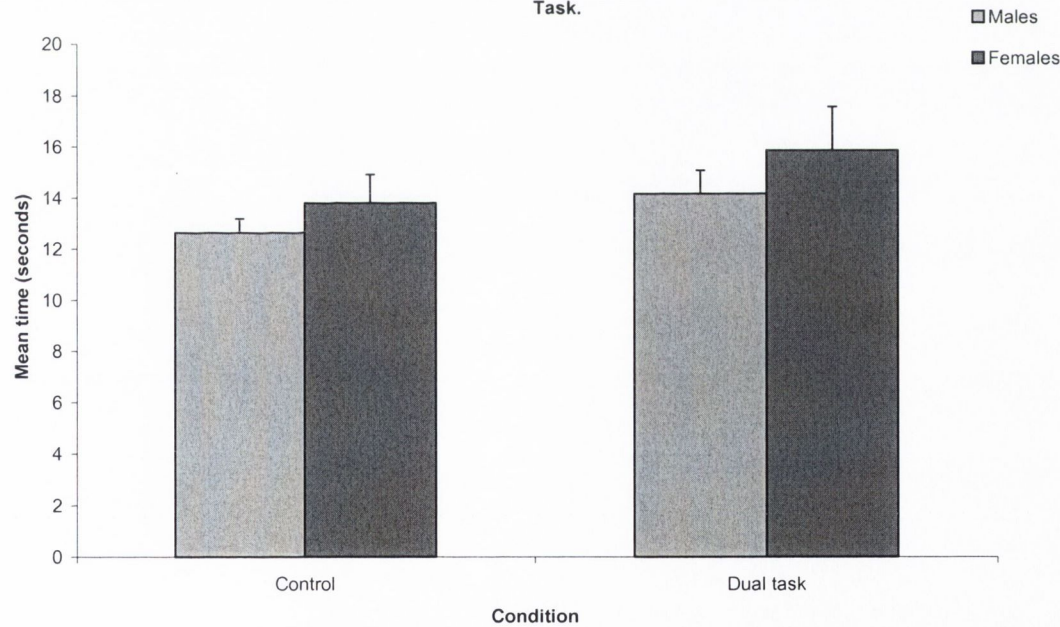
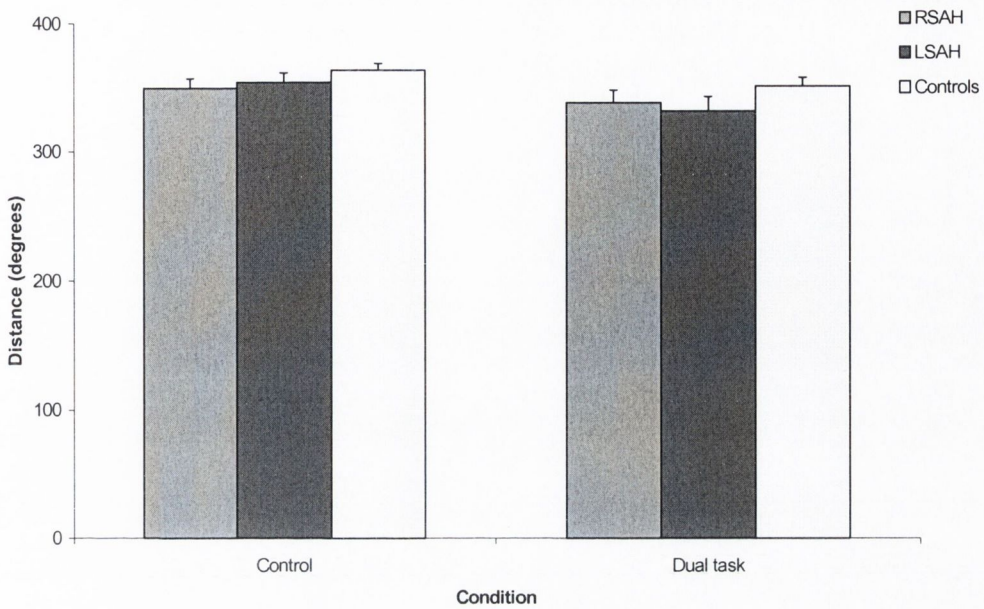


Figure 3.40a: Mean distance walked by each group in the Circular Trajectory Task.



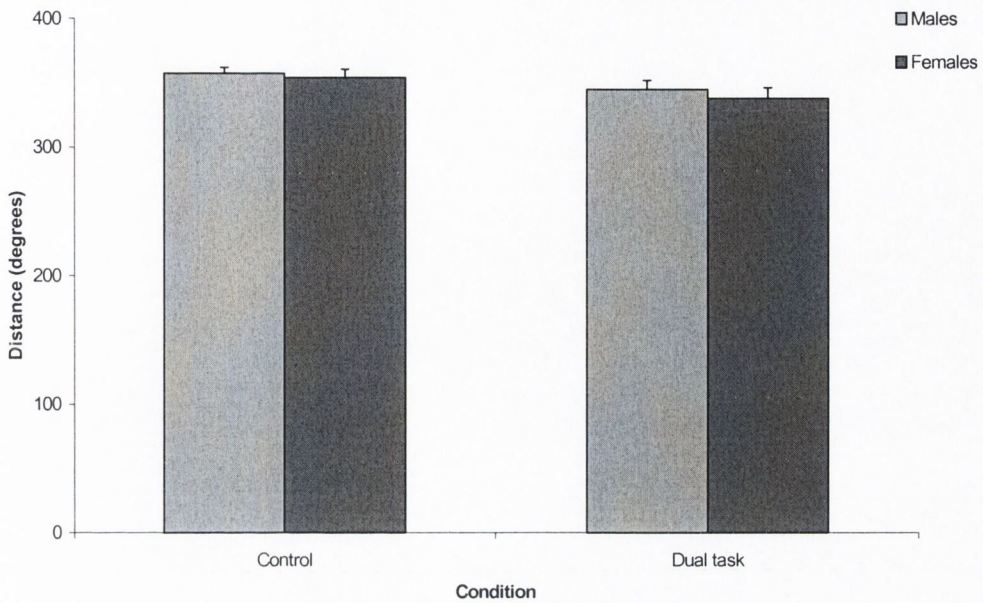
Overshoot/undershoot

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = .937, p > .05$; Group dual task condition: $F(2,43) = 1.282, p > .05$; Gender control condition: $F(1,43) = 1.258, p > .05$; Gender dual task condition: $F(1,43) = .508, p > .05$]. The interaction between the factors was not significant in either condition [Control: $F(2,43) = .141, p > .05$; dual task: $F(2,43) = .119, p > .05$].

Time Taken

There were no main effects for Group or Gender in either condition [Group control condition: $F(2,43) = .360, p > .05$; Group dual task condition: $F(2,43) = 1.218, p > .05$; Gender control condition: $F(1,43) = .583, p > .05$; Gender dual task condition: $F(1,43) = .454, p > .05$]. The interaction between the factors was not significant in either condition [Control: $F(2,43) = .870, p > .05$; dual task: $F(2,43) = 1.308, p > .05$].

Figure 3.40b: Mean total distance walked by males and females in the Circular Trajectory Task.



3.34 Synthesis of overall results

The final section of this chapter contains the results of a factor analysis. This statistical procedure was used to explore the connections between the many different tasks administered to participants. The main rationale for choosing factor analysis is the underlying assumption that the mathematical factors represent latent variables i.e. particular psychological dimensions, which can only be appropriately named and explained by examining the nature of tests that load significantly onto them.

With regard to the tasks used in this study, it is clear that they fall primarily into two broad categories, the ‘memory’ category and the ‘landmark/spatial’ category. However, it is not yet clear whether there are other categories which have associations with both of these factors. Thus, in order to explore this possibility, the data were subjected to one final analysis.

Stages in the factor analysis

In the first stage of the analysis, a correlation matrix of all the possible pairings of the tasks and variables shown in Table 3.33 was performed. The second stage involved the extraction of the factors; this was achieved through a sequence of substages, each of which will be discussed in turn.

Table 3.33: The tasks and variables that were used in the factor analysis.

‘Memory’ category tasks	‘Landmark/spatial’ category tasks
Memory Rating Scale	Dublin Familiarity Scale
Cognitive Failures Questionnaire	Landmark Recognition Task
Everyday Memory Questionnaire	Landmark Location Task
Mundane Memory Questionnaire	Pointing Task
Interview Study (total number of basic activities recalled)	Living in Dublin/not living in Dublin
Percentage of language errors	Route Description Task
	Vividness of Visual Imagery Questionnaire (eyes opened)
	Vividness of Visual Imagery Questionnaire (eyes closed)

Extraction of the factors

The first part of the extraction involved the construction of the table of variable communalities, which is shown in Table 3.34 below. This table displays the communalities assigned to the variables by the factor analysis. The communalities are the squared multiple correlations (R^2) between the variables and the factors emerging from the factor analysis. They represent the proportion of the variance of the test that is accounted for by the factors. From the communalities shown in the table below, it is clear that 94.8% of the variance of the scores on the Landmark Location Task is accounted for by the factors, whereas for the Interview Study, the factors that have been extracted explain only 69.2% of the variance.

The second stage in the extraction proceeds with the construction of a table showing the initial eigenvalues and the how they affect the total variance for each test. In this way, the eigenvalues determine which factors remain in the analysis and following the Kaiser criterion, factors with an eigenvalue of less than 1 are excluded. In this case, as shown in Table 3.35 below, factors 6-14

are omitted from further analysis. From this table, it appears that five factors have been extracted from the analysis and that the proportions of the total test variance accounted for by these factors is 80.16%.

Table 3.34: Variable communalities

Variable	Extraction
Memory Rating Scale	.777
Cognitive Failures Questionnaire	.810
Everyday Memory Questionnaire	.744
Mundane Memory Questionnaire	.800
Interview Study	.692
Percentage of language errors	.770
Dublin Familiarity Scale	.726
Landmark Recognition Task	.754
Landmark Location Task	.948
Pointing Task	.799
Living in Dublin/not living in Dublin	.897
Route Description Task	.711
Vividness of Visual Imagery Questionnaire (eyes opened)	.912
Vividness of Visual Imagery Questionnaire (eyes closed)	.883

The extraction of five factors is graphically displayed in the Scree plot shown in Figure 3.41 below. This plot shows the eigenvalue of each component/factor extracted. It is clear that the amount of variance accounted for successive components declines steeply as successive factors are extracted. It can also be seen that the ‘scree’ begins to appear between the fifth and sixth factors. Component 6 has an eigenvalue less than 1; and therefore only the first five components have been retained.

The rotated factor matrix

Now that the five factors have been extracted from the analysis, the matrix of correlations between the tasks and the factors is rotated in order to maximise the relationships between some tasks and factors and to minimise association with others. The rationale for this procedure is to facilitate interpretation of the factors and in doing so, to make it easier to give them psychologically meaningful labels. In this case, the varimax rotation method, which maintains independence among the factors, was used.

Table 3.35: Initial eigenvalues extracted using the principal components method.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.825	27.324	27.324
2	2.568	18.343	45.667
3	2.032	14.518	60.185
4	1.597	11.408	71.593
5	1.200	8.571	80.164
6	.661	4.725	84.889
7	.506	3.616	88.505
8	.424	3.029	91.533
9	.386	2.758	94.292
10	.311	2.220	96.511
11	.215	1.539	98.050
12	.130	.927	98.977
13	.089	.637	99.614
14	.054	.386	100.000

Figure 3.41: Scree Plot of eigenvalues for each component extracted.

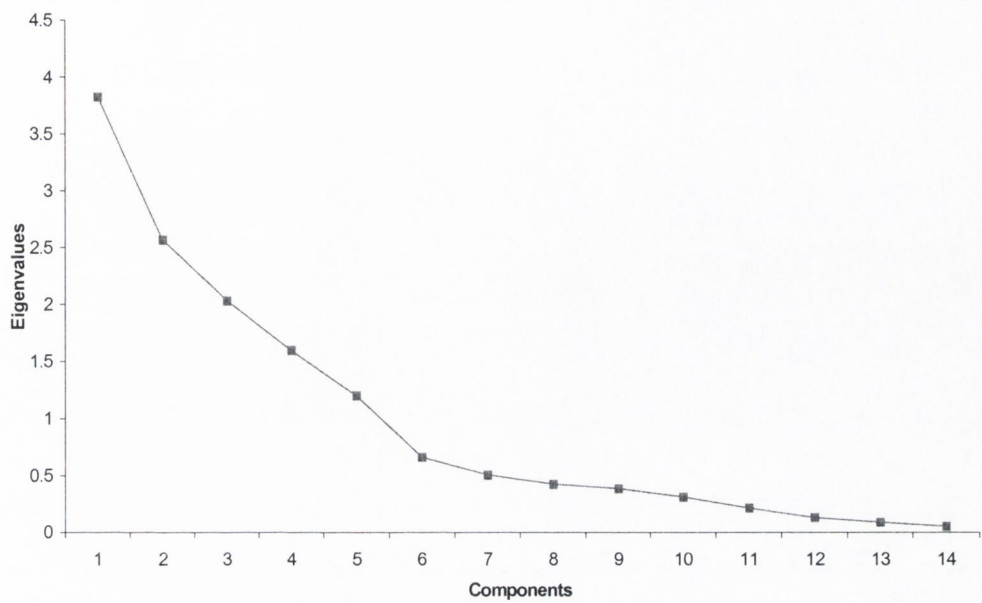


Table 3.36: The results of the varimax rotation method.

Variable	Component				
	1	2	3	4	5
MRS	.176	.853	.115	.069	.026
CFQ	.126	-.888	-.058	-.023	-.048
EMQ	-.044	-.833	-.048	.053	.207
MMQ	.103	.581	.672	-.022	-.056
Interview Study	.363	.103	.728	.127	-.054
% Language errors	.141	-.145	-.743	.185	.378
DFS	.656	.354	-.292	.087	-.280
Landmark Recognition	.792	.095	.132	.226	-.222
Landmark Location	.901	-.025	.179	.033	.321
Pointing Task	-.853	.083	-.240	.048	.073
Living in Dublin	-.164	-.050	-.090	.097	.922
RDT	.267	-.085	.670	-.047	.426
VVIQ (eyes opened)	.045	.078	.163	.939	-.043
VVIQ (eyes closed)	.105	.021	-.257	.881	.169

In the above table, the highest loadings on each of the five factors are shown in bold. It is now possible to examine the nature of the tasks which share high loadings on particular factors. For example, taking the first factor, it is evident that four of the fourteen tasks used in the analysis show high loadings onto this component. On closer inspection, it can be seen that what these tasks have in common is that they are essentially 'landmark' tasks i.e. measure the ability to recognise and locate Dublin landmarks. A plausible label for this factor, upon which these tasks are highly loaded, could be 'Knowledge of Dublin Landmarks'.

Turning to Factor 2 in the above table, it is clear that the tasks which load highly onto this factor comprise the three different memory questionnaires that were used in the study along with the Memory Rating Scale. What is surprising however, is the finding that the Interview Study score does not load highly onto this factor. Bearing this in mind, a possible label for Factor 2 could be 'Memory Questionnaire Ability'.

Moving on to Factor 3, from Table 3.36, it is clear that four tasks load highly onto this factor. These tasks are the Mundane Memory Questionnaire, the Interview Study score, the percentage of language errors made and the score on the Route Description Task. At first glance, the pattern to these loadings may not be immediately apparent, but on closer inspection it is clear that what these tasks have in common is that they measure some form of language ability, either written, as in the Mundane Memory Questionnaire and the Route Description Task, or spoken as in the Interview Study from which the percentage of language errors emerged. Therefore, the most appropriate label for Factor 3 is 'Language Ability'.

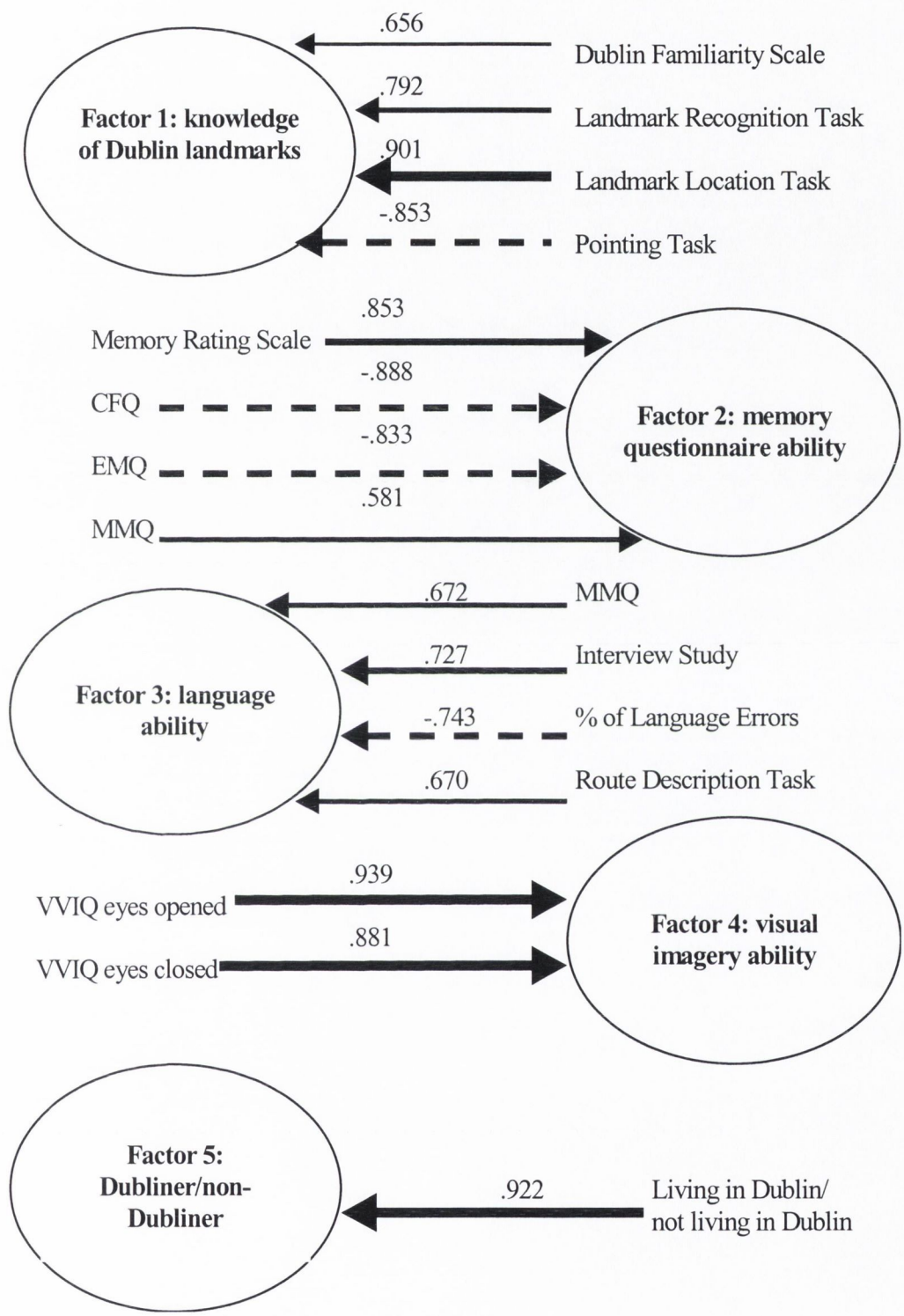
Factor 4, as can be seen from Table 3.36, shows high loadings with only two of the tasks, both of which are part of the same questionnaire, the VVIQ. Thus, the most appropriate label for Factor 4 would be what this questionnaire purports to measure, Visual Imagery.

Finally, there appears to be only one variable that loads highly onto Factor 5, the measure of whether the participant was living in or outside Dublin. Since no other task loads highly onto this factor, the most fitting label for this component would be Dubliner/non-Dubliner.

In summary, the factor analysis procedure yielded a five-factor model, which has been given the following labels:

- Knowledge of Dublin Landmarks
- Memory Questionnaire Ability
- Language Ability
- Visual Imagery Ability
- Dubliner/non-Dubliner

Figure 3.42: Path analysis of the Five-Factor Model



CHAPTER 4 - DISCUSSION

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4.1 Introduction

This thesis aimed to determine whether or not impairments in spatial representation, episodic memory and discourse production could be found among a group of post-operative unilateral selective amygdalohippocampectomy patients using a variety of valid novel tasks. A secondary aim concerned the nature of the deficits and the interaction between them. The third aim of the study was to integrate these findings with those obtained from previous investigations, and in doing so, to examine how the results obtained here could be best explained in the context of current theories of hippocampal functioning.

From the detailed analyses of the data that were conducted in the previous chapter, it is evident that the main hypotheses of the study were supported. In brief, the deficits exhibited by the LSAH and RSAH patients relative to the normal control participants on tasks measuring episodic memory, spatial representation and discourse production provide strong support for the first three hypotheses. Finally, the absence of a group effect on any of the spatial navigation tasks examining route reproduction is highly consistent with the predictions of the fourth and final hypothesis.

In order to coherently structure the remainder of this chapter, the following format will be applied. Firstly, the results pertaining to both of the validation studies will be discussed. Subsequently, the findings of the main study will be discussed in relation to the support they provide for each of the four hypotheses. This discussion will establish important links between the data obtained here and the body of literature arising from previous research. The contribution of the results of the present study to the current understanding of hippocampal functioning will also be emphasised, and a critique of the methodological aspects of the study will be presented. Finally, the implications of the findings of this study for future research into spatial representation, episodic memory and discourse production will be addressed.

4.2 Memory Questionnaire Validation Study

The data from the first part of the Memory Task Validation Study yielded six main results. Firstly, a consistent decline in recall was observed over each of the four days. Secondly, the type of MMQ (i.e. random order or structured) that was administered to participants did not affect their performance. Thirdly, although the gender of the participants did not affect performance on either the MMQ or the EMQ, a significant gender effect was observed on the CFQ. Fourthly, there was no gender difference in the participants' self-ratings of memory on the Memory Rating Scale. Fifthly, the CFQ, MMQ and the MRS were found to be strongly inter-correlated. Finally, the results of an item-analysis of the MMQ revealed a high level of reliability. Each of these findings is now discussed in turn.

4.2.1 Type of MMQ

The observation that the type of MMQ administered did not affect participants' scores on this task was important in demonstrating that presenting the items in a temporal order did not enhance recall. Participants who received the items in a random format performed at the same level as those who completed questionnaires that were organised in a morning to evening sequence.

4.2.2 Decline over the four days

Performance on the MMQ was shown to decline as the number of days between recall and the occurrence of the events was increased (see Figure 3.5). The absolute and relative declines over the four days are shown in Figures 3.6a and 3.6b respectively. In Figure 3.6b, the percentage of details retained between the time-interval of Yesterday and Four Days Ago drops by approximately 20% for both males and females.

This observation of a decline in the number of specific details recalled over each of the four days is consistent with previous research (e.g. Rubin and Baddeley, 1989), showing that retention is greater for recent events. Larsen and Thompson (1995) proposed that the day of the week was reconstructed by reference to a temporal week schema, based on personal experiences. Errors

were thought to occur due to a process of guessing. The results obtained here also imply that individuals are capable of using a variety of temporal schemas to ascertain when events occurred and to establish the details of these episodes. For example, the routine of working appeared to have acted as a powerful retrieval cue in facilitating the retrieval of specific details of a particular day's events. In addition, other items on the MMQ asking about watching TV, meeting friends and doing shopping could also have been influential temporal schemas, that served to organise when it was that particular events occurred. The schedule of programmes on TV is a particularly good example of how the use of such schemas can aid the process of episodic recollection for other events in the day.

Thus, there appear to be a number of ways by which Tulving's (1999) concept of autonoetic consciousness may be established. For example, Huttenlocher et al. (1992) stated that individuals represent the time of occurrence of events in terms of several distinct temporal schemas, for example daily and weekly scripts. They also proposed that such scripts were hierarchically organised in that the weekday period forms a temporal unit in memory. The results obtained using the MMQ concur with this assertion in that the items it contains appear to be important components that make up an individual's daily script. Within this daily schema, these items could act as sub-scripts e.g. the work script, lunch script, or housework script that serve as powerful tools for organising the episodic recollection of the day's activities.

4.2.3 Gender effect on the CFQ

Figure 3.1a shows the mean scores obtained by males and females on the CFQ and MMQ. From this graph, the significant difference between the male and female performance on the CFQ can be seen, with females tending to have higher scores on this measure compared to the males. This observation is consistent with the results obtained by Pollina et al. (1992) in their investigation of the dimensions of everyday memory among a group of 180 male and 207 female college students. They found that overall, females reported a greater number of cognitive failures compared to their male counterparts. Further analyses of this data, using principal components,

revealed significant gender differences for three of the five factors, with females reporting a higher incidence of cognitive failure than males in distractibility and spatial/kinesthetic memory. Interestingly, males showed a significantly greater frequency of cognitive failures than females in memory for names.

Although the findings of the present study provide support for those obtained by Pollina et al. (1992), it must be noted that the level of agreement is with regard to the overall tendency of females to score higher on the CFQ as compared to males. Since the focus of this validation study was on the MMQ and its reliability as a questionnaire, no further statistical analyses were carried out on the data obtained on the CFQ. Therefore, from the results obtained here, it is not possible to determine the precise gender differences between the underlying dimensions of the scale.

4.2.4 Memory Rating Scale

The finding that no gender differences were observed in the self-ratings obtained on the MRS shows that females did not consider themselves to have a higher level of memory functioning than males. This result is reflected in the similar level of performance shown by males and females on the MMQ.

4.2.5 Correlational Analyses

The Path Model contained in Figure 3.3 shows the strong inter-correlations between the CFQ, MMQ, and MRS. The significance of these correlations implies that external validity exists between self-reported memory status and the type of memory measured in both the MMQ and CFQ. It also implies that perception of one's own judgment of one's memory ability is a good predictor of performance on both the CFQ and the MMQ. More than half of the participants (230 out of the total of 422 i.e. 54.5%) rated their memory as being 'good', and this was reflected in their scores on the CFQ and MMQ. A significant negative correlation between the CFQ and age was also noted. However, this result is not inconsistent with previous research. For example, Pollina et al. (1992) examined administered the CFQ to a large number of college students and found that a distractibility factor accounted for their high

scores on this task. They suggested that attentional processes were important components of the everyday memory construct among young adults.

4.2.6 Interview Study

The Interview Study was carried out with a subset of twenty-one participants from the main sample. Analysis of the data recorded during this study revealed a number of important results. Regarding the mean number of basic activities recalled, it was found that significantly fewer activities were recorded for last week compared to the other days (i.e. Typical and Yesterday). This finding is consistent with those obtained on the MMQ; most notably the observation of decreased retention with increasing time. These results also concur with those of Rubin and Baddeley (1989), who found greater retention for more recent events. These data also support those obtained by Eldridge et al. (1994) when they reported that participants in their study recalled fewer activities from last week than they did from yesterday.

As a possible explanation for the differences in the recalls of yesterday and last week, Eldridge et al. proposed that people are not actually remembering their activities of last week, but are simply reconstructing their typical day's activities. This implies that they are trying to apply their daily schema to a day in the previous week but what may be missing is the richness of the details provided by autonoetic consciousness. There was no difference in the recalls for a Typical Day or Yesterday, suggesting that both the daily schema and autonoetic consciousness factors were operating most successfully over briefer time intervals.

A second observation was that the order of presentation of the interviews did not affect participants' recall on this task. This result is also consistent with Eldridge et al.'s findings. However, both studies contained a small number of participants and thus the findings must be considered in this context. Thirdly, the gender of the participants did not affect performance in the interview and this observation is also consistent with that the findings obtained on the MMQ. However, it must be taken into account that each participant in the Interview Study was a student in T.C.D., which is suggestive of similar daily

routines for both the male and female participants i.e. travelling to college, attending lectures, going to the library and so forth.

Fourthly, a significant correlation between participants' self-rating of memory using the MRS and their performance in the Interview Study was observed. When considered in relation to the CFQ and MMQ, (as shown in Figure 3.9), it can be seen that the MRS appears to be the best predictor of performance on all three tasks, the CFQ, the MMQ and the Interview Study. This finding suggests that among the sample of participants in this study, perception of one's own memory ability is the best predictor of performance on each of these tasks. It also implies that the participants in this study had good insight, and were generally accurate in their judgement of their memory abilities.

4.3 Landmark Task Validation Study

The results of the second validation study will now be discussed, taking each of the specific tasks in turn.

4.3.1 Landmark Recognition and Landmark Location Tasks

Analysis of the data from the Landmark Recognition and Landmark Location tasks yielded a number of important findings. Firstly, there was a high level of performance on both tasks with most participants recognising at least six of the seven landmarks and, in the location task, successfully locating at least four out of the five landmarks. Secondly, no gender differences were found in performance on either task. Thirdly, there was no difference on either task in the performance between participants who were born in Dublin compared to those who were born outside of the capital. Fourthly, neither the age of the participants nor the order of presentation of the tasks was shown to affect the results.

4.3.2 Lack of a Gender effect

With regards to the first observation concerning the lack of a gender effect on the Landmark Recognition and Location tasks, this finding is not consistent with previous studies (e.g. McBurney, 1997) which have shown a female advantage in the recall of landmarks and the association of objects with a

particular location. The findings observed on the Landmark Location task also differ from those observed by McGuinness and Sparks (1983), who reported that men were more accurate than women in geometric placement of buildings on a map. In contrast, these results suggest that both male and female participants were equally capable of recognising and locating these landmarks. If sex differences exist in how males and females represent space, as suggested by Sandstrom et al. (1998), then in the context of these tasks, there was no advantage in adopting one strategy over another, since the results were equivalent.

The fact that participants who were born in Dublin did not show increased performance on these tasks is important since it suggests that these landmarks were not more salient to Dubliners; individuals who were born outside of the city were equally successful in recognising and locating these buildings. Similarly, the age of participants was without effect. Both findings suggest that these Dublin landmarks could be considered as National Landmarks. Support for this idea comes from the abundance of research which has stressed the importance of landmarks in organising spatial information, assisting wayfinding and facilitating the construction of a cognitive map (e.g. Golledge, 1999; Couclelis et al., 1987). The results are also consistent with the findings of Daniel and Denis (1998) demonstrating the high dependence on landmarks when describing routes and concluding that landmarks were selected on the grounds of visibility, pertinence, distinctiveness and permanence. Each of these characteristics could be applied to the landmarks used in this study, leading to their acquisition on a national level.

The lack of an order effect with regards to task presentation is interesting because it implies that participants who could be considered to have been 'primed' via presentation of the Landmark Recognition Task before the Location Task did not perform better than those who completed the Location Task first. This suggests that for the present sample, the Landmark Location Task was not more difficult or challenging compared to the Recognition task.

4.3.3 Dublin Familiarity Scale

Two key findings emerged from the analysis of participants' self-ratings on the Dublin Familiarity Scale. Firstly, there was no difference in the ratings of males and females on this scale. This finding is consistent with the participants' performance on the Landmark Recognition and Location Tasks, which failed to show any gender difference, as described above.

Secondly, there was a significant difference between the ratings of participants who were born in Dublin compared to those who were not. However, this difference was in an unexpected direction, with the Dublin-born participants rating themselves as less familiar with the city centre than those who were born outside of Dublin. At first glance, this finding may seem strange, but it is important to note that many of the participants who were not born in Dublin, were living in Dublin for a number of years and had evidently become very familiar with the city centre during this time. This observation is also consistent with the research of Golledge (1978), who compared the cognitive maps of newcomers to a city to those who had been there for two years or longer. A significant relationship between the frequency and length of exposure to the environment and the level of accuracy in recalling its landmarks was found. These observations also concur with Tversky's (2000) idea that newly acquired cognitive maps consist of declarative knowledge, which over time, becomes transformed into procedural knowledge.

4.3.4 Route Description Task

Analysis of the RDT data revealed a number of results. Firstly, there was no effect of gender on either the overall score or word count. Secondly, there appeared to be an age effect on the overall score, but upon closer inspection, this effect was not significant across each of the four questions.

4.3.5 Lack of a Gender effect

Regarding the first observation, namely the absence of a gender difference on either overall score or word count, this result is important in supporting this researcher's early claims concerning the strategies used by males and females in constructing spatial representations of the environment. As proposed by

previous researchers, males and females may represent space in different ways. However, the evidence presented in this study implies that there is no advantage of one particular strategy over another when performing the tasks presented here. These results are at odds with previous studies which have found that men had a better sense of direction than women (e.g. Brown et al., 1998; Roskos-Ewoldsen et al., 1998) and that men were more accurate using cardinal reference points to five directions (Ward et al., 1986). Neither do they accord with the significant female advantage in visual information processing reported by McBurney et al. (1997). However, what is important to note is that these previous studies, with the exception of that carried out by McBurney et al., focused on real-world navigation and wayfinding abilities, whereas this task constituted a novel, 2-D virtual map of an environment, presented as a table-top task. Thus, the similar performance of males and females in this RDT is an important observation and contributes significantly to the literature in this area.

4.3.6 Landmark Pointing Task

The results of the Landmark Pointing Task also provided evidence against a gender advantage in spatial representation abilities for males and females performed equally well on this task. Furthermore, there was no difference in performance between those participants who were born in Dublin compared to those who were not. It was also noted that the participants in this sample were able to point to the location of the various different landmarks with a good deal of accuracy. This supports the findings of earlier research by Sholl (1987, 1996) and Thorndyke and Hayes-Roth (1982), who demonstrated that humans could point successfully to unseen but familiar locations in space. It also provides the first confirmation of the results obtained by Nangle and O'Mara, who designed and originally used this task in patients with right parietal lesions arising from CVA.

Furthermore, these findings are consistent with the idea that cognitive maps are inherently flexible in that they preserve the object-to-object relations of the real world independently of any change in perspective from real or imagined locations (Thinus-Blanc and Gaunet, 1999). They are also in

accordance with the tenets of viewpoint dependence theory (King et al., 2002; Burgess, 2002; Burgess et al., 2002) This would explain the rapid updating that was required in this task, when shifting from one anchor landmark to another. When considered in the context of the findings obtained on the previous tasks, this result adds further support to the assertion that landmarks are important in the building of spatial representations of environments (Poucet, 1993; Peruch et al., 2000). Finally, the second observation, regarding the absence of a 'native Dubliner' effect, supports the statements made suggesting that these landmarks were nationally acquired as opposed to being well-known by those participants who were born in Dublin.

4.3.7 Links between the tasks

From the Path Model presented in Figure 3.14, it is clear that participants' ratings of their familiarity with Dublin's city centre was a good predictor of their performance on both the Landmark Recognition and Landmark Location tasks, but surprisingly not on the Landmark Pointing Task. It is also evident that these three tasks are highly inter-correlated which is not surprising considering they all involve the same set of landmarks.

4.4 The contribution of the validation studies

The results obtained in these two studies provide valuable normative data on the novel episodic memory and spatial representation tasks. The high level of reliability of the MMQ is extremely encouraging and suggests that this questionnaire is a good measure of episodic memory within a particular temporal context, among a normal population. The findings on the MMQ are also consistent with previous research documenting a decline in recall over increasing time intervals. Furthermore, as discussed in a later section, these observations can also be explained by the results of previous literature on autoegetic consciousness and the role of self-schemas in organising personally-relevant information.

The results from the second validation study are also significant in that they refute previous arguments that have supported a gender difference in the performance of males and females on tasks measuring various different real-

world spatial abilities. In particular, the findings of the Landmark Pointing Task provide the first confirmation of Nangle's original observations.

4.5 Limitations of the validation studies

The first limitation with the memory questionnaire validation study is that all 422 participants who completed Part I, should ideally have gone on to complete the interview study. This would have allowed a more thorough comparison of the results obtained in both parts of the study. Unfortunately this was not feasible for a number of reasons, with the main one being that a large number of the participants did not agree to take part in the Interview Study or else they were unavailable at the time when it was being conducted.

The specific limitations associated with the MMQ will be discussed in a later section, but turning to the Interview Study, the main methodological limitations associated with this task were the small sample size and the use of college students as participants. However, it must be stated that in the original study by Eldridge et al. (1994), upon which this current study was based, a sample of only twelve participants, who all worked in the same engineering company was used. Thus, although the current study shows an improvement regarding participant numbers, the tendency to rely on opportunistic sampling means that the results cannot readily be applied to the general population.

Regarding the second validation study, a similar argument can be made as once again it would have been desirable to assess the performance of each of the 185 participants from Part I of the study on the Landmark Pointing Task in Part II. However, this was not possible for reasons similar to those outlined above.

Finally, the main overall implication for the future replication of this study is that ideally, one large sample of participants should be required to complete both parts of the two validation studies. This type of experimental design would allow the simultaneous measurement of both episodic memory and spatial representation and would lead to more accurate comparisons regarding

the between-subjects factors (e.g. Gender, born in Dublin etc.) and the within-subjects factors (i.e. the episodic memory/spatial representation tasks).

4.6 Main Study

The results obtained in the main study will now be discussed. In the interests of following a coherent structure, this discussion will be organised into four main parts, with the four hypotheses forming the divisions between the different sections. The results pertaining to each hypothesis are discussed in turn.

4.6.1 Hypothesis 1

The first hypothesis predicted that on tasks of everyday memory, both patient groups would show impairments relative to the normal controls. Furthermore, the left-resected group will show a greater level of impairment compared to the right-resected group. It is clear from the analysis of the data pertaining to these tasks that this hypothesis was supported. A more detailed account of the results in relation to this hypothesis will now be presented.

4.6.2 Questionnaire results

The results obtained on the CFQ, EMQ and MMQ yielded a number of important findings. Firstly, there was a significant Group effect on both the EMQ and the MMQ. For the EMQ, the difference between the LSAH group and the Controls was significant; the RSAH group did not show significant impairments on this task.

Analysis of the MMQ data showed that both the LSAH and RSAH groups were significantly impaired relative to the controls. This is a very important finding since it shows that this novel survey was sensitive to the memory impairments of both patient groups. What is also of significance is the fact that this questionnaire focuses specifically on recollecting the actual detail of the event. This is very different from the types of questions contained in the CFQ and EMQ, which involve rating how often lapses in memory occur over extended periods of time. It was also noted that the LSAH and RSAH groups

did not differ significantly from each other in performance on either the EMQ or the MMQ. In contrast, no group effects were found on the CFQ.

The second main finding was that both the CFQ and the EMQ required patients (with memory problems) to answer questions which ask them to rate how frequently they have difficulties, or lapses in memory. This may not be the most valid way of ascertaining memory impairments as the effects of these deficits may prevent patients from accurately being able to complete these questionnaires. For example, one item on the CFQ asks patients to rate how often they forget appointments over a six-month period. A patient experiencing memory difficulties may not remember having had any appointments in the last six months and thus, would not be in a position to accurately state whether or not they had forgotten these arrangements.

A similar case can be made against a number of the items contained in the EMQ, although the time interval in question is over a three-month period. Thus, if the patient cannot recall the most recent time when such a lapse in memory occurred then they probably will not be able to accurately rate the frequency with which such lapses occur over a longer time period.

4.6.3 Memory Rating Scale

The participants' scores on the MRS lend support to the above arguments as the analysis of their ratings showed that there was no difference between the ratings of either patient group relative to the controls. It can also be seen that none of the participants in any of the three groups rated their memory as being 'very good'. This is an important observation as it suggests that overall, the patients may not have been aware of their memory difficulties, and lacked insight into their current level of memory functioning. However, the subjective complaints of a number of patients, which are discussed in a later section, must be taken into consideration as they provide a strong counter-argument to this claim, implying the existence of a large individual variation within each patient group.

4.6.4 Correlations between the tasks

From the Path Model contained in Figure 3.19 it is clear that the participants' self-ratings of memory on the MRS remain a good predictor of their performance on the questionnaires. What is also apparent is the high degree of inter-relatedness between the CFQ, EMQ and MMQ, which supports the findings observed in the first validation study discussed earlier. These significant correlations also strengthen the validity of the MMQ as an assessment tool.

4.6.5 Specific MMQ analysis

The results of the analysis of participants' performance over each of the four days on the MMQ showed that for each day, both the LSAH and RSAH group recalled significantly fewer details compared to the Control group (as shown in Figure 3.20). However, although the difference between the LSAH and RSAH group was not significant for three of the four days of recall, the LSAH group consistently recalled fewer details than the RSAH group, providing further support for Hypothesis 1.

Figures 3.21 and 3.22 show the absolute and relative decline in recall on the MMQ respectively, and lend further support to this hypothesis. From these graphs it is clear that both patient groups are performing at a consistently lower level relative to the control group, with the LSAH recalling the least amount of personally-relevant episodic information and showing the most rapid decline in retention of this type of material.

From Figure 3.22 the adverse effects of an increasing time interval on the ability to recall such events is particularly evident. Whereas the control participants experience a decline of only 20% over the four days, thereby retaining over 80% of their episodic knowledge over this time period, the LSAH group show a 20% decline between the first Yesterday and 2 days ago. By 4 days ago, they have retained just over 60% of their personally-relevant episodes. Their performance also contrasts with the intermediate level of retention shown by the RSAH group.

Interestingly, the retention levels of the control participants in this study are equivalent to those observed among the healthy participants who completed the MMQ in the first validation study, discussed earlier. Correlational analyses of the level of retention of personally-relevant episodic information for each of the four days of recall (as depicted in the Path Model in Figure 3.23), revealed a highly significant association between the number of details recalled on each day of the MMQ.

4.6.6 Lack of a gender effect on the CFQ, EMQ or MMQ

The finding that the between-subjects factor of gender did not affect performance on any of the questionnaires in this study is consistent with the results obtained in the Memory Questionnaire Validation Study concerning the EMQ and MMQ. However, regarding the CFQ, the lack of a gender effect in the main study does not accord with the significant gender difference observed in the validation study, where females tended to score higher than males on this measure. This discrepancy may partly be explained by the large difference in sample size between the two studies.

4.6.7 Interview Study

The results obtained from the Interview Study lend further support to Hypothesis 1 in that both patient groups were significantly impaired relative to the controls in their recall of personally-relevant activities. This deficit in performance was shown to be robust as for each of the three days (Typical Day, Yesterday, Last Week), both patient groups recalled significantly fewer personally-relevant activities compared to the control group. The finding that the LSAH group was the most impaired on this task is also consistent with the predictions of Hypothesis 1. Additional support for this hypothesis arose from the observation that for 'Last Week', the LSAH group were significantly impaired relative to both the RSAH and control groups in their level of recall of personally-relevant activities.

This finding is also consistent with the poorer retention levels demonstrated by the LSAH group on the MMQ discussed above. Finally, it was also observed that across all participants, significantly fewer personally-relevant

activities were recalled for 'Last Week' relative to the other two days; the difference in recall between a 'Typical Day' and 'Yesterday' was not significant.

4.6.8 Support for Hypothesis 1

From the above discussion it is clear that the predictions set out in Hypothesis 1 have been consistently supported by the data obtained in this study. The robust impairment in performance of both patient groups, but particularly the LSAH group on the EMQ and MMQ is consistent with this hypothesis.

4.7 Links with previous research.

The results obtained here are also supportive of previous research in this area, including the Memory Questionnaire Validation Study discussed in the previous section. The Interview Study results support those obtained by Eldridge et al. (1994) in that fewer activities were recalled from 'Last Week' compared to 'Yesterday'. In addition, the difference between the number of activities recalled among control participants in both the validation study and the main study is consistent with Eldridge et al.'s assertion that the primary feature of the daily schema was the degree of elaboration. This suggests a high level of individual difference among normal participants. However, as mentioned above Eldridge et al. assessed only twelve participants in their study, whereas this thesis contained interviews recorded from a total of forty healthy controls.

4.7.1 Failure to find group effects using the CFQ

The lack of a significant Group effect on the CFQ is consistent with a recent study by Miotto et al. (2000), who also reported a failure of the CFQ to distinguish between left and right TL patients and controls. It may be that the types of questions contained in the CFQ affects the sensitivity of this task as it is important to note that this survey measures a variety of behavioural or cognitive lapses, and does not exclusively focus on memory difficulties.

4.7.2 Group effects on EMQ

This finding is consistent with the results observed by Miotto et al. (2000) who administered the EMQ to assess memory functioning in right and left frontal and temporal lobe patients. They found that this survey was sensitive to memory lapses in all patient groups. However, the RT group in their study were found to be more impaired than the LT group, a reversal of the results obtained with this sample.

The EMQ thus appears to be sensitive to the impaired memory performance of both the RSAH and LSAH groups relative to the controls. A possible explanation for this could be the inclusion of a broader rating scale, as compared to the CFQ, which would have been more sensitive to individual variation in performance. These findings may also be attributed to the way in which the EMQ focused more specifically on memory for everyday activities i.e. the type of episodic memory that Hypothesis 1 predicts would be most adversely affected by damage to the left hippocampal formation. In contrast, only five of the twenty-seven items specifically addressed visuo-spatial aspects of memory functioning. This may explain why the EMQ failed to detect a difference between the RSAH and the controls.

4.8 Overall impaired performance of patient groups

In the following section, the impaired performance of the patient groups on these memory tasks will be discussed in the light of different ideas that have emerged from previous literature.

4.8.1 Self-reference and self-schemas

The poor performance of the patient groups on each of these memory tasks may be explained in terms of impairments in their self-schemas (Rogers et al., 1997), which fail to act as retrieval cues, thus inhibiting the recall of episodic information. If this is so, it could be suggested that the self-referred items, which were central to the MMQ and the Interview Study, failed to engage the self-schema and without this powerful organising tool, patients were unable to reconstruct their personal past events. Alternatively, it is possible that the self-schemas of these patients were so sparse that they did not serve any

beneficial function in structuring events as experienced by the individual on a daily basis.

In support of this assertion the following example is presented. On a number of occasions during the Interview Study, certain patients had particular difficulty in recalling any personal events from 'Last Week'. In such cases, asking the individual whether or not they could recall if they had been at work that day e.g. Friday of last week, failed to act as a retrieval cue; such patients were unable to recall whether or not they had worked on that day. This observation was particularly interesting since it would have emerged during the course of completing the earlier questionnaires that the individual did indeed work on Friday every week. However, when specifically asked about it in the context of episodic recall, the patient was unable to consciously recollect this self-relevant event. This would support Tulving's (1999) ideas concerning the uniqueness of episodic memory with regard to his autonoetic consciousness component, which in the case of these patients may have been compromised.

With regard to the idea of self-schemas, it could then be argued that in such cases, the routine of work, which may be well-integrated into the self-schemas of healthy controls may not be part of the self-schema of patients with particular episodic memory deficits. Thus, this impoverished self-schema would be of no use to them when trying to consciously recall their activities in the previous week. In this context and as suggested by Bower and Gilligan (1979), it may be that self-knowledge does not possess any special characteristics. The results obtained here also support the claims made by Klein and Kihlstrom (1986) when they asserted that organisation of the information was extremely important in predicting recollection. The impaired performance of the patients in this study may be partly due to poor organisation of their personally-relevant episodic information, which consequently led to their deficits in recall in both the MMQ and Interview Study.

4.8.2 Semantic/Episodic memory distinction

The example cited above is also interesting since it suggests a distinction between semantic and episodic memory. Being able to say that one works on Friday every week, without the additional component of autonoetic consciousness that is unique to episodic memory, implies that this statement has become part of one's semantic store. However, when specifically probed for personally-relevant details of this particular day in the Interview Study, the patients were unable to consciously recollect this same event when forced to do so in a context-dependent and temporally specific mode. This suggestion has strong links with the ideas expressed by Burgess and his colleagues (e.g. Burgess, 2002; Burgess et al., 2002; King et al. (2002) in their theory of viewpoint dependence.

It also accords with the plethora of previous research studies that have consistently demonstrated a dissociation between the semantic and episodic components of declarative memory among groups of normal participants (e.g. Henke, 1999; Conway and Rubin, 1993; Maguire and Mummery, 1999), and amnesic patients (e.g. Vargha-Khadem et al., 1997; Kapur, 1999; Viskontas et al., 2000; Rosenbaum et al., 2000). The findings of the MMQ and Interview Study reported here are also consistent with the results of studies focusing on the critical role of the hippocampal formation in subserving episodic memory (e.g. Tulving and Marowitsch, 1998; Burgess et al., 2002; Maguire et al., 2000). In particular, these data provide significant support for the specialised functions subserved by the left hippocampus (e.g. Maguire et al., 1999; Maguire et al., 2000b; Maguire and Mummery, 1999; King et al., 2002).

4.8.3 Laterality effects

The impaired performance of the LSAH and RSAH patients relative to the healthy controls on these tasks of everyday memory supports the predictions contained in Hypothesis 1. This observation is also consistent with the abundance of previous literature documenting episodic memory impairments following MTL resections for intractable TLE (e.g. Viskontas et al., 2000; Rosenbaum et al., 2000; Tulving and Markowitsch, 1998; Hermann et al., 1994). Although the majority of these studies have focused on the effects of

damage to the left hippocampal formation, Spiers et al. (2001) succeeded in demonstrating context-dependent episodic memory deficits in both left- and right- unilateral temporal lobectomy patients. The results of this study are in particular agreement with the data reported here as in both studies, the performance of the left-sided resected groups was poorer than that of the right temporal lobectomy group. These findings also show that the effects of hippocampal damage cannot be considered as strongly lateralised since both LSAH and RSAH groups were significantly impaired relative to the controls in this task (which may previously have been thought to have been mediated by the left MTL).

Thus, these results do not support the material-specific hypothesis of Saykin et al. (1992), which states that memory function is lateralised with cerebral function i.e. the left hemisphere regulates verbal memory with the right regulating visuospatial memory (in left language dominant individuals). This model predicts that left medial temporal lobe damage results in verbal memory impairment with preservation of visuospatial function and the converse following right-sided damage. The verbal component of this hypothesis predicts severe impairment only after left medial temporal lobe lesions; patients with right-sided lesions should be only minimally impaired.

In contrast, the observation of significant impairments among both patient groups relative to the control participants concurs with the findings obtained by Dobbins et al. (1998). In this study both unilateral left and right hippocampal patients were similarly and significantly impaired in the recall of passages, clearly a verbal memory task, a finding that was taken as evidence against a material specific deficit. This implies that the laterality of verbal memory is conditional on specific task demands in patients with damage to the medial temporal lobe systems (Saling et al., 1992).

In explaining their results, Dobbins et al. (1998) suggested that free recall tasks place heavy requirements on reinstating spatio-temporal context, and this may be why the right hippocampal patients showed significant deficits, despite some ability to benefit from inter-item associations between

exemplars encountered in the word-lists. In contrast, the left hippocampal patients would be at an even greater disadvantage because of an inability to generate either the inter-item or overall contextual associations of the verbal/semantic representations of the items contained in the word lists.

4.8.4 Support for Cognitive Map Theory

These results are consistent with the assertions of cognitive map theory (O'Keefe and Nadel, 1978) that relate episodic memory to the human hippocampus by suggesting that it stores the spatio-temporal context of personally experienced events, an idea that has been supported by Tulving (1983) and more recently by Burgess and colleagues' viewpoint dependence theory. The data reported in this study are also in accordance with a number of other theories of hippocampal functioning. For example, Redish's (1999) theory of reinstatement of context, which claims that in humans, the hippocampus subserves episodic memory via its ability to replay the context of previous events fits nicely with the present results. Other theories concerning the autoassociation properties of the hippocampus as proposed by Rolls and colleagues (e.g. Rolls, 1999; Rolls and Treves, 1998), and the ideas of representational flexibility of Eichenbaum and colleagues (e.g. Eichenbaum et al., 1994; Cohen and Eichenbaum, 1993; Eichenbaum and Cohen, 2000, 2001), may also be in accordance with the findings of this thesis.

These theories share the common premise that the hippocampal formation is responsible for integrating and instantiating the representations of events and their spatio-temporal contexts into a neural network (Good, 2002). The data do not specifically tie in with Baddeley's concept of 'episodic' buffer since he does not specify a role for the hippocampus in this process. The results obtained here also provide support for Burgess's suggestion that the left hippocampal involvement in episodic memory derives from its undoubted role in the encoding of verbal material such as word lists, narratives and paired associates, as has been widely reported. This verbal role may have its basis in a spatial domain (as hypothesised by Redish, 1999; Rolls, 1999; and Rolls and Treves, 1998). This idea is discussed in a later section.

4.8.5 Rapid forgetting

The rapid decline in retention in the patients' performance on the MMQ relative to the controls may be indicative of abnormally rapid forgetting, as proposed by Crane et al. (1995). Although, in their study, the focus was on the recall of spatial location, these researchers argued that the impaired spatial learning among the right-resected groups over multiple trials in this task was due to abnormally rapid forgetting. This conclusion may also be appropriate in the context of the MMQ, where both patient groups experience a more rapid decline in episodic memory during the interval between 'Yesterday' and 'Two days ago' compared to the control group. The idea of abnormally fast forgetting may also explain why certain events fail to become part of the individual's self-schema, leaving it sparsely elaborated.

Furthermore, this account may also shed light on why these patients were unable to engage autonoetic consciousness in order to recall as many events from two, three, four or seven days ago (as measured in the MMQ and Interview Study) compared to normal participants. If such details were subject to a rapid rate of forgetting over shorter periods of time, then there is little wonder why these patients' descriptions of 'Last Week' were lacking in the rich detail associated with episodic autonoetic awareness.

4.8.6 Temporal-order effects

The data reported here are also consistent with the findings observed by Spiers et al. (2001) concerning deficits in temporal-order judgments among patients with left and right unilateral temporal lobe resections using a VR town paradigm. Following navigation through the town, participants were asked a number of context-dependent episodic memory questions pertaining to this experience, including a specific question on temporal context in which they had to state which of two objects they had received first. Spiers et al. found that the left unilateral temporal lobe group was the most impaired on this task, while the right-sided group showed an intermediate level of performance. Although this study involved making temporal-order judgments over a shorter time period compared to either the MMQ or Interview Study, and involved episodic memory for a primarily nonverbal task (i.e. forced-

choice object recognition), the results of this study are nonetheless consistent with the data reported here in documenting the especial role of the left hippocampus in subserving episodic memory.

4.9 Contribution of the MMQ and Interview Study to current research on episodic memory.

The results discussed above make a number of significant contributions to the current body of research in the domain of episodic memory.

4.9.1 Specific contributions of the MMQ

Firstly, the MMQ is a new measure of personally-relevant episodic memory that has been shown to be a reliable assessment tool among a large sample of healthy participants. It has also been highly sensitive to the memory deficits of both left- and right-SAH patients. Furthermore, the MMQ has a number of additional advantages over previous questionnaires such as the CFQ and EMQ since it specifically requires the individual to complete details of the event that took place i.e. it probes the autonoetic consciousness of the episode. In contrast, questionnaires such as the CFQ and EMQ require participants to make more general ratings regarding how well they have remembered to do things. Thus, these measures appear more concerned with prospective memory and this method of probing everyday memory may not be the most appropriate way of accurately gaining insight into patients' episodic memory functioning.

Another advantage of the MMQ is that it specifically requests participants not to guess or to try to make up an answer when completing this questionnaire. If they do not recall the details of a particular event, then they are asked to leave the answer box blank. Although, it was not possible to say for certain that all the details provided by the participants were completely accurate, the inclusion of this clear instruction at the start and reminding participants during the task appeared to deter participants from estimating or confabulating episodic details.

What is also unique to the MMQ is the time-scale upon which it is based. Many other surveys, questionnaires and interview paradigms that have been used by previous researchers have focused over much longer time-scales. For example, early studies investigating event dating (e.g. Linton, 1975; Wagenaar, 1986) both focused on time periods extending over five years. The widely-used Autobiographical Memory Interview (AMI) (Kopelman et al., 1989, 1990) assesses patients over three broad lifetime periods of childhood, early adulthood and recent life, the latter comprising events which occurred in the last five years. Even the CFQ requests participants to consider their cognitive lapses over the past six months, whereas the EMQ focuses on the last three months.

In contrast, the MMQ and Interview Study focus on a much shorter time-scale, i.e. a four-day period and a one-week interval respectively, thereby allowing one to accurately measure how personally-relevant episodic memory declines over this interval. In this way, the MMQ and the Interview Study are useful in providing important information regarding the current status of the participant's memory for self-specific information. The 'real-world' personal episodic events that are central to the MMQ and Interview Study, and its shorter time-scale, serve to distinguish these measures from the tasks typically used in neuropsychological assessments, involving stimuli such as paired-associate word learning, narratives, verbal list learning and so forth. In this way, the MMQ and the Interview Study are both in accordance with Maguire and Mummery's (1999) assertion that the true context for human memory is the real world.

4.9.2 Limitations of the MMQ

The main limitation to the MMQ is the way in which it does not currently measure individual variation in the level of episodic detail recalled; one mark was awarded for including any details of an event but individuals who gave greater amounts of information were not awarded extra points. This method of scoring applied to the MMQ contrasts with that used in the Interview Study, where highly elaborated recollection of personal-schemas could be easily distinguished from those lacking in detail. However, in future, this

disadvantage could be rectified by using a modified version of the MMQ, which employs more explicit scoring instructions, thereby allowing greater levels of individual variation to be recorded.

4.10 Hypothesis 2

The **second hypothesis** predicted that on tasks of spatial representation, both patient groups would show deficits in performance relative to normal controls. However, within this domain and consistent with the predictions of previous literature, it was specifically hypothesised that the right-resected group would be more impaired than the left-resected group.

4.10.1 Landmark Recognition and Landmark Location Tasks

The results obtained on the Landmark Recognition and Landmark Location Tasks revealed significant impairments in the performance of both patient groups compared to the normal control group, thereby providing strong support for the second hypothesis. The poorer performance of the RSAH group relative to the LSAH group on these tasks adds to this support. It was also found noted that the factor of ‘living in Dublin’ significantly affected participants’ scores on the Landmark Recognition Task only, a finding that did not accord with the results obtained in the second validation study discussed earlier.

4.10.2 Dublin Familiarity Scale

Analysis of participants’ ratings on the Dublin Familiarity Scale revealed that both patient groups were less knowledgeable about Dublin’s city centre relative to the normal controls. However, a significant group effect was observed between the RSAH and control groups only; the LSAH group showed an intermediate level of familiarity. This finding is interesting since it concurs with the poorer performance of the RSAH group on both the Landmark Recognition and Location tasks relative to the LSAH and control groups. It was also shown that participants who were currently living in Dublin rated themselves as being more familiar with the city centre than those who were currently living elsewhere.

4.10.3 Pointing Task

The results obtained on the Landmark Pointing Task, showed that both patient groups had significantly higher error scores as compared to the control group. This Group effect was found to be robust as it occurred across each of the anchor landmarks and these findings lend further support for Hypothesis 2. However, it must also be noted that the LSAH and RSAH groups did not differ significantly from each other in their performance on this task (see Figure 3.29a). Furthermore, when pointing from the St. Stephen's Green anchor landmark, the RSAH group only was significantly impaired, whereas the LSAH group showed an intermediate level of performance. In contrast, when pointing from the GPO, it was found that the LSAH group showed the greatest impairment in pointing accuracy, with the RSAH performing at an intermediate level. However, the highest level of inaccuracy in pointing was found on the first anchor landmark, TCD, where both patient groups were extremely deficient relative to the control participants. It is clear from Figure 3.29a that the LSAH group were by far the most impaired at this task.

Analysis of the data obtained on the Landmark Pointing Task also revealed a significant Gender effect, with males showing higher levels of accuracy in pointing from two of the anchor landmarks (TCD and St. Stephen's Green) as compared to their female counterparts. This finding contrasts with the results obtained in the second validation study above which failed to observe any gender differences in this task.

4.10.4 No Group or Gender effects on VVIQ

The failure to observe any main effects concerning Group or Gender in participants' performance on the VVIQ serves to reinforce the idea that the deficits that were obtained on the Landmark Pointing Task were not due to participants being unable to engage in mental imagery of different environmental scenes, including buildings. The rating scale used in the VVIQ also measured the richness and vividness of these images and the similar performance of each of the three groups on this task is a particularly important finding. It suggests that the nature of the RSAH and LSAH

patients' impairments in these tasks has its basis in underlying deficits in the spatial domain, providing additional support for Hypothesis 2.

4.10.5 Route Description Task

The results obtained on the RDT revealed further evidence in support of Hypothesis 2; both patient groups were less accurate in their descriptions of routes as compared to the control participants. For Questions 1 and 2, in particular, both the RSAH and LSAH groups obtained significantly lower scores for their route descriptions than the controls. As can be seen in Figure 3.32a, it was also found that the LSAH group showed the greatest level of impairment on this task across each of the four questions. However, the difference between the groups did not reach significance on Question 4 and on Question 3, only the LSAH group's scores were significantly worse than those obtained by the controls; the RSAH group showed an intermediate level of performance

Consistent with the results of the second validation study, there were no gender differences found in this task. Analysis of the frequency of correct and incorrect routes chosen by the participants for each question revealed some additional interesting results. Whereas no difference was found between the groups for Questions 1, 3 and 4, it was shown that for Question 2, both the RSAH and LSAH groups were significantly more likely to choose an incorrect route compared to the control participants. This result is consistent with the finding that both patient groups scored significantly lower than the control group in their route descriptions on Question 2.

4.10.6 Correlations between the tasks

From the Path Model depicted in Figure 3.31, the relationships between the tasks measuring spatial representation can be seen. It is clear that the highest correlations occur between the Landmark Recognition and Landmark Location Tasks, and that both of these tasks correlate very significantly with the scores on the DFS, and show expected significant negative correlations with the Landmark Pointing Task and the Living in Dublin Factor. Interestingly, the Landmark Recognition Task also correlates significantly

with the VVIQ (eyes closed condition). Another point of interest is the way in which the RDT is significantly correlated with the Landmark Location Task and shows a significant negative correlation with the Landmark Pointing Task. Less surprising is the finding that the DFS showed a strong negative correlation with the Living in Dublin factor.

This pattern of highly significant correlations between these different tasks is important in demonstrating good external validity among a set of tasks, which have never been used before. Furthermore, the correlations are all in the expected directions, as is apparent when one considers how the data pertaining to these tasks was scored. Apart from their obvious focus on landmark recognition, these tasks measure some additional aspects of spatial representation (e.g. wayfinding, updating, or shifting viewpoints), as is suggested by the high level of association between the RDT and both the Landmark Location and Landmark Pointing Tasks. Finally, the relationship between these tasks is consistent with the significant correlations observed in the second validation study discussed above.

4.11 Links with previous research

In the following section, the results obtained in this study pertaining to Hypothesis 2 are discussed in connection with the findings from previous literature in this domain. In particular, the impaired performance of the patients in this study are discussed in terms of their implications for cognitive mapping and the overall representation of the environment.

4.11.1 The detection of a 'lingual landmark area'

The observation of significant impairments among the RSAH patients on the Landmark Recognition Task is in accordance with previous research documenting landmark agnosia among patients with damage to the anterior area of the right lingual gyrus. What is particularly relevant is Aguirre et al.'s (1998) assertion that this region, which they refer to as the 'lingual landmark area' is located adjacent to the right parahippocampus, and may in fact be the same area labelled by Epstein and Kanwisher (1998) as the 'parahippocampal place area'. An earlier study by McNaughton et al. (1989) had concluded that

this region may have been specifically involved in associating particular landmarks with particular spatial relationships. The observation of 'view cells' in the primate hippocampus and parahippocampal region by Rolls and O'Mara (1995) was another important discovery in this area. These neurons were found to be selectively responsive to where the monkey was looking in its environment (Taube, 1998).

Thus, the results observed in this study correspond with the widely held idea that the right hippocampal formation serves a specialised role in spatial representation and wayfinding behaviour (e.g. Barrash et al., 2000; Morris et al., 1999; Kopelman et al., 1997; Maguire et al., 1996; Van der Linden and Meulemans, 1998; Van der Linden and Seron, 1987). These data are also in accordance with the observations of Spiers et al. (2001) and Pigott and Milner (1993) which showed that RTL patients were impaired at the recognition of both environmental scenes and objects. However, Aguirre et al.'s (1998) and Epstein and Kanwisher's (1998) focus on the right hippocampus fails to explain the impaired performance of the LSAH group on the Landmark Recognition Task.

Although there have not been any specific studies focusing on landmark recognition deficits in both RSAH and LSAH patients, the assumption of laterality of function has been recently challenged by a number of studies (e.g. Dobbins et al., 1998; Owen et al., 1995; Feigenbaum et al., 1996), which have shown that patients with right and left unilateral temporal lobe resections show impairments on both verbal and visuo-spatial memory tasks. More recently, and more specific to the present study are the findings obtained by Astur et al. (2002) and Spiers et al. (2001), which found spatial learning and memory impairments among both right and left unilateral temporal lobe patients. Of particular relevance is Spiers et al.'s demonstration of impaired map-constructing ability among both right and left temporal lobectomy patients when navigating through a VR town.

4.11.2 The implications of landmark recognition for cognitive mapping

The demonstration of significant impairments among both RSAH and LSAH patients on the Landmark Recognition Task is an extremely important result because of its implications concerning the cognitive mapping and spatial representation abilities of these patients. Both Siegel and White (1975) and Pick and Lockman (1981) have suggested that humans acquire cognitive maps through the memorisation of main landmarks, the integration of those landmarks into a path or a sensorimotor sequence, and finally the elaboration of a survey-type representation where landmarks and routes are interconnected.

Other researchers (e.g. Golledge, 1999; Couclelis et al., 1987; Daniel and Dennis, 1987; Aguirre et al., 1998) have also stressed the crucial role of landmarks in cognitive mapping and topographical orientation. These researchers have consistently reported how important these environmental features are in facilitating one's ability to engage in orienting, and wayfinding. In particular, the study by Daniel and Dennis (1987) showed how their participants relied heavily on landmarks when asked to describe routes on a university campus. This could imply that these landmarks had been assimilated over time into their cognitive maps of the college environment and, in line with Tversky's (2000) view, this knowledge had shifted from its original declarative basis to become more automatically retrieved as a procedural process.

These results of these studies serve to highlight how essential landmarks are for the acquisition of cognitive maps in humans. The RSAH and LSAH patients in this study clearly showed gross deficits in landmark recognition, a task in which a large sample of normal participants performed almost at ceiling level, as shown by the results obtained with the second validation study. This implies a resultant impairment in the overall cognitive maps of Dublin city among these patient groups. In contrast, the control participants in this study performed at the same high level as those in the second validation study discussed earlier.

From this perspective, it could also be argued that the RSAH and LSAH patients may be impaired in direction giving, route description, orienting and wayfinding since they are unable to recognise and use the information provided by landmarks in the same way as normal controls. This argument is supported by the findings obtained on the Landmark Location Task, the Landmark Pointing Task, and the Route Description Task, which all show that the performance of both the RSAH and LSAH groups is significantly impaired relative to the controls. Furthermore, on the DFS both patient groups rated themselves as being less familiar with Dublin's city centre than participants in the control group.

What was also interesting about the participants' scores on the Landmark Recognition Task was the observation of a 'living in Dublin effect', which implies, that for these participants, these landmarks were not nationally known. This finding also contrasts with that observed in validation study two, but it must be noted that in that study, the factor 'born in Dublin' as opposed to 'living in Dublin' was used. However, the overall suggestion from the data observed in this study is that these landmarks had not been assimilated into the patients' cognitive maps of Dublin's city centre. It could be alleged that over time, these buildings did not generate sufficient levels of salience in the cognitive representations of the patients and therefore did not acquire the status of 'National' landmarks.

The impaired performance of the patients on these tasks could be interpreted as indicating that they were unable to use the landmark information to locate these landmarks relative to each other, even when presented with a modified map of the city centre as in the Landmark Location Task. Not surprisingly, then, both patient groups were also impaired on the Landmark Pointing Task. Equally unsurprising is their deficient performance on the RDT and their tendency to choose incorrect routes when the description became more challenging, as was observed in their scores for Question 2 on this task. Thus, the overall findings from the Landmark Recognition Task provide strong support for the second hypothesis.

4.11.3 Laterality effects

The results of the Landmark Recognition and Location Tasks are supportive of Hypothesis 2 and also concur with previous literature demonstrating spatial memory deficits among both right and left unilateral temporal lobectomy patients, but which place particular emphasis on the tendency of the right-sided patients to be more severely impaired on these types of tasks. The present findings support those obtained by Bohbot et al. (1998) who found that patients with right hippocampal damage were impaired on an object location task.

However, they are only in part agreement with the observations of Abrahams et al. (1997) who showed a dissociation between the impaired performance of patients with right-sided resections and intact performance among patients with left-sided resections on a task analogous to the radial arm maze paradigm associated with rodent studies. However, the results obtained by Astur et al. (2002) and Spiers et al. (2001) are in greater accordance with the findings of this study, as they demonstrated impairments among both RTL and LTL patients in their VR tasks.

The results of the Landmark Pointing Task are consistent with the first part of Hypothesis 2 in that both patient groups showed significantly impaired performance relative to the control group. However, extremely impaired performance of the LSAH group relative to the other two groups, when pointing from the first anchor landmark, TCD, is not consistent with previous research, which documents a specialised role for the right hippocampal formation in processing landmark information and facilitating topographical orientation.

These deficits in performance as demonstrated by the patient groups cannot be attributed to the fact that some participants were not living in Dublin since this factor was shown to have no effect on pointing accuracy. Furthermore, these impairments are not due to an inability to engage in visualisation, since there was no difference between the performance of the three participant groups on the VVIQ, as mentioned above.

Instead, these findings appear to be consistent with the ideas of Ploner et al. (2000), who argued that anterograde topographical disorientation may result from deficits in creating durable representations of landmarks and spatial relationships between items of the environment (allocentric representation). They also propose that an inability to establish spatial relationships between items of the environments and the subject (egocentric representations) may also contribute to topographical disorientation.

4.11.4 Gender effects

The gender difference observed on the Landmark Pointing Task is a particularly interesting finding and at first glance it may seem to be consistent with the large amount of previous research documenting gender differences in how males and females use and depend upon landmark information (e.g. McBurney, 1997; O’Laughlin and Brubaker, 1998). The presence of a gender effect also contrasts with the findings obtained in the second validation study described above, where both males and females were shown to perform equally well on this task.

However, from closer inspection of the data contained in Table 3.22 it appears that the gender effect is specific to the patient groups and is not evident among the control participants. Table 3.23 provides further support for this idea, and it is clear that the only discernable difference between the male and female control participants occurs when pointing from the TCD anchor landmark, with the males outperforming the females. In contrast, when pointing from the GPO, the females’ error scores were lower than the males and for the remaining two anchor landmarks, the performance of the males and females was equivalent. These observations mean that the results obtained here regarding the performance of the control group are consistent with the data recorded in the second validation study.

With regard to the patient groups, when pointing from the GPO anchor landmark, females were shown to outperform males. However, for the remaining three landmarks, the male patients of both the RSAH and LSAH groups were more accurate than their female counterparts. Thus, the gender

effect appears to be more robust among the patient groups and, in addition, outweighs any laterality effects.

4.11.5 Dublin Familiarity Scale

What is most interesting about the participants' ratings on the DFS is the observation of a group effect between the RSAH and control groups only. This implies that the RSAH group are aware of their wayfinding deficits and may have insight into their difficulties, which contrasts strongly with their ratings on the MRS where they failed to show the same awareness of their memory impairments.

4.11.6 Route versus survey knowledge

The RDT can be considered to assess participants' survey knowledge in that it requires them to describe a route between two landmarks using a map as opposed to physically navigating through the environment. According to Shelton and Gabrieli (2002), this type of knowledge allows direct access to the global spatial layout of the environment. The results of their study showed that survey knowledge led to increased activation of a specialised subset of regions thought to subserve route knowledge. This finding led Shelton and Gabrieli to conclude that the survey-based learning system may develop as a secondary system within the larger route-learning system.

What is important about this result in relation to the findings of the present study is the observation of survey-based deficits in route description among both patient groups relative to the control participants. The additional finding that these patients have deficits in their spatial representations of landmarks implied deficiencies in their cognitive maps of real-world environments. If, as Shelton and Gabrieli claim, survey-based learning is derived from route-based learning, then it is not surprising that patients with deficient route-based learning will also show impairments in their survey knowledge.

The results of the present study also suggest that the impairments are particularly evident when patients are required to describe more complex routes, as in Question 2 on the RDT. It was also found that patients were

significantly more likely to describe an incorrect route on this particular question as compared to the control participants.

4.11.7 The role of updating

The results of each of the above tasks can also be explained with regard to the concept of updating. For example, with the Landmark Recognition Task, for each consecutive presentation of the pictures of the landmarks, participants were required to update or reorient themselves appropriately in order to correctly name the buildings. The ability to engage in successful updating could also underlie participants' performance on the Landmark Location Task, whereby following the location of each landmark, updating would allow one to infer the relative orientation of one building to another on the map. Indeed, this is what appeared to be happening with the control participants, who upon locating one landmark, e.g. TCD, were able to successfully infer which landmarks were located at the remaining four positions. In contrast, when patients were attempting this task, they appeared to experience a greater difficulty with being able to successfully update or reorient themselves in a way that would facilitate them in locating either any of the landmarks, or remaining landmarks.

Deficiencies in updating could also be put forward as a possible explanation for the impaired performance of the patients in the Landmark Pointing Task, particularly the extremely poor performance when pointing from the first anchor landmark. The control participants appeared to rapidly adjust to the demands of this task right from the start, and performed at a fairly consistent level of accuracy over each of the four anchor landmarks. In contrast, both patient groups, and especially the LSAH group seemed to have great difficulty with orienting themselves at the start of the task i.e. at TCD and then having to update this position in order to point to each of the target landmarks from this the location. The demands of this task, which were performed with relative ease and accuracy by the control group, may have placed too great a challenge on the updating process of the patients.

4.11.8 Allocentric impairments in spatial representation

Shelton and Gabrieli (2002) also proposed that survey encoding allows more direct access to the global structures of the environment and requires updating that is continuous with this global structure rather than relative to bodily orientation in space. An inability to engage in this form of updating may explain the deficits found among both patient groups on the Landmark Location and Route Description Tasks since both of these map-based tasks specifically focused on survey-knowledge, even though the latter consisted of a virtual city. Shelton and Gabrieli state that the medial temporal and parietal lobe areas that are responsible for spatial navigation also play an important role in integrating various aspects of the local environment as it changes. This idea is specifically pertinent to the Landmark Pointing Task used in the current study, and may explain the deficits observed among both the LSAH and RSAH groups on this task.

Furthermore, these ideas proposed by Shelton and Gabrieli have strong links with Foreman and Gillet's (1997) differentiation between egocentric and allocentric modes of representing space. Their assertions are also consistent with those of Burgess et al. (2002) and King et al. (2002) who have stressed the importance of viewpoint dependence in spatial representation, which will be discussed in a later section. Interestingly, Wang and Simons (1999) stated that automatic processes could support the accommodation of a change of viewpoint within one's mental representation of object location. In the case of the patients who were assessed on the tasks discussed above, their adaptation to a changing perspective does not appear to have been quite so automatic.

The present findings are also highly consistent with those of Christou and Bulthoff (1999) who demonstrated the importance of the movement of the viewpoint relative to the participant's cognitive model of the world rather than actual movement. This observation is strongly supported by the results obtained on the above tasks, since it appears that the impairments in the patients' cognitive models of the world could underlie their inability to successfully update changing viewpoints. Thus, tasks which require participants to carry out numerous successive reorientations within an

allocentric framework or a framework that necessitates the ability to transform such representations in to egocentric coordinates, will place immense challenges on patients with deficient cognitive maps. The results of the Landmark Recognition, Landmark Location, Landmark Pointing and Route Description Tasks all provide strong support for this statement.

4.12 Theoretical frameworks linking Hypothesis 1 with Hypothesis 2

From the discussion of the results pertaining to the first and second hypotheses, it is evident that there has been strong support for both of these predictions. The results of the present study will now be discussed in terms of the support they provide for different theories of hippocampal functioning in both the spatial and episodic domains.

4.12.1 Viewpoint dependence theory

Good (2002) states that a number of recent theories of hippocampal functioning are based on the shared premise that the hippocampus plays a fundamental role in integrating representations. Burgess and his colleagues (e.g. Burgess, 2002; Burgess et al., 2002; Spiers et al., 2001a, 2001b) have been extremely prolific in the generation of ideas concerning the link between episodic and spatial processing in the hippocampus.

In their recent studies examining the role of the left and right hippocampi in topographical and episodic memory using VR paradigms, Spiers et al. (2001b) found that for spatial navigation tasks, the right temporal lobectomy patients showed the greatest impairments, whereas for the context-dependent memory questions, the left temporal lobectomy patients were most impaired. The discovery of this dissociation led Spiers et al. to conclude that the right temporal lobes are more deeply involved in spatial memory and navigation as compared to the left temporal lobes. In contrast, the left temporal lobes are more critical for context-dependent episodic memory than the right temporal lobes. The importance of these findings must be stressed; in particular, the demonstration of the critical role of the left temporal lobe in what was essentially a non-verbal episodic memory task.

These results led Burgess et al. (2002) to propose that the episodic memory functions subserved by the left temporal lobes intimately linked with the allocentric spatial processing that takes place in the right temporal lobes. Hartley et al. (2002) have shown that the right paRSAHippocampal gyrus contains allocentric representations of the locations of the contents of a scene of an event. Thus, what constitutes episodic memory is a series of spatial codes. Upon retrieval, these representations are translated from allocentric to body-centred and then to head-centred representations via connections with the right posterior parietal cortex and BA7 into a viewpoint-dependent representation for visual imagery. This leads Burgess (2002) to conclude that the hippocampal role in episodic memory is derived from its ability to represent a viewpoint moving within a spatial framework.

The above theory contains a number of ideas that are consistent with the results obtained in the present study. Firstly, the observation of a dissociation between the left and right temporal lobectomy patient performance on episodic spatial navigation tasks, respectively, is generally consistent with the findings of this study, which have shown a tendency for the LSAH group to be the most significantly impaired on the episodic memory tasks. Although the present results concerning the landmark and spatial tasks are also in agreement with Spiers et al.'s (2001b) findings, the pattern of RSAH and LSAH dissociation is not as clear, with mixed findings on the Landmark Pointing Task in particular. However, one must recall the strong gender effects on this task, which appeared to overpower any laterality effects.

The data obtained in the present study are consistent with the ideas of Burgess and colleagues in another important way. In its simplest form, Burgess asserts that hippocampal episodic memory functioning is derived from hippocampal allocentric spatial representations. Thus, the content and context of events is encoded into a viewpoint-dependent representation, which is used in the later retrieval of the details of episodes. The results of the present study have shown deficits in the ability of patients with unilateral hippocampal damage to use landmark information in the acquisition of their cognitive maps, implying less elaborate spatial representations of their environments. The

patients' deficits on the Landmark Location, Landmark Pointing and Route Description Tasks also provide strong evidence of impairments in the use of allocentric spatial representations to facilitate translation into egocentric frameworks leading to difficulties with updating and reorienting one's location following successive shifts in viewpoint.

Finally, the episodic memory deficits for personally-relevant information that were observed among both patient groups in this study are clearly in line with the predictions arising from Burgess et al.'s ideas. From this perspective, these deficits can be understood as stemming from an underlying impairment in the fundamental ability of these patients to generate accurate spatial representations or cognitive maps of their environments, which can be attributed to their longstanding hippocampal damage.

The above theory of viewpoint dependence is particularly persuasive in that it provides a plausible account of the findings obtained in the current study. Further support for the link between spatial and episodic processing comes from Aggleton and Brown (1999), who stated that the same anatomical systems (mammillary bodies, anterior thalamus, subicular/hippocampal complex) are involved in both the representation of head-direction and episodic recollection.

Burgess (2002) also stresses the component of spatio-temporal context that is specific to episodic memory and that serves to distinguish it from semantic and recognition memory. This emphasis on spatio-temporal context is similar to Tulving's (1999) idea of autonoetic consciousness and both concepts can be thought as mediating the richness associated with episodic recollection. The results of the current study are also in agreement with these postulations, in that both patient groups were significantly impaired in the recall of their personally-relevant events on the Interview Study, where it was possible to measure how elaborate or impoverished their memories were.

However, viewpoint dependence theory runs into difficulty with Burgess's (2002) proposition concerning 'event cells', which he envisions as

representing the location of one event and thus facilitating the recall of the spatial context of the event. This additional component to the theory comes from Burgess's review of computational modelling studies focusing on single unit recording in rodents, and he states that his concept of 'event cells' is similar to that of goal cells which have been hypothesised to exist in the subicular complex. However, recent work by O'Mara and colleagues (e.g. Gemmell and O'Mara, 1999; Gemmell et al., 2002) has challenged this assertion by providing strong evidence for the critical role of the prefrontal cortex in subserving goal-directed behaviour in rodents. From these studies, Gemmell et al. (2002) concluded that the activation of prefrontal cortex neurons was not spatially determined, but that the level of firing seemed to depend upon the animals' internal state.

Despite these challenges concerning the location of goal cells, the main difficulty in accepting Burgess' theory of event cells, in its current form, lies in his account of how the spatial context of an event is reconstructed. He specifically states that these hypothetical event cells allow navigation back to the location of the event that reactivation of an event cell, via some non-spatial cue, allows reconstruction of the spatial context of the event. However, it is unclear what is meant by his vague concept of 'some non-spatial cue' and it is evident that further research on this idea must be carried out before the theory can be regarded as having a substantial evidential base.

Viewpoint dependence theory also shares a number of salient links with other theories which are based on the premise that the hippocampal formation contains a neural network comprised of integrated representations of objects/events and their spatio-temporal context (Good, 2002). Thus, the findings obtained in this study are also in agreement with a number of ideas generated by other independent accounts of hippocampal functioning that share some common elements with viewpoint dependence theory.

4.12.2 Autoassociation Theory

The idea that the hippocampus plays a critical role in integrating representations is supported by Rolls and his colleagues (e.g. Rolls, 1999;

Rolls and Treves, 1998). In this theory, spatial processing is thought to involve a 'snapshot' type of memory in which one whole scene must be remembered. Episodic memory, which involves an arbitrary association of a particular set of events describing a past episode, is viewed as a special form of spatial memory. Rolls (1999) states that this idea may account for the deficits in both spatial and seemingly non-spatial tasks that are impaired as a result of hippocampal damage. Thus, Rolls and Treves (1998) argue that the hippocampus is used for both spatial and non-spatial types of memory.

The concept of 'autoassociation' is derived from the finding that the hippocampus contains the CA3 network, which acts as an autoassociation memory (Rolls and Treves, 1998). They suggest that the CA3 neurons equally enable whole (spatial) scenes or episodic memories to be rapidly formed, with a snapshot quality that depends on the arbitrary associations of concurrent activity. This implies that details pertaining to the spatial context where an episode occurred, the people present during the episode and so forth are associated together and stored as one event. This idea may be what Burgess was suggesting with his concept of 'event cells'.

In support of this theory, Rolls states that later recall of the particular episode from the hippocampus in response to a partial cue can lead to reinstatement of the activity in the neocortex that was originally present during the episode. Thus, Autoassociation Theory aims to explain how the hippocampus acts as a temporary buffer store, the contents of which can be recalled and used to help long-term storage elsewhere in the neocortex.

The results obtained in the present study can be seen as evidence in favour of Autoassociation Theory in that both spatial and episodic memory impairments were observed among patients with hippocampal damage. Rolls' account of how spatial and episodic memories are both rapidly formed in the CA3 neurons of the hippocampus may explain how deficits in both domains arise from damage to this structure, as was experienced by the patients in this study.

What is most attractive about this theory is Rolls and Treves (1998) discussion of the importance of synaptic plasticity within the hippocampus. They stress how many of the types of synapse within the hippocampus are modified as a result of experience, in a way explicitly related to the types of learning for which the hippocampus is necessary. Their account of the autoassociation memory served by the CA3 neurons implies that any new event to be memorised is given a unitary representation as a firing pattern of CA3 pyramidal cells, and that the pattern is stored into associatively modifiable synapses. Subsequently, the extensive recurrent collateral connectivity allows for the retrieval of a whole presentation to be initiated by the activation of a small part of the same representation via cueing.

Rolls and Treves state that cue retrieval of the CA3 representation might enable recall within the hippocampus, which in turn may allow recall of neuronal activity present during the original learning to be reinstated in the cortex. This would provide the neocortex with the necessary information it requires in the establishment of long-term memories.

This idea of cue retrieval as instigating hippocampal activity in recall is important since the present results show that cueing participants who were extremely impaired in the Interview Study (see above), did not facilitate the recall of their personally-relevant activities. Autoassociation Theory offers a possible explanation for this finding since it suggests that in such patients, damage to the hippocampus resulted in a failure of the neuronal activity associated with the memory of these events to activate the neocortex to a sufficient level that would facilitate episodic recollection.

4.12.3 Reinstantiation of context

Both the above theories of Viewpoint Dependence and Autoassociation are also similar to the hippocampal reinstatement theory proposed by Redish (1999). According to this account, which has been developed from lesion studies in rodents, reinstatement of context allows an animal to reset its internal coordinate system from external cues when it returns to a familiar environment. Redish states that an inability to successfully reinstantiate a

context is one of the key problems characterising patients with hippocampal lesions. The concept of hippocampal reinstatement has strong parallels with the ideas proposed by Burgess and Rolls concerning how the hippocampus mediates the processes of viewpoint dependence and autoassociation of arbitrary information. What unites these different perspectives is the consistent emphasis that is placed on the critical role of the hippocampus in linking or binding spatial, temporal, and contextual aspects of scenes and events. The data obtained in the current study provide further support for these assertions.

Redish (1999) also states that a secondary role of the hippocampus in spatial navigation concerns the replaying of recent memories i.e. of routes travelled. What the hippocampus actually does is replay the general context of the event and, this contextual replay is considered as constituting episodic memory. This idea of contextual replay appears to be equivalent to Burgess et al.'s concept of context-dependent episodic memory and is also consistent with the results of the present study.

4.12.4 Rapid learning in the hippocampus

The ideas expressed by Rolls and Treves (1998) and Rolls (1999) above in relation to the CA3 autoassociation network have been recently supported by the computational principles of O'Reilly and Rudy (2000). They state that the neocortex employs a slow learning rate and uses overlapping distributed representations to extract the general statistical structure of the environment. In contrast, the hippocampus learns rapidly, using separated representations to encode the details of specific events with minimal interference.

O'Reilly and Rudy assert that episodic memory requires rapid learning and separated patterns and the hippocampus rapidly binds information using pattern-separated representations to minimise interference. Thus, sparse hippocampal representations are characterised by a combination of pattern separation and conjunctive representations which bind separate features into a unitary representations.

If these principles are applied to the current study, it may be speculated that damage to the hippocampus could negatively affect the processes of pattern separation and the formation of conjunctive representations thereby hindering the ability to engage in rapid learning. Impairments to the process of pattern separation could lead to interference effects, which implies that the specific details of individual events may not be kept separate from other events. Difficulties in the formation of conjunctive representations could prevent the features pertaining to specific events from being encoded into a single representation. If the ability of the hippocampus to rapidly learn is affected in such a way, then deficits in the retrieval of information it was supposed to have processed and assimilated would be expected.

The data obtained in this study is consistent with this account of hippocampal learning principles in that these patients with hippocampal damage displayed significantly impaired episodic memory performance which may be interpreted as stemming from an inability to engage in this type of rapid learning. However, these principles do not specify differences between the functions of left and right hippocampi and they also fail to address the now widely-accepted link between the episodic and spatial functions of the hippocampus. While this model is interesting, and shares some common properties with other frameworks such as Autoassociation Theory, and the Theory of Representational Flexibility, developed by Eichenbaum and colleagues (e.g. Eichenbaum et al., 1994; Eichenbaum and Cohen, 2000, 2001), it fails to account for the remaining data obtained in this study.

4.12.5 The concept of Reconsolidation

The controversial question of the role of the hippocampus in the consolidation, and storage of information in long-term memory and the subsequent retrieval of that has been specifically addressed by Squire's Consolidation Theory (Squire, 1992; Squire and Alvarez, 1995) and Nadel and Moscovitch's (1997) Multiple Memory Trace (MTT) Theory. Unfortunately, the theories discussed in the previous section have failed to fully address this important issue. However, the recently proposed theory of reconsolidation (Debiec et al., 2002; Nader, in press) offers a very appealing

account of a process that may reconcile the diverging views of hippocampal functioning. This model states that reactivating a 'remote' or 'hippocampally independent' memory makes it become dependent on the hippocampus once again, although for a shorter time than was necessary at initial consolidation. Thus the idea of reconsolidation it is consistent with the general principle of consolidation theory, which states that the hippocampus has a time-limited role in memory. In addition, it concurs with MTT by demonstrating that reconsolidation occurs in the hippocampus after remote memory activation.

This idea of reconsolidation implies that remembering is a constructive and dynamic process that is heavily dependent on the hippocampus and is thus consistent with the results obtained in the present study. The impaired performance of both patient groups on both the Interview Study and the MMQ could be viewed as failures to successfully reconsolidate or reconstruct the details of events that occurred one 'day in the previous week' or three or four days ago. Their deficits in the Landmark Recognition, Location and Pointing tasks could also be interpreted as concurring with this theory implying that the demands of these tasks required participants to be able to reconstruct accurate representations of these landmarks and the cognitive maps in which they were located. The critical role of the hippocampus in the process of reconsolidation is strengthened when comparing the results obtained from this study with those found by Nangle (unpublished doctoral thesis), which used the Landmark Pointing Task was used for the first time. The results showed no difference in the performance on this task among a group of patients with right-sided parietal lesions and a normal control group.

4.12.6 Constraints to these theories

It must be argued that although the theories of hippocampal autoassociation, reinstatement of context and rapid learning do provide possible explanations of some of the findings in this study, it is clear that they do not share the same level of agreement as shown by viewpoint dependence theory. This may be due to their more direct connections with animal lesion studies focusing primarily on spatial navigation, the findings of which have then been applied

to human spatial navigation and from there extended to episodic memory functioning.

In contrast, the theory of viewpoint dependence, appears to have been less directly influenced by animal models and focuses specifically on human navigation and context-dependent episodic memory. Although it is clear that this model acknowledges the contributions of cognitive map theory, its primary concern is with human participants, and in particular those who have sustained damage to the hippocampus via temporal lobe epilepsy. Thus, viewpoint dependence theory appears to contain a number of advantages over the other perspectives and is considered the most appropriate means of explaining the present results.

Debiec et al's (2002) reconsolidation theory makes a highly significant contribution to the current literature and can enhance the current level of understanding into hippocampal functioning by integrating and expanding on the ideas generated by Consolidation Theory and Multiple Memory Trace Theory. The results obtained in this study are strongly supportive of the concept of reconsolidation.

4.13 Hypothesis 3

Hypothesis 3 predicted that on tasks measuring discourse production, both patient groups would show impairments compared to the normal controls. The support for this hypothesis will be discussed by referring to the results obtained with the Interview Study, the Route Description Task and the MMQ.

4.13.1 Interview Study – Discourse Production

The aforementioned Interview Study measured participants' abilities to recall their basic activities for three specific days i.e. a Typical Day, Yesterday and this day Last Week. Significant impairments in the number of events retrieved were found for each of the patients groups relative to the normal control participants. However, the Interview Study was also designed to assess discourse production competency in the participants. The discourse analysis

techniques used in this study were based on the methods used by Haravon et al. (1994) and the results of this analysis revealed a number of very interesting findings which were taken as supportive evidence for the third hypothesis.

Firstly, from Table 3.20, it is clear that for each category of language errors i.e. repetitions and pauses, verbal tics and pragmatics, and the inclusion of irrelevant and ambiguous information, both the RSAH and LSAH groups showed a greater percentage of errors of commission as compared to the normal controls. More specifically, the LSAH group was shown to be most deficient in terms of their discourse production abilities, while the RSAH group showed an intermediate level of impairment. From Figure 3.26, which contains the ratio of language errors made by each groups, it can be seen that for the category of verbal tics and pragmatics, there was a significant difference between the LSAH and RSAH groups. Further analysis of the data revealed a significant negative correlation between the number of basic activities recalled and the percentage of language errors made.

Finally, inspection of the mean number of words spoken in the Interview Study for each group, showed that the control participants were the most verbose, with the RSAH producing the least number of words. The LSAH group showed an intermediate level of verbosity in this task.

4.13.2 Route Description Task

Written discourse production on the RDT was measured by examining the word counts produced for each question by each of the three participant groups. The results of this analysis are contained in Figure 3.34a, where it is evident that the LSAH group tended to write the least amount for each route description. This robust finding extended across each of the four questions and contrasts strongly with the performance of the RSAH group who tended to write the most for three out of the four descriptions.

Interestingly, the control participants tended to write the most for Question 2, the most difficult route to describe. Furthermore, the difference between the

Question 2 word counts for the LSAH and controls was found to be significant. This observation is consistent with the significantly higher score obtained by the control participants' for this question compared to the patients' performance as shown in Figure 3.32a. Analysis of the word counts for Question 3 of the RDT revealed a significant difference between the number of words written between the RSAH and LSAH groups only.

Table 3.39 shows the results of a correlational analysis of the mean number of words produced for each question on the RDT. From the highly significant correlations reported in this table it is clear that the word counts for each question showed strong levels of association with each of the other questions.

Thus, the results from both the Interview Study and the RDT provide clear support for the hypothesis that both the RSAH and LSAH groups showed impairments in discourse production relative to the normal control participants.

4.14 Links with previous research

In Chapter 1, it was noted that there has been an unfortunate tendency among researchers to ignore the numerous ways in which language can be negatively affected among patients with TLE. Even when aspects of discourse production have been investigated (e.g. Hermann et al., 1992; Bell et al., 2002; Mayeaux et al., 1980), the emphasis has been on single-word confrontation naming, with strong reliance on the Boston Naming Task (BNT). The results of such studies have consistently reported impairments in confrontation naming among pre- and post-surgical TLE patients have been found, particularly in the case of patients with left-sided damage. This line of research has led other investigators (e.g. Troster et al., 1995; Bell et al., 2000) to focus their attention on the domain of verbal fluency impairments, which they attributed to a disruption of the semantic networks of both left and right TLE patients.

4.14.1 Circumstantiality

However, extensive literature searches revealed that only one study had specifically focused on TLE discourse production beyond the level of the single-word. This study by Field et al. (2000) was concerned with the tendency of patients with left TLE to engage in a particular type of language known as circumstantiality, which was characterised by three main features, verbosity, longer speaking time and reduced fluency. The results of the study showed that, compared with normal controls, the left TLE patients tended to become more verbose with each retelling of the 'Cowboy Story', as reflected with their increase in speaking time over the three occasions. Field et al. suggested that the differences in discourse production between the two groups were attributable to a psycholinguistic effect at the macrolinguistic level, which is responsible for establishing interrelatedness between the sentences that form a narrative. They concluded that the increased language output could have been socially motivated; participants' strong desire to preserve social contact may have been an attempt to compensate for their declining information content.

Before turning to the links between this study and the current research, a number of important differences between Field et al.'s study and the Interview Study used in this research must be noted. Firstly, the former investigation focused only on left TLE patients who were in the pre-surgical phase of treatment and therefore did not address how right hemisphere damage could impact on discourse production. Furthermore, the assessment tool used to elicit discourse production among Field et al.'s sample was a fictional story and did concern the personal lives of the participants in any way. It must also be noted that the story card from which the narrative was generated remained in front of the participants for the entire procedure thereby minimising memory load. Thus, it appears that although the story card remained in place while each narrative was being recorded, the left TLE group could not create a stable internal representation of the key points of the story. This implies that they were unable to extract and retain the common properties of the narrative over each retelling.

4.14.2 Maintaining an ‘internal summary’ of the narrative

However, despite the methodological differences, Field et al.’s assertion, that the left TLE group was unable to form an internally condensed ‘summary’ version of the narrative, is particularly interesting in the light of the episodic memory deficits shown among the patients in the Interview Study of the present research. These deficits could be interpreted as stemming from an impairment in the ability of the LSAH and RSAH patients in extracting the common elements from their typical day and then retaining these elements across the different time intervals of Yesterday and Last Week. If this is the case, then it could be argued that a significant memory problem underlies the observed discourse production errors.

In addition, Field et al.’s idea that verbosity is maintained by social and motivational drives, may well explain the performance of a number of the LSAH patients in the current study. Although extremely lengthy interviews were obtained in certain cases (see for example Interview Transcript of patients C.W.), they actually consisted of very little relevant information pertaining to the individual’s specific self-schema of their activities for each of the days in question. Thus, in the interests of keeping the conversation going, these patients will continue to talk despite being unable to provide the required information.

This observation provides support for the aspect of circumstantiality in TLE language. This peripheral style of speaking has been attributed to lexical access difficulties (e.g. Bear et al., 1982; Benson, 1991) but the results from the current study suggest that it is strongly linked with the level of memory impairment. The highly significant negative correlation between the number of basic activities recalled in the Interview Study and the percentage of language errors made supports this line of reasoning.

Further support for the influence of social and motivational factors on discourse production can be found from inspecting the types of errors made by the RSAH and LSAH participants in the current study. The idea that these patients are attempting to compensate for their memory deficits may explain

the significantly higher percentage of the repetitions and pauses recorded during their interviews relative to those of the control participants. Furthermore, the tendency of LSAH group in particular to produce significantly more verbal tics and pragmatics as compared to either the RSAH or control groups is consistent with this argument. Verbal tics such as ‘am’ or ‘ah’ etc. serve a functional purpose in that they buy the person some extra time while they think of something to say and yet keep the conversation going. According to Ball (1998), the repetition of pauses filled with verbal tics may reflect that the speaker is not willing to yield the floor to the other individual but intends to carry on searching for the words required, or in this case, to retrieve the event information.

The use of pragmatics such as “I can’t remember”, or “I really don’t know,” or “I’m sorry...,” which occurred with a significantly greater frequency among the LSAH group clearly reflected the difficulties these patients were experiencing with trying to retrieve personally-relevant episodic information. Finally, the inclusion of ambiguous and irrelevant information, which was even more associated with the LSAH group, provides strong support for both the presence of circumstantiality and the social-motivational influences keeping the conversation alive.

Thus, the key difficulty experienced by both the LTLE patients in Field et al.’s study and both the LSAH and RSAH patients in the present study is a problem with integrating different aspects of events, be they personally-relevant or otherwise, to form a consistent narrative. Therefore, the memory deficit seems to underlie these macrolinguistic difficulties. It is also worth noting that microlinguistic level of discourse production involving the lexical and syntactic language components is unaffected among these patients. Perhaps the knowledge contained at this level may be akin to procedural skills in the usage of various different language components and remains preserved in such cases.

Instead the discourse production deficits evident among the TLE patients are more context-dependent in that they reflect an inability to retain the context of

the narratives over time. This idea has strong links with the previous demonstrations of the adverse effects on performance of TLE patients when increasing delays in time are introduced (e.g. Smith and Milner, 1981, 1984, 1989; Crane et al., 1995).

4.15 Theoretical frameworks

In the following section, the results retaining to Hypothesis 3 will be discussed with respect to three specific theoretical frameworks; theory of mind, the maintenance of context across different time periods, and cognitive map theory.

4.15.1 Theory of mind and the importance of reference and topic construction

According to Baron-Cohen's (1995) 'theory of the mind' model, refers to the ability of humans to be able to take account of each other's views and representations of a shared world. Although Wilson and McAnulty (1998) use this model to explain the nature of the conversational disabilities shown by children with pragmatic impairments, their focus on referential and topic construction difficulties is particularly important in shedding light on the findings of the current study. This is especially applicable in interpreting the tendency of patients with LSAH to include ambiguous and irrelevant information in their descriptions of their personal routines.

Wilson and McAnulty state that effective referential and topic construction relies heavily on the ability of speakers to take account of each other's knowledge and beliefs. With regard to reference, it's key role in discourse production stems from the way in which it marks out objects and concepts in differing ways so that they may be brought into mind or maintained within an emerging story or account (Wilson and McAnulty, 1998). Reference may be achieved either directly through physical location or indirectly through inference or reflection. Thus, there are clear links between these ideas of reference and topic construction and the results obtained by Field et al. (2000) in their study.

What is of critical importance in Wilson and McAnulty's discussion of reference and topic construction is that it provides online access and negotiation of elements either in the world or in the mind of both the speaker and hearer. Thus, a speaker who attempts to construct a topic area for joint attention when the 'context' of the topic is not available to the listener may have failed to adequately take account of relevant knowledge in the construction of the topic. From the listener's perspective as in the case of the Interview Study, the information included at this point may seem ambiguous and irrelevant to what should be the shared focus of the conversation.

The same point holds for the findings concerning discourse production on the RDT, where the poorer performance of the patients, in particular those in the LSAH group, relative to the controls could be explained from a theory of mind perspective. The objective of this task specifically requires participants to write the description of a route they would take if asked to travel from one landmark to another on a map of a virtual city. To successfully complete this task, participants must engage in reference and topic construction to establish the level of shared knowledge between their perceptions of the route and the perceptions of the person reading their directions.

As discussed above, the results of the RDT showed impoverished route descriptions among the LSAH patients (as shown by their consistently lower word counts) along with a tendency to choose or include incorrect or ambiguous directions. These patients may have particular difficulties in achieving reference and topic discussion via the indirect method of inference. Their tendency to write shorter and more ambiguous route descriptions implies that the LSAH group is incorrectly assuming that the reader is aware of what route they have in mind, and will thus be able to get from 'A to B' even in the absence of clear directions. This suggests a particular impairment among these patients in the ability to keep track of the current levels of shared knowledge between the two parties which may arise from an inability to construct what Baron-Cohen (1995) terms 'the shared attention mechanism'. Alternatively these observations may stem from a more fundamental problem at the level of theory of mind. Wilson and McAnulty argue that this would

imply that such individuals construct the beliefs of others as if they were their own beliefs.

Baron-Cohen's (1995) model of mindreading proposes that a shared attentional mechanism is crucial in order to negotiate conversation around a topic. However, unless one also takes account of what the hearer knows or believes about this topic relative to what the speaker knows or believes, then interactional progress will be limited (Wilson and McAnulty, 1998). Thus, the ability to represent different mental states is of critical importance.

What is of specific relevance to the current study is Sperber and Wilson's (1996) consideration of 'mindreading' where they argue that, achieving some form of joint attention which focuses on the needs of the listener in specific contexts, is the fundamental underlying principle. The importance of being able to take account of another's viewpoint and in representing another's beliefs as different from one's own has strong parallels with the ideas expressed in viewpoint dependence theory. The concept of viewpoint dependence proved extremely useful as a means of explaining the link between the spatial and episodic memory deficits of the patients in this study. However, it has not yet been applied to the domain of discourse production among such patients. It may be possible that the inability of patients with hippocampal damage to update changing viewpoints of spatial or context-dependent scenes may be linked to their inability to take account of the needs of listeners in different situational contexts. Support for this idea comes from the results of the Interview Study and the RDT, which clearly constitute different contexts and present different mnemonic challenges. However, in both cases, the participant must engage in appropriate reference and topic construction, and in order to do so, they must possess the necessary tools for 'mindreading' i.e. the ability to take account of another's viewpoint and to construct a shared level of knowledge.

4.15.2 Effects of being unable to maintain context across different time intervals

The theory of mind was originally developed and used with the intention of explaining the specific language impairments of autistic children (e.g. Rapin and Allen, 1987). However, it is now evident that this framework is also effective in shedding light on the nature of the discourse production errors among the patients in the current study. This lends further support to the idea that the key function of the hippocampus is characterised by its ability to integrate spatial and contextual episodic information within a particular representation, which can be reinstated at a later time (Redish, 1999). This process of representing changing viewpoints (King et al., 2002; Burgess, 2002; Burgess et al., 2002) presupposes the ability to be able to keep track of the elements that remain stable as well those that require updating over time. In the realm of discourse production, the awareness of the difference in the viewpoints or shared knowledge of the speaker and listener, and the ability to change between one's own perspective and that of the other person characterises reference and topic construction and underlies theory of mind.

4.15.3 Cognitive Map Theory

The results of the current study have provided strong support for O'Keefe and Nadel's (1978) assertion that the left hippocampus is particularly critical for the formation of long-term context specific memories for episodes and narratives. Although O'Keefe and Nadel stated that the left hippocampus contained a cognitive mapping system or a 'deep structure' for language, they failed to consider the area of discourse production in their application of cognitive map theory to language functioning. Thus, their ideas cannot fully explain the adverse affects of hippocampal damage on discourse production as shown in the current study. Instead, it appears that the most appropriate way of explaining the discourse production errors demonstrated by the patients in the current study is by referring to the research of psycholinguists who have specialised in discourse analysis among patient populations.

4.16 The link between the three components of episodic memory, spatial representation and discourse production.

In the final section of Chapter 3, the results of a factor analysis were reported. This analysis was carried out for two main reasons. Firstly, in order to examine the relationships between the many different tasks used in the current study, and secondly, to provide specific support for the idea that the hippocampus subserves spatial representation, episodic memory and facilitates discourse production (via the development of a theory of mind).

The results of this analysis yielded a Five-Factor Model consisting of the following components: knowledge of Dublin landmarks, memory questionnaire performance, discourse production ability, visual imagery ability and a final factor labelled Dubliner/non-Dublin (as shown in Figure 3.42). The first factor, the knowledge of Dublin landmarks can be considered as tapping into the spatial representation abilities of the participants, with the DFS, Landmark Recognition, Landmark Location and Pointing Tasks all loading significantly onto this component.

In contrast, the second factor, memory questionnaire performance was extracted due to its high loadings with the MRS, the CFQ, EMQ and MMQ. What was of interest here was the way in which the results obtained on the Interview Study were not shown to load significantly onto this factor. The third factor of the model, discourse production ability, is the most important of all the factors and is critical in establishing the link between the spatial, mnemonic and linguistic aspects of hippocampal functioning. The number of items recalled on the MMQ, the number of basic activities recalled in the Interview Study and the overall score on the RDT were found to load significantly onto this factor. However, it was also clear that there was a significant negative relationship between this factor and the percentage of the percentage of language errors produced in the Interview Study.

Thus, the common underlying property between these four significant relationships was their emphasis on discourse production, either verbal or

written. Whereas the Interview Study measured discourse production in the domain of speech, the MMQ and the RDT, measured discourse production in the context of the written word. Furthermore, the Interview Study and the MMQ shared a common focus i.e. the retrieval of personally-relevant context-dependent episodic information. In contrast, the RDT did not require participants to engage in the recall of personal events but it did request that they describe routes from their personal perspective. Thus, it appears that the shared component of discourse production between these seemingly diverse tasks may derive from the critical role played by theory of mind in establishing an accurate account of the other individual's viewpoint.

It is argued that the deficits in the ability to adequately reinstate previous context-dependent episodes and to represent and update the current context of the other individual's level of knowledge attributed to the kinds of discourse production errors produced by the RSAH and LSAH patients. Thus, the revelation of a factor, which ties together these three aspects of hippocampal functioning is unique to the current study. Until now, no study has simultaneously examined these three elements and therefore the results obtained here make a highly significant contribution to the literature in this area.

4.17 Hypothesis 4

Hypothesis 4 predicts that on spatial navigation tasks focusing on route reproduction and spatial circular trajectory estimation, there would be no differences between the patients and controls. In examining the supportive evidence for this hypothesis, the results of the Linear Navigation, Backward Walking and Spatial Circular Trajectory Tasks will be discussed.

4.17.1 Lack of a Group effect

Beginning with the Linear Navigation and Backward Walking Tasks, the key finding here was the absence of a group effect across any of the measures taken. Thus, there were no differences between the patients and controls on measures of absolute error, deviation to the left or right of the line, the total

distance walked, the level of undershoot/overshoot or the time taken. Analysis of the results obtained on the Spatial Circular Trajectory Task also failed to obtain a group effect. These results provide strong support for the argument that these tasks are not affected by unilateral left or right hippocampal damage.

Furthermore, it was also shown that the addition of an interference task by requiring participants to count aloud, for example in multiples of three's from zero or backwards from 100 in four's, did not interfere with performance on these tasks. These findings contrast strongly with the impaired performance of the patient groups on each of the other tasks.

4.17.2 Gender effects in the Linear Navigation and Backward Walking Task

The results contained in Figure 3.36b show a significant difference in the total distance walked by males and females in the control condition of the Linear Navigation Task where the males tended to be more accurate in their judgements of the distance to the target line. In contrast, Figure 3.37b contains the mean scores obtained by participants in the control condition of the Backwards Walking Task. The results showed that female participants deviated significantly less from the target line in this task compared to the male participants. However, it should be noted that for this particular control condition, participants were not blindfolded; the target remained in view of the participants throughout each of the five trials. A significant gender difference in the time taken to complete this task was also found, with males walking more rapidly to the target as compared to their female counterparts (see Figure 3.37d). A final gender difference was observed in the third condition of the Backwards Walking Task where participants were required to walk forwards while blindfolded. The results showed that males were significantly faster at completing this task compared to the females.

In attempting to explain these gender differences, the small sample size must be taken into account. Furthermore, the lack of a Spatial Navigation Validation Study, equivalent of the Memory Questionnaire and Landmark

Validation studies means that it is not possible to compare the results obtained with this sample with those from a normative population. The differences in time taken to complete two of the four conditions of the Backward Walking Task may simply reflect the tendency of males to take larger steps than females and thus to cover a greater distance in a smaller amount of time. Although the differences regarding judgements of total distance and deviation from the line on the Linear Navigation and Backward Walking Tasks respectively are acknowledged, they should best be viewed in the context of the overall similar performance of males and females on both of these tasks. The absence of any additional gender effects on any of the other measures of these tasks or the Spatial Circular Trajectory Task implies that males and females showed an overall equivalent level of performance.

4.18 Links with previous research

These results will not be discussed with reference to the previous research into spatial navigation and focuses especially on the process of path integration and updating.

4.18.1 Path Integration, updating and the vestibular system

The results obtained here support those obtained by Worsley et al. (2001), who found no differences between RTL, LTL and controls in a task that required participants to reproduce the distance they had travelled while blindfolded. This contrasted with the results obtained when Worsley et al. assessed participants on a more difficult task which required them to reproduce two distances separated by a turn, the RTL group was impaired in both reproducing turns and returning to the start position. Worsley et al. attributed this finding to an impairment in path integration, reflected by the inability of the RTL patients to estimate direction rather than distance.

They hypothesised that both path integration and allocentric spatial memory could be linked since they may both be subserved by the right hippocampal formation. Thus it appears that for the less complex tasks of reproducing distance travelled, the process of path integration is challenged to a lesser extent and therefore such patients do not experience any difficulties with such

tasks. This idea is consistent with the observations of a number of other researchers (e.g. Thomson, 1983; Loomis et al., 1993) who have shown that humans can navigate to a previously seen target on the floor if blindfolded. Takei et al. (1996) also showed that healthy adults could remember a previously walked circular path and reproduce the trajectory with reasonable accuracy when visual and auditory cues were eliminated via blindfolds and earphones. In contrast, on tasks that require path integration in order to estimate direction, patients with right hippocampal damage may show impaired performance. Worsley et al.'s observation that the impairment among the RTL group was one of directional error parallels Berthoz et al.'s (1999) detection of a directional error that was found among a group of patients with damage to the vestibular system when performing a triangulation task. This is not surprising when one takes account of the high level of vestibular-hippocampal connections (e.g. O'Mara et al., 1995; Smith, 1997; Taube, 1995; Sharp et al., 1995) and the role of the vestibular system in path integration as reported by a number of researchers (e.g. Berthoz, 1999; Takei et al., 1996).

Berthoz (1999) attributes this vestibular deficit to a specific impairment of the head-direction cell system. However, this approach contrasts strongly with Burgess et al.'s (2002) suggestion that self-motion causes an automatic updating of an internal representation within a cognitive representation that does not necessarily rely on vestibular or proprioceptive signals.

According to Loomis et al. (1999), the internal representation underlying path integration is an abstraction derived from computations on the route information that is continuously updated as one navigates along this route. The emphasis on updating (e.g. Loomis et al., 2001) in path integration is consistent with earlier discussions on how this process can be negatively affected by hippocampal damage, as shown by the impaired performance of patients in the current study on tasks specifically requiring spatial updating (e.g. the Landmark Location, Landmark Pointing Task and Route Description Tasks). Thus, it lends support to the theory that path integration may lie within the hippocampal formation (e.g. McNaughton et al., 1996; Whishaw,

1998). However, it must be stated that this line of reasoning contrasts with the assertions of a number of other theorists who have argued that path integration lies outside the hippocampus (e.g. O'Keefe, 1976; Redish, 1999, 2001).

Good (2002) argues that further research is required to examine the precise anatomical substrate of the temporal lobe impairment in path integration in humans before a role in path integration can be conclusively ascribed to the human hippocampus. This is particularly true in the context of the current findings when only route reproduction was measured and the more complex triangulation tasks were not used with these patients. Thus it is only possible to hypothesise that tasks requiring the ability to estimate both distance and direction engage the path integration system via continuous updating of current orientation and self-motion. It is argued that deficient performance on such tasks would be found among patients in the RSAH group.

4.18.2 The extent of the challenge to memory

The Linear Navigation, Backward Walking and Spatial Circular Trajectory Tasks can be distinguished from the remaining groups of tasks in that they do not challenge memory to the same extent. For example, the ability to reinstantiate a previous context or manipulate one's viewpoint is not necessary for one to successfully reproduce a route distance during blindfolded navigation. Furthermore, unlike the episodic memory tasks which involve the storage of information with the addition of specific spatial, temporal and contextual details, path integration requires minimal storage of information in memory (Tversky, 2000). It is argued that the increasing the memory load by adding successive turns between distances to be traversed leads to a greater impairment in performance among patients with damage to the right hippocampal formation.

4.18.3 Dissociation between temporal and parietal lobe damage

The performance of the RSAH and LSAH patients in the current study on these navigation tasks also contrasts strongly with the impairments found by Nangle when she originally used these tasks with a group of right parietal

stroke patients. Her results showed that these participants tended to produce significantly more overshoots and undershoots, and a greater number of deviations to the left and the right on both the navigation tasks and also on the spatial circular trajectory tasks as compared to a mixed aetiology group and normal control participants. Furthermore, their performance in the dual-task conditions was significantly poorer than on the control conditions.

In contrast, when these patients with right parietal lesions did not show any impairment in performance on the Landmark Pointing Task, which led Nangle to conclude that the parietal cortex was essential for updating egocentric as opposed to allocentric spatial relationships. More specifically, from the results on the Landmark Pointing Task, it was argued that while these patients were able to acquire an accurate cognitive map of the environment, their problems arose from their inability to use vestibular, proprioceptive, and idiothetic cues to navigate within this environment. Thus, there appears to be a clear dissociation between the effects of right parietal lobe damage and right and left hippocampal damage.

Right parietal damage appears to affect egocentric spatial representation and navigation in conditions where the environment was unfamiliar, and when visual and auditory information was reduced. In such conditions, the patients were forced to rely on idiothetic and vestibular information in order to successfully engage in path integration. However, their impaired ability to accurately represent egocentric space prevented them from being able to carry out these tasks at a normal level. In contrast, their ability to acquire a cognitive map and to use allocentric spatial information remained intact.

On the other hand, the RSAH and LSAH patients in the current study showed preserved performance on the navigation tasks, suggesting preserved egocentric representations, but grossly impaired performance on the Landmark Pointing Task, which relied heavily on the use of a cognitive map.

The findings reported by Worsley et al. (2001) and Nangle (unpublished doctoral thesis) and the results of the present study raise a number of

important issues concerning the role of the hippocampal formation in spatial navigation. Firstly, the preserved performance of the RTL and LTL groups on the route reproduction task observed by Worsley et al. (2001) and in the present study is strongly dissociated with the impaired performance of the right parietal lesion patients assessed by Nangle. The deficits revealed among this group were attributed to difficulties in processing vestibular information, and engaging in egocentric updating.

The nature of the impairments that were observed among the RTL group in Worsley et al.'s task requiring the computation of a homing vector was thought to arise from difficulties with successively updating changes in allocentric orientation, which in turn affected the ability to engage in path integration. Worsley et al. (2001) argued that this difficulty with estimating direction arose from an underlying impairment in allocentric spatial memory which was subserved by the hippocampal formation.

The results obtained on the Landmark Pointing Task support this assertion as the RSAH and LSAH groups showed a significantly higher level of error when asked to point to the locations of imagined landmarks. In contrast, the right parietal lesion patients in Nangle's study performed at a normal level at this task. This provides strong evidence for the idea that the hippocampal formation plays a more critical role in the representation of allocentric spatial relationships, whereas the right parietal cortex subserves egocentric spatial relationships. However, the main limitation to the present study and to that carried out by Nangle is the absence of data showing the performance of these three groups of patients on the triangulation task, where the computation of a homing vector is required. This task requires the integration of both egocentric and allocentric representations of space since participants travel two distances, separated by an angle and are then asked to find their way back to the origin.

In order to complete this task, a third vector must be constructed, which takes into account both the distance and direction traversed. Since the RSAH and LSAH groups in the current study show impairments in the ability to

represent spatial information from different viewpoints, deficient performance in this task would be expected. However, the right parietal lesion group is impaired in their ability to estimate both distance and direction, and to use idiothetic, and vestibular signals to update their egocentric locations. Thus it would be hypothesised that they too would show impairments on this task.

4.19 Summary of the overall findings in this study

The results of the main study can be summarised in four points:

- Both the LSAH and RSAH patients showed significant impairments in tasks requiring the ability to recall context-dependent personally-relevant episodic memory. In each of these tasks, the performance of the LSAH group was most adversely affected.
- Gross impairments among the LSAH and RSAH groups were also found in tasks measuring the ability to use spatial information and cognitive representations. Although there was a tendency for the RSAH group towards a greater degree of impairment, this dissociation of laterality effects was not as strong as that observed with the memory tasks.
- On tasks measuring discourse production, both the LSAH and RSAH groups were impaired relative to the controls. As with the results from the episodic memory tasks, the LSAH group showed the greatest frequency of discourse production errors, with the RSAH group performing at an intermediate level.
- Finally, on the spatial navigation tasks measuring route reproduction, there was no difference on any of the measures, in the performance of the patient groups relative to the control participants. This finding is strongly dissociated with the results obtained by Nangle (unpublished doctoral thesis).

4.20 Implications for quality of life issues.

Regarding the important issue of quality of life following surgery for TLE, the high level of individual variation with respect to overall memory functioning within both patient groups must be considered. In particular, the significant impairments reported in this study have been matched by the

subjective complaints of a number of patients in both groups. For example, patient J.B. (RSAH) remarked that his overall memory functioning was worse since the operation, particularly for books and music. Another RSAH patient S.W. also reported numerous problems with her memory since surgery. These ranged from getting lost when driving, to being unable to locate herself in familiar buildings. Similar to J.B., this patient also complained about having to re-read books and re-watch videos a number of times in order to be able to follow the plot of the story. Finally, S.W. reported a significant and noticeable decline in her overall memory functioning, with memory for spatial information, directions, faces, and buildings being worse affected.

From similar reports from a number of other patients, it appeared that the workplace constituted the area of life most affected by these difficulties. For example, A.D. (LSAH) stated that in his job, he continuously needed to be reminded about what task was to be done next. Patients K.S. (LSAH) and S.W. also reported a heavy reliance on diaries and memos to compensate for their memory problems and to assist them in work. Finally, a small number of patients complained about a difficulty in the ability to engage in independent travel, resulting from the deficits in wayfinding. Indeed, the vast majority of patients arrived to participate in this study accompanied by a spouse or parent. One patient in particular (N.P., RSAH) would not travel alone, and although A.D. arrived at the hospital unaccompanied, he was contacted by another family member to ensure that he had found his way. On the other hand, K.O'B (RSAH) avoided the city centre as she was unable to find her way around. These anecdotal remarks shed light on the ways in which the patients themselves view the impact of their difficulties on their lives. However, it must be stated that not all of the patients who took part in this study were affected to the same degree by their memory impairments. As can be seen from the results obtained on the Memory Rating Scale, there were no overall differences between the ratings of either patient group relative to the controls.

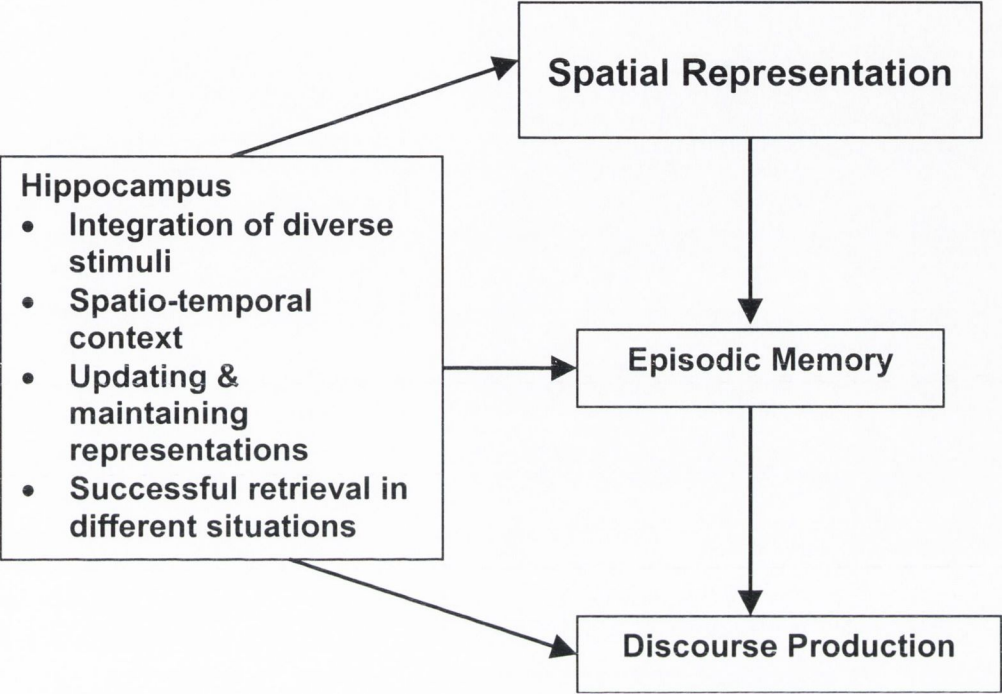
4.21 A framework for explaining the findings of this study

The preceding sections of this chapter have focused on integrating the above results with previous research, literature and theories on hippocampal functioning in humans. A number of the findings reported in the present study lend themselves readily to explanation through the perspectives of a number of researchers (e.g. Burgess et al., 2002; Redish, 1999; Spiers et al., 2001) most notably the theories of viewpoint dependence and reconsolidation. However, there has clearly been a paucity of research into the area of discourse production among post-surgery TLE patients. Furthermore, no previous study has yet attempted to simultaneously assess episodic memory, spatial representation and discourse production among such a population. The uniqueness of this research therefore means that it is currently not possible to find any one theory that fully accounts for the diversity of the results obtained here.

In order to deal with this challenge, a new framework is proposed in the following section (see Figure 4.1; Mangaoang et al., 2003). This model is largely based on integrating previous ideas and theories of hippocampal functioning and aims to provide an adequate account of the results pertaining to each of the three components of episodic memory, spatial representation and discourse production that were obtained in this study. However, it must be noted that this account is only intended as a way of understanding the findings obtained here and has not been formally tested elsewhere.

In its simplest form, the model states that the difficulties in landmark recognition associated with left and right unilateral hippocampal damage, imply an associated deficit in acquiring a cognitive map of the environment. This means that such patients are impaired in integrating and using the information obtained from landmarks to assist them in gaining adequate route-knowledge of an environment. This results in difficulties with using survey-knowledge, since these forms of representations are developed from route-based knowledge of the environment.

Figure 4.1: A three component model of hippocampal functioning



These deficits impact adversely on the ability to update one’s orientation in relation to the environment in situations where both route- and survey-based knowledge is required. Thus, there is an impairment in the ability to shift between viewpoints in an allocentric mode of representation, which can be attributed to the problems with the underlying cognitive map. This results in problems with continuous updating previous goals, with regard to the demands of the current situation.

This difficulty in representing and reinstating different contexts links to both the episodic memory deficits and discourse production errors associated with damage to the hippocampus. The spatio-temporal and contextual demands required for episodic memory retrieval challenge the ability of the hippocampus to integrate diverse stimuli into one scene and then to reinstate the context of this scene from a different perspective upon retrieval.

The ability to produce appropriate discourse is also heavily context-dependent and relies on the process of being able to take account of the differing perspectives and current status of knowledge of the listeners or readers present. Thus, a failure to adequately represent the frame of reference of another person or to inappropriately infer the presence of shared knowledge or beliefs means that communicative needs of others are not met. This leads to problems in effective communication and errors in discourse production.

Furthermore, consistent with the general tenets of reconsolidation theory, this model argues that the hippocampus is necessary for the retrieval and reconstruction of memories of previous events, whether verbally mediated or expressed through a visuo-spatial context. Finally, this model can also be applied to the spatial navigation deficits observed in tasks requiring the computation of a homing vector, since they also require the ability to update via the use of a cognitive map. In such tasks, the deficits in estimating direction, impair the process of path integration and the successful plotting of a route to the origin. From this framework, it can be argued that these difficulties arise from the need to be able to construct an allocentric representation or cognitive map of one's environment. Deficits in this domain result in these kinds of navigational errors.

4.22 Contributions of this research to current literature

This thesis has made a significant and valuable contribution to the current body of literature focusing on hippocampal functioning in humans. The most important contribution is the extension of O'Keefe and Nadel's (1978) theory to the domain of discourse production. Although they were the first to propose a link between language and the functions of the left hippocampus, this idea was only vaguely expressed in the concept that the left hippocampus contained a 'semantic map' underlying the 'deep-structure' of language. Their ideas concerning episodic memory as context-dependent provided the catalyst for focusing research almost exclusively on elucidating the link between the spatial and episodic functions of the hippocampus in humans. This was to the detriment of increasing understanding of aspects of discourse production among patients with hippocampal lesions.

In contrast, this thesis has given due attention to each of the three aspects of episodic memory, spatial representation and discourse production. It has also involved the development of a series of novel, real-world tasks to assess the nature and impact of the deficits among post-surgical SAH patients.

4.23 Limitations and strengths to the current research

The main limitation to the current research was the failure to carry out the more complex spatial navigational task of triangulation, which requires the computation of a homing vector. The results of this additional task would have greatly enhanced support for the model presented here. Furthermore, the assumptions of Worsley et al. (2001) may have been less tentatively accepted. However, due to constraints on the amount of time available to assess each participant, and the limitations of the room size, it was not feasible to conduct this task.

Furthermore, although it was intended to have equal numbers of both LSAH and RSAH patients, unfortunately this was not possible for two main reasons. Firstly, the population sizes for both groups were quite different, with a higher frequency of patients undergoing the RSAH procedure compared to LSAH. This meant that there were fewer patients in the LSAH group available to partake in the study. Secondly, a greater proportion of these LSAH patients compared to the RSAH group declined to take part in the study when contacted by the researcher.

A final limitation of the present research concerns the pre- and post-operative neuropsychological assessment results of the patient groups. Although the results obtained from the control sample are contained in Appendix 3.1, the absence of an equivalent set of data for the patient groups requires clarification. As stated in Chapter 2, Section 2.15, the patients completed these tasks as part of their one-year post-operative assessments, which were carried out by staff in the Department of Neuropsychology at Beaumont Hospital. However, at the time that this information was required for the purposes of this thesis, it was no longer available from the patients' hospital records. Furthermore, the staff of the Department of Neuropsychology no

longer worked in Beaumont Hospital; they had since taken positions in other hospitals, and therefore were unable to provide this material. The availability of such data would have enhanced the findings of this study in a number of ways. Firstly, by allowing comparisons to be made between the pre- and post-operative neuropsychological functioning of the patients who participated in this study. Secondly, have access to this data would have allowed additional comparisons to be made between the results of these standard assessments and those obtained through the use of the novel tasks that were designed and developed through this research.

However, it is this researcher's opinion that the merits of this study far outweigh its limitations. The main strengths of this study lie in the rigorous methodological procedures that were consistently applied in each of the validation studies and also in the main study. The inclusion of the two validation studies as ways of piloting the novel tasks among a large sample of control populations yielded important normative data. Regarding the main study, participants were selected via stringent selection procedures, which aimed to ensure that each of the participant groups was appropriately matched in terms of variables such as age and gender and so forth. Particular attention was applied to the patient groups, in ensuring as far as possible that the all participants had undergone the same surgical procedure, were at least one-year post-surgery, were seizure free and had an IQ level above 75.

In the main study, each participant was assessed by one person only, who used identical conditions and procedures for administering the various different tasks. The scoring of these tasks was carried out by this same person using an identical set of rules for each participant. In addition, all of the data entry and statistical analyses were performed by this one person. Furthermore, the same experimental environment was used for the spatial navigation tasks for all the participants and the same control of extraneous variables was applies (i.e. blindfolds and headphones). Thus, this researcher is confident that this study was carried out to the highest possible standards.

4.24 Future recommendations.

The findings reported in this study have serious implications for future research into the areas of episodic memory, spatial representation and discourse production among temporal lobe epilepsy patients. However, the overall recommendation is that it may no longer be appropriate to investigate the nature of impairments in one of these areas without considering the influence of the other components and their possible impact on the findings. If future investigations adequately assess the effects of hippocampal damage on episodic memory, spatial representation and discourse production, then a more complete understanding of hippocampal functioning in humans will be achieved.