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**AN ANALYSIS OF PERFORMANCE ON THE REY AUDITORY-VERBAL  
LEARNING TEST AFTER TRAUMATIC BRAIN INJURY, AND ITS  
ASSOCIATION WITH REPORTED EVERYDAY  
MEMORY PERFORMANCE.**

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**ROSLYN A. MCGILL**

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## ABSTRACT

The current study was conducted in two parts. Study 1 examined the Rey Auditory-Verbal Learning Test (AVLT) performance of 353 individuals who had been referred to an outpatient psychology clinic having sustained a traumatic brain injury (TBI). Individuals were divided into subgroups based on their patterns of performance on the AVLT. Individuals with low trial 1 scores were divided into three groups based on their subsequent AVLT performance. Individuals with low delayed-recall scores were divided into four groups based on their performance on preceding AVLT trials. For the TBI group as a whole, significant correlations were found between AVLT scores and age, education, and general intelligence (as measured by verbal IQ). Study 2 investigated relative ratings of everyday memory performance on the Patient Competency Rating Scale). This data was available for 82 of the individuals in the initial sample. The relationship between reported everyday memory performance and test performance on the AVLT was examined for this group. No significant correlations were found between these two variables. Low correlations were found between patient and relative ratings on the PCRS. Individuals were divided in four groups based on their everyday memory and test performance. Individuals with low everyday memory performance were found to have a similar type and number of difficulties, regardless of their AVLT performance. The results of this study highlight the varied performance of individuals after TBI, both on memory tests such as the AVLT and reported everyday memory performance. The AVLT should not be used to predict the level of difficulty in daily life as the correlations are not significant.

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## CHAPTER 1

### OVERVIEW

Traumatic brain injury (TBI) has an annual incidence of approximately 200/100,000 (Kraus & Sorenson, 1994; Morse & Montgomery, 1992; Smith, Barth, Diamond, & Giuliana, 1998). Motor vehicle accidents (MVA) are the cause of 50-70% of TBI (Ponsford, 1995; Smith et al., 1998) with falls, assaults, occupational accidents, and recreational accidents accounting for most of the remaining injuries (Evans, 1996; Ponsford, 1995). A high frequency of diffuse axonal injury (DAI) and damage to the orbitofrontal and inferior temporal regions result from MVA. Characteristic deficits associated with this type of injury include impairment of attention, information-processing speed, memory, learning, executive functions, and abstract thinking (Smith et al., 1998; Morse & Montgomery, 1992; Ponsford, 1995).

As stated, memory difficulty is one of the most common complaints following TBI and as such, is a leading cause of referral for neuropsychological assessment. Of those who have sustained a TBI, a large proportion (approximately 70%) continue to report significant memory impairment at one year post-injury (Brooks, 1983). Due to a large number of individuals with memory disturbance, and because memory is critical to most everyday activities, research into various aspects of memory has received considerable attention.

Memory involves multiple brain systems, including both the frontal and temporal lobes. Frontal deficits tend to involve source memory, temporal ordering, prospective memory, and working memory (Banich, 1997; Delis & Lucas, 1996), whereas the temporal lobe is involved in the storage and consolidation of new information (Ponsford, 1995). Specific structures proposed to contribute to memory include the hippocampus, fornix, thalamus, and mammillary bodies (Wilson, 1987). Damage to any of these regions can result in memory difficulties.

Memory difficulties vary widely among individuals, depending on factors such as the site and severity of damage, the type of injury, time since the injury, age at injury, and characteristics of the individual (Gilandas, Touyz, Beumont, & Greenberg, 1984; Long & Williams, 1988; Taylor & Price, 1994). Impairments can occur in one or all sensory modalities, and may occur for all types of material, or only certain types

(Golden, Moses, Coffman, & Strider, 1983). As a general rule, left hemisphere damage tends to result in problems with verbal memory, and right hemisphere damage is associated with visual or spatial memory difficulties.

Memory is involved in a variety of other cognitive processes, and is necessary for everyday functioning. Problems with memory tend to be debilitating educationally, socially and vocationally (Gilandas et al., 1984; Mateer & Sohlberg, 1988). Memory difficulty is also a barrier to successful rehabilitation or therapy, as little information tends to be retained from one session to the next (Ponsford, 1995).

Memory problems resulting from TBI can be evaluated by means of neuropsychological assessment, which can evaluate the subtle effects of TBI, usually not detectable with the current brain imaging techniques (Long & Williams, 1988). Neuropsychological assessment however, does not perfectly correlate with functional outcome. Some individuals who score below average on neuropsychological tests of memory have a great deal of difficulty in their everyday life. However, others with similar scores may have very few problems and be coping surprisingly well. Just why some individuals can cope in the face of low neuropsychological assessment results and others cannot is unclear. It would seem worthwhile identifying factors that enhance the individual's ability to compensate for difficulties resulting from TBI. It is proposed that the present study will investigate these factors.

The research will consist of two studies. Both studies will involve the use of a database of individuals who have undergone a neuropsychological evaluation due to difficulties resulting from TBI. In Study 1, Rey Auditory-Verbal Learning Test (AVLT) performance will be analysed, and the patterns of performance that follow low trial 1 scores and the patterns preceding low delayed-recall scores will be investigated. The contributions of age, gender, education and injury severity to AVLT performance will be analysed. The second study will compare AVLT scores and everyday memory performance (measured by the Patient Competency Rating Scale). Individuals will be divided into four groups based on high or low AVLT and PCRS performance, and will be compared on demographic and injury-related characteristics.

As background to the topic, a literature review of three chapters will cover mechanisms of TBI (Chapter two), cognitive and emotional sequelae of TBI (Chapter three), and memory (Chapter four). Chapter five presents the hypotheses and rationale for the studies, and methodology is presented in Chapter six. Chapter seven contains the results for each hypothesis, and these results are discussed in Chapter eight.

## CHAPTER 2

### TRAUMATIC BRAIN INJURY

#### EPIDEMIOLOGY

Statistics related to the prevalence of traumatic brain injury (TBI) are difficult to calculate for several reasons. Individual studies vary in the definitions and data collection methods employed. In terms of definitions, cross-study comparisons are difficult because no consistent method is used for identifying brain damage in patients. This is partly due to the fact that brain injury is not a part of the hospital classification systems. Some studies classify patients on the basis of the Glasgow Coma Scale score, others use the duration of loss of consciousness or post-traumatic amnesia, and others still classify on the basis of chart notations such as ICD codes. However, approximately ten ICD rubrics are required to cover most individuals with brain injury. Also several of these codes, such as those involving skull fractures, refer to injuries that may or may not have accompanying brain damage (Kraus et al., 1984; Tate, McDonald, & Lulham, 1998). Therefore, the use of these codes in estimates may result in the inclusion of individuals with no neurological impairment.

Annegers, Grabow, Kurland, & Laws (1980) and Kraus et al. (1984) are examples of studies using a variety of symptoms to define TBI, including the presence of concussion, brain lacerations, post-traumatic amnesia, loss of consciousness, skull fracture, development of a hematoma, or neurologic deficits. Others have used International Classification of Diseases (ICD) causality codes (Guerrero, Thurman, & Sniezek, 2000; Jennett & MacMillan, 1981; Klauber, Barrett-Connor, Marshall, & Boweres, 1981). Tate et al. (1998) used a combination of both, with ICD rubrics being initially used to identify patients, and then only including patients who had experienced an alteration in consciousness, such as loss of consciousness, post-traumatic amnesia, or amnesia for the event. Of the 1259 patients originally identified by the ICD codes, only 413 remained after being checked for alterations in consciousness. This indicates that ICD studies may result in inflated estimates of brain injury prevalence. Deb (1999)

reported low detection rates of ICD codes, with less than half of hospital admissions for TBI being detected by these codes. This indicates that many incidences of TBI are also missed by the ICD classifications. Deb proposed that one explanation for this was that ICD codes were often completed by trainee doctors or non-medical staff.

Estimates of prevalence also vary widely depending on the location of the data collection. The majority of estimates are based on hospital admissions and sometimes death certificates. Those with injuries mild enough not to require hospitalization are excluded from estimates, however a significant number will suffer from persisting difficulties related to their injury. Hospital policies for admission after mild brain injury vary, so studies in different geographical areas include varying proportions of these individuals. Since it is estimated that only 2/3 of individuals who have sustained a closed head injury will require hospitalization (Banich, 1997), current estimates based on hospital admissions are likely to underestimate the actual prevalence of brain injury in the community. Guerrero et al. (2000) report that recording emergency room visits rather than hospitalization yielded a prevalence estimate of 392/100,000.

The most accurate estimates are likely to be obtained from community-based epidemiological studies rather than studies conducted in hospitals or specialist centres where a number of selection processes influence the range of patients seen (Jennett, 1990). Studies based on small geographic areas have the least methodological problems, and are therefore seen as the most reliable. However, the incidence of brain injury in these small areas may not be representative of other populations (Rimel, Jane, & Bond, 1990).

Estimates of incidence were compiled for the purpose of this study in Table 1. As shown in this table, estimates can vary widely. The current conservative estimate of the annual incidence of brain injury is 200/100,000 (Kraus & Sorenson, 1994; Morse & Montgomery, 1992; Smith et al., 1998). New Zealand ACC statistics for 2001 report 14,255 new concussions and brain injuries. This translates to an incidence of 371/100,000, which is much higher than the overseas statistics. This data includes all individuals who are receiving income support, rehabilitation, or services such as home help. The cost of these new injuries in New Zealand is \$5,638,000 each year, with an additional \$17,185,000 per year from ongoing cases ("ACC injury statistics", 2001).

Table 2.1. Comparison of epidemiological studies

	Location	Sample Period	Sample N	Male:Female Ratio	Incidence per 100,000		
					Males	Females	Total
Annegers et al. (1980)	Minnesota	1965-1974	3587	2.3:1	270	116	-
Jennett & MacMillan (1981)	Scotland	1974	3615	-	-	-	322
Klauber et al. (1981)	San Diego	1978	5055	1.3:1 - 2.8:1	335	205	295
Kraus et al. (1984)	San Diego	1981	3358	2.0:1	247	111	180
Tate et al. (1998)	NSW, Australia	1988	413	2.7:1	-	-	100

## CAUSES OF INJURY

The main cause of brain injury in young children is falls, accounting for 63% of injuries to children under 5 years old (Tate et al., 1998). The major cause of brain injury from 5-14 years was sporting injuries, accounting for 47% of accidents in this age group (Tate et al., 1998). Annegers et al. (1980) found the largest cause within this category to be horseback riding accidents, especially among teenage girls, a finding that was replicated in a New Zealand study (Leathem & Body, 1997).

Males in general are 2-3 times more likely than females to sustain a brain injury (Kraus & Sorenson, 1994; Ponsford, 1995; Rimel et al., 1990). This can be seen in Table 1 with ratios ranging from 1.3-2.8:1. The highest risk for brain injury is among males aged 15-24, with an incidence of 245-658/100,000 (Annegers et al., 1980; Klauber et al., 1981; Tate et al., 1998). This increased incidence may reflect different levels of exposure to situations where TBI is likely to occur, especially motor vehicle accidents (MVAs) which are common between 15 and 24 years of age (Kraus & Sorenson, 1994). Tate et al. (1998) found that 64% of all MVAs occurred in this age group. The highest rate was for



males, with an annual incidence of 317/100,000 (Annegers et al., 1980). Assaults also peaked among males in the 15-24 age group, with an incidence of 67/100,000 reported by Annegers et al. (1980). However, this rate especially is subject to cultural influences. In Scotland among males of this age, the incidence of assaults was over twice that for MVAs (Jennett & MacMillan, 1981). The incidence of brain injury declines in middle age and rises again in older adults with an incidence of approximately 220/100,000 (Klauber et al., 1981), with the majority of these accidents (76%) being caused by falls (Tate et al., 1998).

Data on causes of TBI were compiled for the purpose of this study in Table 2. As Table 2 shows, some 40-53% of brain injuries are a result of MVAs. These accidents are more likely than not to result in damage, with more than 2/3 resulting in a brain injury (Rimel et al., 1990; Tate et al., 1998). The next most common cause is falls, accounting for 20-27% of brain injuries. In various studies, estimates have ranged from 5-45% for assaults, 6-10% for occupational accidents, and 6-25% for recreational accidents (Evans, 1996; Kraus et al., 1981; Kraus & Nourjah, 1989; Ponsford, 1995; Smith et al., 1998).

Table 2.2. Comparison of causes of brain injury

	Location	Sample N	Causes				
			MVA	Falls	Assaults	Sport	Other
Klauber et al. (1981)	San Diego	5055	53%	27%	9%	-	11%
Kraus et al. (1984)	San Diego	3358	48%	21%	12%	10%	9%
Tate et al. (1998)	NSW, Australia	413	40%	20%	8.2%	25%	6.8%

## RISK FACTORS

Brain injuries tend to occur more frequently among lower socioeconomic groups and among those with pre-existing behaviour problems (Kraus & Sorenson, 1994; Ponsford, 1995). Sufferers of brain injury are often risk-takers and are frequent drinkers or alcoholics (Jennett, 1990). Alcohol is frequently a contributing factor in accidents resulting in brain injury. Not all individuals hospitalized for brain injury are tested for brain injury. However, of those tested, 50-85% have been found with blood alcohol levels over 100mg% (Kraus & Nourjah, 1989; Smith et al., 1998).

A previous brain injury also increases the risk for future injury. After one injury the risk of another is increased three fold, and two previous injuries result in eight times the risk (Annegers et al., 1980; Morse & Montgomery, 1992). There are two common explanations for this phenomenon. The first is that the individual has personality and social characteristics, such as risk taking, that increases their involvement in behaviours likely to lead to TBI. The second explanation is that the first TBI results in poor judgment and reduced attention that increase the likelihood of a subsequent injury (Banich, 1997). A variable number of neurons and axons are irreversibly damaged at all levels of injury severity. When a second brain injury occurs, a large number of neurons often have already been damaged or destroyed by a previous brain injury or brain disease (Miller, Pentland, & Berrol, 1990). Therefore, a second brain injury of equal or lesser severity to the first will result in a greater amount of damage because the effects of brain injury are cumulative (Sweeney, 1992).

## MECHANISMS OF BRAIN INJURY

### *Primary Damage*

There are two main types of brain injury: blunt or closed injuries where the brain forcefully impacts with another object, but there is no skull penetration, and sharp or open injuries that involve an object, such as a bullet, penetrating the skull. The majority of brain injuries are closed, which tend to result in more diffuse injuries. Damage in these

injuries is caused by the rapid acceleration, deceleration and rotation of the brain within the skull. This can result in both focal damage and tissue strain. Regardless of the impact point, brain damage from a closed head injury (CHI) is likely to result in contusions to the frontal and temporal lobes, and stretching or disturbance of nerve fibres of white matter throughout the brain stem and cerebral hemispheres (Jennett, 1990).

The brain has a limited range of movement within the skull and dura. During the injury, the brain repeatedly comes into contact with the irregular inner surface of the skull due to lagging behind, continuing to plunge forward or oscillating during deceleration (Smith et al., 1998). The direction, force and velocity of the impact all influence the extent of the resulting damage. Impact can result in bleeding, bruising, compression and the brain tearing away from the skull at the point of impact (Golden et al., 1983). Contusions can also result from cavitation, in which pressure gradients from skull distortion at impact result in a sudden, negative vacuum-like pressure. Cavitation is thought to cause the contusions to gyri crests under a smooth area of the skull (Morse & Montgomery, 1992).

The most common areas in which contusions occur are the inferior frontal lobes, and the anterior and inferior temporal lobes where the skull surface is particularly rough. In these areas the brain crashes into the sphenoidal ridges, middle fossa, rough orbital bones, and frontal bone (Miller, et al., 1990; Walsh, 1991). Maximum damage at the site of impact (coup) tends to occur if the head is still on impact. If the head is moving during impact, pressure may result in the brain rebounding off the skull at the point opposite point from impact, causing a contrecoup lesion. Contrecoup lesions are especially likely in the temporal and orbital areas, and may lead to local loss of neurons followed later by subcortical demyelination (Golden et al., 1983; Wilson, 1987). Both coup and contrecoup lesions may occur, depending on the magnitude and location of the impact.

However, impact to the head is not necessary for brain damage to occur. There is often no impact to the head in MVA when the body is restrained by a seatbelt. Acceleration-deceleration injuries with no direct impact to the head typically result in diffuse damage (Bowman, 1996), however focal contusions and secondary damage may also occur. These more focal areas of damage affect certain aspects of functioning more

than others, leading to a wide range of variability among individuals in the sequelae of TBI.

### *Diffuse Damage*

The damage resulting from brain injury is generally widespread. Focal damage such as contusions often affect many areas, and axonal injuries may occur throughout the brain (Jennett, 1990). This widespread nature of damage is thought to be responsible for the typical dysfunction resulting from brain injury that affects many areas of mental functioning.

Diffuse damage is the most common type in CHI and it occurs as the brain moves within the skull resulting in the twisting, compression and shearing of neurons. The shearing of axons is referred to as diffuse axonal injury (DAI). DAI can be seen at the microscopic level and can occur without loss of consciousness (Morse & Montgomery, 1992). However, diffuse damage typically has negative findings on brain imaging, which in the past has led to the conclusion that there was no neurological basis for sequelae experienced after this type of injury. The brain looks relatively normal, apart from moderate ventricular enlargement. On autopsy, axon retraction balls can be found to scattered through the white matter, and microglial stars are found along with demyelination at the points where axons converge into tracts (McAllister, 1994; Miller et al., 1990).

The neurons most susceptible to twisting or shearing are those with long axons that connect distant brain regions (Banich, 1997). Commonly affected areas include the corpus callosum, grey-white matter junctions around the basal ganglia, the periventricular zone of the hypothalamus, parasagittal and rostral midbrain areas, and the dorsal lateral quadrant of the rostral brainstem (Morse & Montgomery, 1992).

Disruptions to membrane permeability or the breaking of axons result in electrical transmission dysfunction (Morse & Montgomery, 1992). The compression or stretching of axons can have rapid consequences, leading to impaired axoplasmic transport and swelling within 3 hours of the injury. Axons may attempt to regenerate through

sprouting, or reactive deafferentation (death of neurons that receive input from the damaged axons) may occur within 60 days (Lucas, 1998).

### *Secondary Damage*

Secondary damage results from processes that begin at the moment of injury, but do not clinically appear immediately. This includes increased intracranial pressure (ICP), hematomas, hydrocephalus, diffuse hypoxia-ischemia, generalized edema, swelling and distortion of brain tissue, altered brain metabolism and neurotransmitter dysfunction (Jennett, 1990; Lucas, 1998; Smith et al., 1998).

Undamaged cells are subject to metabolic and neurochemical changes. There is an initial sharp increase in acetylcholine and excitatory amino acids (e.g. glutamate) (Lucas, 1998). The increased concentration of glutamate results in neuronal depolarization and flux of potassium across the membrane out of the cells. The change in potassium increases glycolysis and results in metabolic depression- metabolism and CBF (Lucas, 1998).

The brain is a large consumer of blood and oxygen, using 1/5 of the resting cardiac blood flow output and 1/6 of the body's oxygen (Miller et al., 1990). Any interruptions in these supplies can result in further brain damage. Raised intracranial pressure is one factor that can limit the amount of cerebral blood flow (Miller et al., 1990). In a MVA, the airway is often obstructed by blood from a facial injury, vomit, or the face being smothered in a seat. Neurologic dysfunction occurs after 15 seconds without oxygen, and after a few minutes the damage may be irreversible (Miller, et al., 1990). Areas vulnerable to hypoxia are those with a high metabolic demand, including the hippocampus, basal ganglia, cerebellum, and cortex (Morse & Montgomery, 1992). The hippocampus is involved in 81% of hypoxic cases, and the basal ganglia is involved in 79% (Miller, et al., 1990).

Swelling may occur in any area in which a lesion has occurred. The brain tissue surrounding the lesion may swell and compress against the skull (Miller et al., 1990; Thomas & Trexler, 1982). Areas especially vulnerable to distortion are the cingulate gyrus, the brain stem and the parahippocampal gyri (Morse & Montgomery, 1992).

Hematomas are estimated to occur in 15-35% of severe CHI in adults (Eisenberg & Weiner, 1987). They are more common after low velocity injuries such as falls. Hematomas after TBI can result in death or disability, however they are avoidable complications. Hematomas (especially if they are anterior and unilateral) may not result in any abnormal neurological signs until several days later when herniation and swelling occur (Miller et al., 1990). Individuals who have suffered a brain injury are at risk whatever their injury severity, so even those with reasonably mild injuries tend to be kept in hospital for observation until the risk period is over.

Subdural hematomas result from lacerated cortical vessels. Focal damage in these cases is from a combination of the mass of the clot and adjacent lacerated swollen tissue (Morse & Montgomery, 1992). Intracerebral hematomas result from shearing forces. They tend to initially be smaller and expand later. Focal damage occurs through direct structural damage and lacerations of blood vessels. Epidural hematomas are associated with fractures or distortions of the skull and do not tend to involve tissue injury. They mainly occur over the temporal lobe (Miller et al., 1990).

## **SEVERITY**

There are a variety of methods used to classify injury severity. These include the Glasgow Coma Scale, and the duration of post-traumatic amnesia and loss of consciousness. Each study may use a different method of classifying severity, making cross-study comparisons of severity levels difficult.

### ***Post-traumatic Amnesia***

One of the most widely used severity classifications is the length of post-traumatic amnesia (PTA), however studies vary in the exact lengths assigned to each severity level. PTA involves the lack of continuous memory for daily events immediately after the injury, and can last from a few minutes to months (Lucas, 1998). It occurs as a result of the interruption of the mechanisms for encoding and storing new memories (Lucas, 1998). These include the diencephalon and other higher systems that are slow to

recover after injury (Mateer & Sohlberg, 1988). One advantage of PTA is that it can be assessed retrospectively long after the injury by asking the patient how long it was before they 'came to' or began to be aware of their surroundings (Jennett, 1990). However, if memory difficulties are present this report may be unreliable, especially if the assessment is carried out a long time after the injury.

It has been found that the length of PTA is closely related to evidence of tissue damage (Golden et al., 1983). It is also correlated with interval before return to work and late outcome (Jennett, 1990). An injury is generally classified as mild if PTA is less than one hour, 1-24 hours is moderate, and more than one day is severe (Jennett, 1990; Lucas, 1998; Morse & Montgomery, 1992; Tate et al., 1998). However, Annegers et al. (1980) differed from these studies, defining mild injuries as those with a PTA less than 30 minutes, and moderate as 30 minutes to 24 hours. Some researchers such as Jennett (1990) divide PTA further, with less than 5 minutes classified as very mild, 1-4 weeks as very severe, and more than 4 weeks as extremely severe.

### *Loss of Consciousness*

The duration of loss of consciousness (LOC) is also used as an indicator of injury severity. LOC ranges from clouding of consciousness to a coma lasting weeks or months (Banich, 1997; Ponsford, 1995). Impaired consciousness tends to follow most closed head injuries (except very mild injuries) and the duration is associated with injury severity, with longer durations linked to more permanent brain damage (Golden et al., 1983; Jennet, 1990; Tate et al., 1998). Consciousness depends on the integrity of the ascending reticular activating system and its interaction with the cortex, thalamus, hypothalamus, cerebellum, medulla and spinal cord (Miller & Pentland, 1990). A gross estimate of the level of brain damage sustained can be inferred from LOC because a diffuse injury affects the brain stem and other areas of the brain at an equivalent level (Banich, 1997). Injuries are classified as mild if LOC is less than 30 minutes, moderate from 30 minutes to 24 hours, and severe for periods longer than 24 hours (Annegers et al., 1980).

### *Glasgow Coma Scale*

The Glasgow Coma Scale (GCS) is another widely used measure for classifying severity. It assesses the level of consciousness based on verbal response, motor response, and stimulus to provoke eye opening. However, this scale has been criticized for only providing a narrow range of information, and having no provision for untestable modalities (Eisenberg & Weiner, 1987). Earlier versions of the GCS contained more items, but they have been removed to increase the reliability of the scale. The inter-rater reliability of the GCS is high (Miller et al., 1990), enabling comparisons of severity across centers. The GCS is also a time-dependent measure that must be administered as soon as possible after the injury. In practice, it tends to be administered at arbitrary time points. Another disadvantage of the GCS is that it cannot be administered retrospectively as PTA can. A score of less than or equal to 8 is classified as severe, 9-12 as moderate, 13-15 as mild.

The scale is useful in the prediction of survival rates and future level of functioning (Banich, 1997). However, the scale is more sensitive and more useful for prediction with moderate and severe injuries (Lucas, 1998). Miller et al. (1990) found a GCS score of 8 or less was associated with 40-48% mortality (excluding gunshot wounds). Mortality dropped to 6% with a score of 9-11, 1% for 12-13, and no mortalities occurred with a score of 14 or 15.

## **LEVELS OF SEVERITY**

### *Mild TBI*

Mild injuries are generally defined as having PTA or LOC lasting one hour or less. They generally have a GCS of 13-15, and have no skull fracture present. Incidences range from 62.2% (Tate et al., 1998) to 72.5% (Kraus et al., 1984). Usually, only hospitalized individuals with mild injuries are included in these estimates. There are estimated to be 4-5 more mildly brain injured individuals not admitted to hospital for every patient hospitalized with brain injury (McAllister, 1994).



Cognitive deficits may result even from damage not large enough to cause a coma (Jennett, 1990). Dikmen, Machamer, Winn, and Temkin (1995) found that those with a coma of less than 1 hour were not significantly different from controls on neuropsychological tests. However, selective attention and memory deficits became apparent in those with a coma of 1-24 hours duration.

Mild TBI has a better prognosis than injuries of greater severity. Most cognitive deficits (such as memory, slow information processing speed and attention) fail to be detectable on neuropsychological tests beyond 3 months (Lucas, 1998; McAllister, 1994; Ponsford, 1995), but some individuals continue to experience functionally significant difficulties for some time.

Hanlon, Demery, Martinovich and Kelley (1999) studied 100 patients with mild TBI and found more individuals with negative CT scan results had prior psychiatric problems (22%) and were involved in litigation (48%) than those with positive CT findings (4% and 18% respectively). In the sample as a whole, there was no significant relationship between litigation status and vocational outcome. Vocational outcome was also not significantly related to CT results, the presence of LOC, gender, presence of prior concussion or a psychiatric history. Logical Memory I and Visual Reproduction II scores were moderately correlated with vocational outcome ( $r=0.39$ ,  $p<0.01$  and  $r=0.32$ ,  $p<0.01$ ), suggesting that the hippocampus and cholinergic system may be disrupted in mild TBI.

### ***Moderate TBI***

Moderate injuries have an LOC or PTA ranging from 1 to 24 hours and a GCS score of 9-12. Incidences range from 8% (Kraus et al., 1984) to 20.3% (Tate et al., 1998). Injuries of this severity tend to be the most variable in their outcome. Dikmen et al. (1995) found that those with moderately severe injuries had a range of impairments on neuropsychological tests.

The distinction between mildly and moderately injured individuals is often not obvious clinically. There is an overlap in these groups, so many in the mildly injured group continue to have functional difficulties for some time, and some of those in the

moderately injured group may only have high level difficulties in the long term (Morse & Montgomery, 1992).

### *Severe TBI*

Severe injuries involve a period of PTA or LOC longer than 24 hours, and a GCS of 8 or less. TBI may also be classified as severe if neurosurgery is required (Kraus et al., 1984). Incidences range from 7.9% (Kraus et al., 1984) to 13.6% (Tate et al., 1998). Severe injuries are more concentrated among 15-24 year olds, mainly due to car or motorcycle accidents, which are the cause of 43-66% of all severe injuries (Annegers et al., 1980; Tate et al., 1998). Most fatal injuries (50-73%) are also caused by MVAs (Annegers et al., 1980; Klauber et al., 1981).

In more severe injuries, permanent impairment is probably inevitable (Gilandas et al., 1984). Severe injury is likely to result in both cognitive and physical difficulties. The combination of these leads to greater social handicap than either of them alone (Jennett, 1990). Dikmen et al. (1995) found severely injured individuals (>2 weeks coma) to have large impairments on all measures. Verbal IQ was 14 points lower and performance IQ was 22 points lower relative to controls (who had sustained some other trauma and were matched on age, sex and education).

For all severity levels of TBI the association between the severity of the injury and the level of subsequent difficulties is not perfect. Both good and bad outcomes occur through all levels of severity.

### **POST-CONCUSSIVE SYNDROME**

Individuals who have experienced a mild injury are most likely to have suffered a fall or assault. Concussion is often associated with this level of injury. Concussion involves a period of loss of consciousness or confusion, along with other symptoms indicating brain-stem involvement. These include changes in blood pressure, heart rate, and respiration (Miller et al., 1990). A significant portion of individuals who have experienced a mild TBI continue to complain of difficulties and exhibit problems on

neuropsychological tests for months and even years after the injury (Morse & Montgomery, 1992). These persistent symptoms are referred to as post-concussive syndrome.

The existence of persistent difficulties following mild TBI has been an area of controversy in recent years. It was previously believed that concussion was a transient alteration in consciousness without structural damage to the brain, so behavioural symptoms should be brief in duration (Lucas, 1998). Since damage is diffuse, brain imaging usually shows no evidence of structural damage, and many of the deficits are too subtle to be detected on neuropsychological tests. Due to these factors, persisting symptoms were thought to be psychogenic in origin. Recently there has been a growing recognition that structural damage does occur in mild brain injury, with consequences for cognitive and emotional functioning (Lucas, 1998; Morse & Montgomery, 1992).

Post-concussive syndrome is estimated to occur in 15% of mild TBI (Alfano & Satz, 2000). The greatest risk for post-concussive syndrome occurs in individuals who are of lower SES, over the age of 40, have had a previous TBI, in demanding occupations, and have family or social stressors (Morse & Montgomery, 1992; Sweeney, 1992). Complications such as fractures also increase the likelihood of persistent symptoms (McAllister, 1994).

Symptoms of post-concussion syndrome include dizziness, headaches, irritability, tinnitus, blurred vision, restlessness, reduced speed of thought, insomnia, nausea, loss of appetite, sensitivity to noise and light, concentration difficulties, memory problems, fatigue, irritability, anxiety, and depression (Morse & Montgomery, 1992; Ponsford, 1995; Tiersky, Cicerone, Natelson, & DeLuca, 1998).

## **PREDICTORS OF OUTCOME**

Several factors have been found to influence the outcome of TBI. These include the individual's personality, medical history, other injuries sustained in the accident, psychosocial status, economic and vocational status, location and type of injury, environmental factors, the emotional response to changes in cognition, the length between the injury and testing, and the impact of post-injury changes on personal and

professional roles, relationships and families (Dikmen et al., 1995; Gilandas et al., 1984; Tate & Broe, 1999; Taylor & Price, 1994).

Age is an important factor in outcome, with younger individuals more likely to survive than older individuals (Levin, Benton, & Grossman, 1982; Ponsford et al., 1995, as cited in Bowman, 1996). Intracranial hematomas, which have a higher mortality, are more common among older people (Miller et al., 1990), and the likelihood of dying from medical complications of prolonged coma is increased.

Pre-morbid characteristics of the individual are also thought to influence the extent of the cognitive difficulties experienced (Morse & Montgomery, 1992; Ponsford, 1995). Factors reported to be associated with lower outcomes include previous head injuries, previous personality disorder and adjustment problems, drug or alcohol abuse, psychiatric disorders, a demanding occupation, and concurrent stresses (Ponsford, 1995). However, several of the previously mentioned factors have not been well established. Factors associated with a greater likelihood of a favourable outcome include higher IQ and SES, younger age and a stable home environment (Long & Williams, 1988).

Some post-injury symptoms, such as headaches, dizziness, fatigue, crying and irritability are thought to be related to anxiety in the brain-injured individual (Ponsford, 1995). These are post-concussion symptoms, and were previously thought to be purely psychological, however it has been established that there is a neurological basis for these symptoms in some individuals. Another proposed explanation for these symptoms is that they result from chronic effort to cope with the acquired cognitive deficits and expectations that the brain-injured individual will be able to resume their pre-injury activities without difficulty (van Zomeren & van den Burg, 1985, as cited in Ponsford, 1995). The individual's response to the new cognitive deficits and the emotion repercussions mediate the cognitive and behavioural difficulties experienced following TBI (Tate & Broe, 1999).

Litigation status has received a reasonable amount of attention in research in the United States, but it is unlikely to be a factor among New Zealanders with brain injury as litigation is uncommon. A more likely factor in this country is likely to be the provision of compensation for lost earnings from the ACC. Overseas research regarding litigation

has been inconclusive, with some studies reporting a relationship and others not (Dikmen et al., 1995).

Deficits tend to gradually improve over time, however there is sometimes a negative relationship between time since injury and functional outcome. This may be due to the individual having an increasing vulnerability to deteriorating influences. Any deterioration interacts with other factors and may lead to other negative effects such as the erosion of support systems (Putnam & Adams, 1992).

## **CONCLUSION**

TBI is a wide-ranging problem, affecting thousands of individuals each year, mainly young males. Many of these individuals experience lasting cognitive, behavioural and emotional deficits as a result of these injuries. These resulting deficits will be discussed in the next chapter. The average age at which a brain injury occurs is less than 30 years old, so these individuals have many years of disability ahead of them (Jennett, 1990). Persisting deficits after TBI place a large financial burden on health services, and both financial and emotional burdens on the families of affected individuals.

More and more brain-injured individuals are attending neuropsychologists for assessments. A major reason for this increase is that medical advances have reduced mortality, resulting in a larger number of individuals with chronic deficits (Long & Williams, 1988). Acute management has been improved, with more rapid transfer to hospital and improved techniques for monitoring and reducing intracranial pressure (Ponsford, 1995). With 339/100,000 new cases in New Zealand each year requiring medical care and possibly rehabilitation and compensation for lost earnings, TBI requires a large amount of resources.

With the high prevalence of TBI and the large burden it creates, any attempts to reduce the consequences of TBI are worthy of further investigation. The present study will attempt to identify factors associated with a good functional recovery, and examine how these can be applied to help reduce functional difficulties in TBI sufferers.

## **CHAPTER 3**

### **SEQUELAE**

#### **INTRODUCTION**

Traumatic brain injury can result in a wide range of symptoms, including cognitive, interpersonal, emotional and physical. These difficulties can negatively influence the individual's ability to work, learn, live independently, and maintain relationships with others.

Deficits are often not apparent immediately after the injury, when few cognitive demands are placed on brain-injured individuals. Even though neuropsychological test results improve over time, deficits may subjectively appear to increase. With time, individuals gradually return to social activities and work. These activities place more cognitive demands on the individual, exposing previously undiscovered deficits (Prigatano, 1995). It is only when individuals attempt to return to their everyday activities that the individual and their family will be able to see to full extent of the difficulties.

Deficits can be extremely incapacitating, leaving the brain-injured individual unable to participate in their previous occupational and social activities. The loss of friends and work status can result in lower self-esteem and other emotional reactions that can also contribute to difficulties after brain injury (Brooks, 1990).

#### **COGNITIVE SEQUELAE**

The majority of brain injuries are MVA, which typically results in frontal and temporal damage accompanied by diffuse axonal injury (DAI). This results in a characteristic range of impairments, including problems with information processing speed, attention, memory (especially for new information), executive function, cognitive flexibility, abstract thinking, and self-regulation of thoughts (Banich, 1997; Livingston, 1990; Lucas, 1998; Morse & Montgomery, 1992; Ponsford, 1995; Smith et al., 1998).

The primary source of cognitive difficulties is proposed to be DAI (Morse & Montgomery, 1992). It affects signal transmission in white matter, which slows the speed and integrity of neuronal processing (Grafman & Salazar, 1987). Thought processes, and the analyzing, processing and integrating of information are all slowed. Brain injured individuals tend to obtain reduced success on speeded tests due to this reduced information processing speed.

### *Attention*

Attention difficulties are a common consequence of TBI and can occur at all levels of severity (Ponsford, 1995; Watt, Shores, & Kinoshita, 1999). There seem to be deficits in selective and sustained attention. Attention problems may be the basis of what appears to be memory difficulties (Lezak, 1995). Adequate attention is necessary for learning of new information to take place. Difficulties such as reduced selective attention, sustained attention, fatigue and reduced speed of information processing can all lead to memory difficulties (Gilandas et al., 1984; Ponsford, 1995).

Others such as van Zomeren & Brouwer (1984, as cited in Ponsford, 1995) suggest that there is little evidence for the existence of attention deficits, with poor test performance resulting from slower information processing speed. Individuals with TBI are slower at most aspects of cognition, from understanding the task to forming plans to carrying out those plans (Brooks, 1990). Slower information processing leads to difficulties coping with complexity and focusing on more than one thing at once (Ponsford, 1995).

The role of attention in memory is often investigated through studies of implicit memory. Individuals with TBI tend to have impaired explicit memory (consciously remembering previously presented information), but their implicit memory is generally intact. (Schmitter-Edgecombe, 1996; Schmitter-Edgecombe & Nissley, 2000). Implicit memory is assessed without conscious recollection of the learning experience, using word-stem completion or word fragmentation. Priming is the enhanced tendency to complete word-fragments with previously presented stimuli. These two types of memory

are thought to require different amount of attentional resources (Parkin, Reid, & Russo 1990, as cited in Watt et al., 1999).

Attention is a capacity limited processing resource (Schmitter-Edgecombe, 1996). This is especially apparent after TBI when attention capacity is often reduced (Schmitter-Edgecombe, 1996; Schmitter-Edgecombe & Nissley, 2000). In normal controls, conscious recollection declines as attention available at learning decreases but there is little change in implicit memory (Schmitter-Edgecombe & Nissley, 2000; Watt et al., 1999). Watt et al. (1999) found that divided attention during learning interfered with the implicit memory of the TBI group, but not the control group. They concluded that reduced attention may have greater effects if information processing speed is already reduced. They also proposed that implicit memory may require additional attentional resources not available after a severe TBI. Schmitter-Edgecombe (1996) also found that divided attention reduced the implicit memory of TBI group relative to controls, but the priming of the TBI group was higher in the full attention condition. The priming in the divided attention condition was the same level for both groups. It was suggested that this hyper-priming could result from slower perceptual processing or stimuli being identified more slowly.

### *Neuroanatomical Correlates of Memory*

The reasons underlying memory difficulties are often difficult to identify. Deficits are generally thought to occur as a result of diffuse brain damage, and specifically limbic damage (Teasdale & Brooks, 1984, as cited in Brooks, 1990). However memory difficulties are often also associated with reduced motivation, depression, attention problems, and frontal damage where plans for efficient learning are not made (Brooks, 1990; McKinlay & Watkiss, 1998).

Memory involves a variety of cognitive processes and brain structures (Lovell & Franzen, 1994). The type of memory disorder experienced depends on the site and extent of the damage sustained. Temporal lobe damage is associated with difficulties storing and consolidating new information, and recent memory. The temporal lobe and limbic areas are particularly susceptible to contusions and hypoxia, which result in memory



difficulties (Gilandas et al., 1984; Lovell & Franzen, 1994). The hippocampus is located in the medial temporal lobe. This is a vulnerable location, as the anterior temporal lobe is often propelled into the sphenoidal ridge at the front of the skull (O'Shanick & O'Shanick, 1994). Severe damage to both medial areas of the brain and the temporal lobes results in amnesic syndrome. This involves profound deficits of both short- and long-term memory, and manifests as a complete loss of recall, except for partial recall of events preceding the injury (Rosenthal & Bond, 1990).

Frontal lobe damage creates deficits that are qualitatively different from those of temporal lobe damage. Some memory difficulties are caused by failure to use active learning strategies, reduced memory for temporal or contextual information, and difficulties in the self-monitoring of performance, detecting errors, and using feedback on errors to modify responses (Malloy, Cohen, & Jenkins, 1998; Walsh, 1991).

### *Memory Outcomes*

Except in very mild injuries, individuals often experience a period of PTA after their injury during which they lack continuous memory for what is happening around them. This period can last minutes to weeks. For many individuals, residual difficulties in learning and storing new information exist after PTA has ended (Gilandas et al., 1984; Long & Williams, 1988; Lovell & Franzen, 1994; Mateer & Sohlberg, 1988; Ponsford, 1995; Schmitter-Edgecombe & Nissley, 2000; Walsh, 1991; Watt et al., 1999).

The occurrence of memory difficulties appears to be associated with the duration of PTA (Gilandas et al., 1984; Grafman & Salazar, 1996). After a severe TBI, 59% report forgetfulness after 6 months, 69-87% after 12 months, and 68-80% after 2 years (Taylor & Price, 1994). A minimum of 25 % are thought to have disabling memory disorders after severe TBI (Lovell & Franzen, 1994).

The range of memory impairment after TBI is very diverse. It varies regarding the types of material (verbal versus nonverbal) and modalities (auditory versus visual) affected. Right hemisphere damage is associated with visual memory impairment, and the left hemisphere is associated with auditory-verbal deficits (Gilandas et al., 1984).

After severe TBI, individuals often have a generalized difficulty with episodic memory, while immediate recall and older memories tend to be unimpaired (Grafman & Salazar, 1996; Watt et al., 1999). Immediate memory impairment is usually minor unless the injury was extremely severe (Brooks, 1990). However, deficits may be found on very complex or prolonged tasks, especially soon after the injury (Wilson et al., 1988, as cited in Brooks, 1990).

Frontal damage tends to result in difficulties maintaining the intention to remember and using organizational strategies aid learning (Ponsford, 1995). Difficulties appear with novel and complex information. There are also difficulties in organizing the material to be learned. The mental programs that usually control strategies that aid encoding and retrieval are suppressed (Walsh, 1991).

Stuss & Benson (1986) have proposed two frontally mediated functional systems. These systems are named drive and sequencing. They provide the motivation needed for the effective functioning of posterior and basal systems, including the integration and sequencing of information from these areas, and the sequencing of behavioural responses. Drive and sequencing are proposed to be monitored by the executive control system. The dorsolateral prefrontal cortex is associated with short-term or working memory (Kertesz, 1994, as cited in Vanderploeg, 2000), and is also proposed to be involved in sequencing abilities.

Frontal damage can result in enhanced proactive interference, impairment of working memory and retrieval, forgetting to remember, and problems with contextual memory. The first two of these indicate control difficulties in screening for irrelevant stimuli, or keeping information active and organized in working memory. The next two difficulties seem to indicate problems with initiation of a memory retrieval search. Contextual memory difficulties are consistent with sequencing problems. Information must be correctly categorized and sequenced with reference to time and place for contextual memory to be intact (Vanderploeg, 2000).

### *Test Performance*

The ecological validity of neuropsychological tests is especially important in rehabilitation settings. Tests have advantages in their standardization and normative data, however, they test performance in an artificial setting. Tests are often strictly timed, context-free, and generally require short answers (Gardner, 1987). Due to these characteristics, they do not reflect the demands of daily life. Because tests do not directly measure everyday activities, performance in these activities must be inferred from the measured skills. As a result, the tests often have low correlations with everyday functioning. Individuals are tested in a distraction-free environment to obtain a measure of performance under optimal conditions. However, conditions in everyday life are seldom optimal, so the individual may have functional difficulties that are not apparent in their test results.

Test results are also vulnerable to distortion by factors such as motivation, depression, fatigue, and performance anxiety (Alfano & Satz, 2000). It has been suggested that while tests capture domain-specific performance, they do not examine the ability to integrate multiple cognitive functions as is done in real-world tasks.

Neuropsychological testing of brain injured individuals show evidence of continued problems in learning, recall and recognition (Ponsford, 1995). A common complaint after TBI is the loss of memory for events in immediate life, such as where the car keys were placed, or being unable to recall a list. This is the result of encoding difficulties, which is assumed to involve the hippocampus (O'Shanick & O'Shanick, 1994). Working memory deficits also contribute to these difficulties.

Memory problems are most apparent on tests of recall, especially if there is a delay between presentation and recall (Morse & Montgomery, 1992). Individuals with TBI tend to do better on recognition tests than tests of recall (Ponsford, 1995). If recognition test scores are significantly better than recall scores, this suggests that the difficulty is in retrieval of information rather than encoding or storage. Successful retrieval also requires the hippocampus (O'Shanick & O'Shanick, 1994).

One function of neuropsychological assessment is to identify at which stage of the memory process (encoding, storage or retrieval) the problem occurs. Slow information

processing can result in disorders of all three memory stages. The nature of the deficit is often difficult to unravel, leading to the conclusion that all three stages may be impaired, or another process such as information processing or the formation of plans for learning may be partly responsible (Brooks, 1990).

### *Functional Memory*

A consideration of functional memory in the assessment process is important, as it provides a description of the interaction between the deficit and the memory demands of the individual's environment. Studies on the elderly have found that fewer prospective memory failures is related to having fewer appointments to keep and being involved in less demanding activities (Maylor, 1996).

The functional problems typically experienced relate to problems recalling details of recent experiences. They include forgetting to follow through with intentions and obligations, misplacing objects, repeating questions, difficulty learning new information and getting lost more easily (Heaton & Pendleton, 1981). Memory deficits can also reduce an individual's ability to follow conversations, spontaneously use compensation strategies, plan activities, and complete other activities of daily living (Makatura, Lam, Leahy, Castillo, & Kalpakijan, 1999). These individuals have problems living independently- they have problems keeping track of activities, finances and social relationships, and may cause fires through forgetting to turn off appliances or put out cigarettes. Memory deficits impact least on tasks where it is apparent what steps need to be taken and can be completed without interruption (Heaton & Pendleton, 1981). Those with the most severe difficulties may be unable to retain and information from recent experiences, and consequently would not improve over subsequent learning trials on tests.

Compensation strategies may be used to reduce functional memory difficulties. Individuals with mild memory deficits are unlikely to have many functional difficulties if they use some compensation techniques (Heaton & Pendleton, 1981). A commonly used environmental modification is signs around the house or workplace describing where items are located or how to operate a machine or appliance. This decreases the need for

retrieval of information from memory. The memory notebook is another external aid, and has been one of the more successful memory aids (Mateer & Raskin, 1998). This notebook is also used to reduce memory demands by recording names of people, appointments, and other information needed in daily life. Another category of memory aids is cues. Cues may be specific information given by a family member, or they may be more general, such as an alarm when it is time to carry out a task. This places more demands on memory than the former approach, as the individual must recall what task needs to be done or where to look up that information. Internal strategies are even more demanding on memory. They require the individual not only to remember the strategy, but also to recognize when to apply it. Such strategies include such methods as peg words, method of loci and visual imagery.

## **OTHER FACTORS INFLUENCING ASSESSED OUTCOME**

### *Personality and Emotional Factors*

Emotional disturbance and behavioural changes are common after almost all types of brain dysfunction. These changes may be due to alterations in neural substrates for mood or behaviour, psychological reactions to the loss of previous abilities, or environmental changes resulting from altered neurobehavioural status (Gass, 2000). Common emotional problems after TBI include anxiety, depression, frustration, irritability, apathy, anger and withdrawal (Lucas, 1998; Morse & Montgomery, 1992; Taylor & Price, 1994). Emotional problems such as anxiety, depression and low frustration tolerance can lead to cognitive inefficiency in daily life, which in turn results in impaired test performance and complaints of memory or attention difficulties (Gass, 2000).

Significant social and emotional problems are likely to result from cognitive dysfunction, particularly if it has not been detected (Long & Williams, 1988). It seems natural that emotional reactions would occur given the vast changes in the life of the individual. They must cope with loss of their previous capabilities, loss of relationships and roles, and the expectations of themselves and others that they will be

able to resume their previous activities. In the short-term, an individual may attempt to compensate for their deficits by increasing the effort they put into tasks. However, chronically raised levels of effort can result in secondary symptoms of stress, such as anxiety (Brooks, 1990).

Some personality changes are based on structural brain damage, and depend on the severity and location of the lesions. Lesions in the temporal lobe (limbic) are associated with changes such as dull or flattened affect, uncontrolled rage, irritability, sudden changes in mood, and unprovoked laughing or crying (Lucas, 1998; Rosenthal & Bond, 1990; Taylor & Price, 1994). Frontal lesions are associated with lack of goal-directed behaviour, lack of awareness of deficits, apathy, perseveration, emotional blunting, disinhibition, childishness, lack of organization or planning and problems with self-regulation of behaviour (Banich, 1997; Cook, 1990; Livingston, 1990; Morse & Montgomery, 1992; Rosenthal & Bond, 1990; Taylor & Price, 1994). These changes are often referred to as dysexecutive syndrome. Different locations of damage within the frontal lobe may result in different symptoms. Dorsolateral lesions tend to result in disorders of planning and a lack of ability to correct behaviour after errors are made (resulting in learning difficulties) (Brooks, 1990). Basal lesions are associated with disinhibition (difficulty suppressing a previously learned response), and medial frontal damage, which is less common, tends to result in poor self-direction, reduced drive, and apathy (Brooks, 1990). Dysexecutive symptom can also result from DAI. There can be a widespread disruption of white matter connections, which can affect widely distributed frontal systems (Malloy, Cohen, & Jenkins, 1998).

### *Depression*

It is not clear how depression affect neurocognitive performance after brain injury. Depression is associated with more uncorrected errors, less elaboration of responses, and slower speed of thought and idea generation (Morse & Montgomery, 1992). However, some psychologists believe that both clinicians and relatives often mistake the lack of initiation and apathy resulting from frontal damage as being signs of depression (Gass, 2000).

Sherman, Strauss, Slick, and Spellacy (2000) found that 33% of brain-injured individuals had Depression scores on the MMPI in the clinical range. The individuals were tested on the WAIS-R, Boston Naming Test, Logical Memory, CFT, Trials A and B, Word Fluency, WCST, Stroop, and PASAT. The low depression group most frequently had no neuropsychological impairment (31%), and the high depression group was most frequently impaired on 10-20% of the tests. Only 12% of the high depression group had no neuropsychological impairment. Wider ranges of impairment (on more than 20% of tests) had similar proportions of high and low depression. It was concluded that depression only has a small effect on neuropsychological functioning that is only apparent in those impaired on a small range of tests.

### *Physical Factors*

Symptoms such as fatigue and irritability are often enough to result in dysphoric mood after a mild TBI. The presence of residual cognitive difficulties can further add to this effect. Mildly injured individuals are more likely to retain full awareness of their attentional and information-processing difficulties. Effort is required for tasks that were previously automatic, and the individual often has difficulty tracking multiple tasks. These effects can result in a loss of self-confidence and anxiety about the future unless they are addressed early with appropriate education on the consequences of mild TBI (Lucas, 1998).

### *Awareness*

A decrease in self-awareness is often a consequence of damage to the frontal lobes, in particular the prefrontal area. This involves deficits in the individual's ability for self-reflection concerning limitations in cognitive, social, and behavioural competencies (Gass, 2000). It relies on the integrity of executive control and involves the posterior and basal frontal lobe systems. These systems operate in a goal-directed way through the frontally mediated drive and sequencing functions proposed by Stuss & Benson (1986). Low self-awareness may involve the individual being completely unaware of deficits, or

being aware but indifferent. Without the ability to recognize inconsistencies between a mental comparison and the present state, the result is decreased self-regulation (Stuss & Benson, 1986). In some cases, both the individual and their family are unaware of difficulties (Golden et al., 1983).

In the case of memory difficulties, it becomes harder to determine the level of insight, because the individual may not remember tasks they have had difficulty with. Asking an individual to report on memory difficulties is a memory task itself, so if the individual fails to report problems that are obvious to others, it may not entirely be related to insight. The use of self-report measures have been criticized after brain-injury due to the lack of self-awareness that can accompany brain injury. Neither self or family ratings of everyday functioning have been found to be correlated with formal test results (Gilewski, 1983, as cited in Gilewski & Zelinski, 1986).

After TBI, insight develops in stages. Initially the individual is only focused on their physical difficulties without insight into the implications of them or the existence of any cognitive difficulties. In the next stage, individuals come to accept the implications of their physical problems and are aware of the existence of cognitive difficulties. Then the individual gradually comes to accept the implications of their cognitive deficits. The final stage involves the adaptation of a future life plan. It includes both adaptation to the limitations imposed by deficits, as well as aims for a degree of recovery (McKinlay & Watkiss, 1998). The increase in frequency of reported difficulties in the months after injury may be partly related to this gradual increase of insight.

This lack of awareness can result in individuals taking on more responsibilities than they can cope with, which can create even more functional difficulties (Heaton & Pendleton, 1981). Family conflicts can also occur when there is a discrepancy between the individual's perceptions of their abilities and that of their family (Wallace & Bogner, 2000). Lack of awareness has implications for rehabilitation. The individual will not be motivated to compensate for difficulties they do not realize they have (Ben-Yishay & Prigatano, 1990). These individuals also lack realistic perception of their future capabilities, and may insist on pursuing unrealistic goals in rehabilitation. An expectation that they will completely recover and return to their pre-injury roles and activities could be due either to lack of self-awareness or psychological factors such as denial. However,



difficulties are also related to the individual being aware of their residual difficulties (Rosenthal & Bond, 1990). This insight often results in frustration or depression when the individual realizes they are unable to do, or can only do with considerable effort, activities that were once effortless. A study of 50 patients with moderate or severe brain injury in a rehabilitation centre found that a higher level of awareness was associated with more depression and anxiety (Wallace & Bogner, 2000).

Awareness that a deficit exists is required before an individual is able to implement compensation strategies. Therefore, functional outcome is connected to the individual's awareness of their deficits. Newman, Garmoe, Beatty, and Ziccardi (2000) studied 37 individuals in a rehabilitation centre an average of 8 weeks after sustaining a moderate or severe injury. They found that brain-injured patients underestimated their deficits relative to staff ratings, and there was no significant relationship between the ratings made by the individual and their neuropsychological test performance. Patient ratings of their own deficits showed no significant differences between admission and discharge. However, the ratings made by staff improved over this time, reflecting the recovery process. Patients were not only unaware of their deficits, they also did not detect changes in their abilities over time.

### *Social and Family Support*

After a TBI, individuals often have difficulties in their relationships with family and close friends (McNeny, 1990). For young adults, who make up the majority of brain-injured individuals, the loss of friends is particularly difficult to deal with. TBI often results in the individual being less interested in leisure activities and having reduced social contacts. Often, the family of the individual is embarrassed by their lack of inhibition and other behaviour problems. This results in the family restricting the activities of the individual and opportunities for social contact (Lezak, 1978, as cited in Long & Williams, 1988). One of the deficits that cause the most stress on families seems to be the affective functioning of the brain-injured individual (Kosciulek & Lustig, 1999).

After a TBI, the family is often required to care for the individual, especially if the brain-injured individual is unable to carry out ADLs independently. This situation is

difficult for both the individual and their family. Brain-injured individuals, especially adolescents or young adults who have recently left home, may resent the dependency on their parents. Parents may be faced with the task of raising their children again.

In the first year after injury, problems become apparent in role performance, marital relationships and physical health of both the individual and family members (Livingston, 1990). The roles of an individual are based on an interaction of factors such as the family structure, age, personality, marital status and cultural expectations (Bond, 1990). After a TBI, changes in the individual may result in an alteration in roles, or the individual may function relatively well in their previous roles despite residual impairment. If the individual is unable to perform their previous roles, family members also have the added burden of assuming the roles that were previously performed by the brain-injured individual.

Caregivers often have difficulty dealing with the cognitive and personality changes of the individual. Cognitive problems are often perceived by families as more stressful than physical problems (Tate & Broe, 1999). Behavioural problems such as difficulties in self-regulation, impulsivity, and restlessness especially contribute to stress for the family (Lezak, 1978, as cited in Long & Williams, 1988). Often the stress is too great, and caregivers may be unable to deal effectively with day-to-day problems or plan for the future (Livingston, 1990).

A study of 32 brain-injured individuals in a rehabilitation centre found that cognitive abilities both before and after intensive rehabilitation are correlated with future social participation. Individuals were tested on the Rey Complex Figure Test, Motor Free Visual Perceptual Test (which includes visual memory) and Visual Scanning. Results of these tests both before and after rehabilitation consistently correlated with a measure of social participation at the post-test (average 4 months after injury), and the follow-up at one year (Pépin, Dumont, & Hopps, 2000).

Personality changes can be particularly difficult for spouses. These changes often result in a person whom seems completely different from the person they married. Spouses of brain-injured individuals may feel they have a non-participating partner in the marriage (Lezak, 1978, as cited in Livingston, 1990). Wives of severely injured men report that their partner no longer expresses physical or emotional affection, and positive

feelings about the relationship consist of a sense of mutual commitment from being in an unpleasant situation together (Gosling & Oddy, 1999). In young adults, marriages are likely to be quite new, and often are not strong enough to survive the changes that occur after TBI (Jennett, 1990). The brain-injured individual may struggle with housework and childcare duties due to cognitive and emotional deficits. Their spouse may have to become the primary earner as well as dealing with these duties, and often becomes overwhelmed (Sander & Kreutzer, 1999).

A social network is important in the individual's reintegration into a normal environment after their brain injury. An adequate social support structure is related to employment, independent living and psychosocial adjustment (McKinlay & Watkiss, 1998). A social network can include relatives, friends, co-workers, church members or any other member of the community the individual has frequent contact with or could provide assistance if needed.

Zencius and Weslowski (1999) found that among individuals in rehabilitation settings, the social network of brain-injured individuals was 2-3 times smaller than that of non-injured individuals. The social network of non-injured individuals averaged 23.5 individuals, with a range of 15-43. The majority of these networks consisted of friends, especially fellow church members and co-workers. The average for brain-injured individuals was 7.1 with a range of 0-15. 66% of these social networks consisted of family members, with 14% friends, 14% rehabilitation staff, 5% church members and neighbours, and 1% co-workers. The individuals in this study were living in residential rehabilitation centres, making staff a reasonable proportion of their social network. Individuals may have difficulties making new friends in this type of setting due to a lack of the social skills necessary to meet new people and foster friendships. Friends from before the injury will often stop visiting or calling because the brain-injured individual is often markedly changed from the person they used to know.

The reaction of the family to changes in behaviour is important. Pre-injury psychologic or emotional problems between the individual and family members can be reflected in the reactions. If the individual returns to live with their parents, this may revive conflicts of adolescence regarding independence, authority and competence (Sander & Kreutzer, 1998). The response of the family may lead to the maintenance of

dysfunctional behaviour, or result in a secondary behaviour disturbance (Livingston, 1990). Education and modeling by members of the rehabilitation team can help the family learn to reinforce appropriate behaviour.

Families have an important role in rehabilitation and should be involved as early as possible (McNeny, 1990). They are especially useful in encouraging carry-over of skills learned in rehabilitation to home and community (Berger & Regalski, 1990). It is important that caregivers initiate and structure leisure activities after discharge from hospital or rehabilitation, especially if the individual is unable to return to work. A lack of meaningful activity can lead to dissatisfaction, and maladaptive pre-injury behaviour may reappear (Rosenthal & Bond, 1990).

## **FUNCTIONAL OUTCOME AFTER TBI**

The cognitive, behavioural and emotional sequelae of TBI have a considerable impact on the individual's functioning in everyday situations. Physical problems obviously affect the ability of the individual to return to work, however the cognitive sequelae are often more disabling than physical injuries (Ponsford, 1995). It is difficult to predict exactly what impact the specific deficits of the individual will have in their daily life. The effects of TBI can be classed as impairments, disabilities and handicaps. Impairments are the changes to the structure or function of brain areas. Disabilities are the difficulties of the individual in carrying out daily tasks, and handicaps are the resulting social disadvantages in role valued by the individual (Ponsford, 1995).

The independence level of the individual is based on their ability to perform activities of daily living (ADL). They range from simple tasks like feeding and dressing, to more complex activities such as financial management and driving (McNeny, 1990). Being able to perform these activities independently is important to the individual's quality of life. Assessment of these activities is oriented to practical problems rather than focusing on the causes of specific forms of impairment (Bond, 1990). During the period of recovery that follows brain injury, there will be times when the individual is partially or completely dependent on others. A factor that influences the independence level of the individual is the presence of a friend or relative who will do things for the individual

rather than fostering independence by encouraging them to do things for themselves (Brooks, 1987).

The more advanced ADLs require a variety of high-level skills that take longer to recover, and for some individuals they may never be possible. Financial management is affected by illogical thinking, poor judgment, impulsivity, poor organizational skills, memory difficulties, attention deficits and mathematics problems (McNeny, 1990). Practice, especially in real-world settings, can improve financial management skills to some extent. Compensation techniques can also be helpful for some ADLs. For example, time management can be aided by the use of a written schedule.

The majority of individuals are unable to return to work after a severe TBI, however the outcome is more variable after mild or moderate injuries (Bowman, 1996; Ponsford, 1995). The individual's return to school or an entry position in their chosen career is commonly used as a measure of recovery (Grafman & Salazar, 1987), and is often the main goal of the brain-injured individual to the neglect of other areas such as relationships and family life. However, return to work does not give an accurate representation of the individual's actual level of ability. It can be the case that the individual can be employed, but is not because they are unable to accept their lower status, or others are not able to accept the behaviour changes of the individual (Brooks, 1987).

Employers may help the individuals return to work by providing a position in which the individual is sheltered and supported. In this situation, the individual may appear to be functioning at their full capacity when they may actually require a great deal of support. Employers often report that brain-injured individuals have irregular punctuality and attendance, along with difficulties in their interpersonal relationships with co-workers (Weddell et al., 1980, as cited in Cook, 1990).

Often employment is dependent on how understanding employers are and the level of unemployment in the region. In areas that are economically depressed, less employers are likely to accommodate brain-injured individuals (Cook, 1990). Younger individuals tend to have a better general outcome after TBI than older individuals, however age can be a disadvantage in terms of work. Young adults who are new to the

workforce are less likely to have concessions made by employers than older individuals with many years of good service to the company (Jennett, 1990).

Memory and personality difficulties are among the greatest obstacles for the individual in returning to work, and the larger these difficulties are, the poorer work adjustment tends to be (Taylor & Price, 1994). Cognitive functioning is a significant predictor of occupational outcome (Tate & Broe, 1999). A study by Bowman (1996) found that 21% of the variance in occupational outcome could be explained by neuropsychological variables, and 27% was explained by demographic variables. The individual's subjective ratings of their difficulties did not predict work outcome. It is proposed that some individuals may have under-reported difficulties due to poor insight, and other may have over-reported due to anxiety or being exceptionally observant.

Memory problems are one of the most disruptive effects of TBI. It has extensive involvement in other cognitive processes, and is a requirement of successful functioning in daily life (Mateer & Sohlberg, 1988). Memory deficits influence rehabilitation, the ability for independent living, and both educational and vocational goals (Mateer & Sohlberg, 1988). In terms of rehabilitation, the ability to learn and recall new information set limits on the types and complexity of activities and information the individual can be taught, and the rate at which new learning will take place. Learning to learn is impaired in individuals with memory difficulties, so memory retraining is not a useful rehabilitation technique (Lezak, 1987). Another implication of memory difficulties is that therapy is less likely to be useful, as little may be retained from previous therapy sessions (Ponsford, 1995).

Frontal dysfunction is frequently reported after TBI and it is a potential predictor of successful reintegration into the community (Tate & Broe, 1999). The ability to regulate behaviour has been found to be more important than cognitive abilities in predicting interpersonal relationships and independent living following TBI (Tate & Broe, 1999).

## CONCLUSION

Attention, memory and executive function problems are the most common after brain injury. These functions are assessed by means of neuropsychological tests, however, these test often do not correlate highly with everyday functioning. Performance in an everyday setting contains a range of distractions that are controlled for in a clinical setting. It can be influenced by other factors such as social support, compensation strategies, and the demands of the environment. The present study will investigate the relationship between a formal memory test (the AVLT) and a measure of everyday memory functioning (the PCRS).

## **CHAPTER 4**

### **MEMORY**

#### **INTRODUCTION**

Memory is “a persistent CNS change consisting of both environmental information and activities of the organism that can be reproduced by the organism after some interval of time in an exact or equivalent form” (Russell, 1981, p288). A variety of systems work together to achieve memory processes. Memory and attention are closely linked. Often apparent memory difficulties are really underlying attention deficits. Information must be attended to, or it will not be encoded. Information must be encoded to be stored in memory, and both encoding and storage are necessary for retrieval to occur.

Two major divisions in memory are short-term memory (STM) and long-term memory (LTM). STM is a limited-capacity memory store that can hold approximately seven items (plus or minus two). Information will only remain in this store for 30 seconds to a few minutes, after which it decays or moves into LTM (Lezak, 1995). Working memory is also seen as a part of the STM system, and allows information to be held while it is being manipulated. LTM provides more permanent storage of information than STM and its capacity is unlimited. Long-term memory is often divided in various ways, including declarative and procedural memory, semantic and episodic memory, and implicit and explicit memory.

Short-term and long-term memory are not a serial system. Deficits in one do not imply deficits in the other. The systems work in parallel, with STM carrying out information processing, and LTM creating lasting records (Cohen, 1997).

#### **STRUCTURAL ASPECTS OF MEMORY**

Each memory system makes its own functional contribution and is supported by different brain systems. These systems work so well together that it is often difficult to



see their separate contributions (Cohen, 1997). When one of the memory systems is selectively disrupted by a brain injury, its contribution can be inferred by the resulting deficits. The main brain areas involved in memory are the hippocampal formations, the thalamus, the fornix, and the mammillary bodies (Wilson, 1987).

The amygdala, with connections with all the sensory processors in the cortex and the thalamus, plays a role in associations across modalities, and attaching emotion to memories. (León-Carrión, 1997; Wilson, 1987). The fornix is the fibre system that links the hippocampus, anterior commissure, and mammillary bodies. The role of this area in memory is less established than the other mentioned areas.

The parahippocampal formations consist of the parahippocampal gyrus and the hippocampus. The hippocampus receives and chunks converging input from higher order sensory, motor and limbic processors (Cohen, 1997; Cytowic, 1996). This includes information about people and objects, the temporal and spatial context, and accompanying affective and behavioural responses during the learning experience. The hippocampus is especially associated with declarative memory and new learning (Cohen, 1997). It plays an important role in the formation of new memories, however the memories are not stored in the hippocampus itself. Visual, auditory, linguistic and spatial information is processed by separate cortical processors specialized for each type of information. These processors are reciprocally connected to the hippocampus. After information is integrated in the hippocampus, the visual elements of the memory are thought to be stored in visual processing areas, and the linguistic elements stored in language areas (Cohen, 1997). This is a popular explanation for the location of memory storage, but it is not definitely proven as yet (Cytowic, 1996). Hebb believed that if a group of neurons were excited simultaneously, they would become functionally connected (Cohen, 1997). Growth processes or metabolic change would then occur in order to increase the efficiency of the connection. This was thought to occur by way of the growth of additional synaptic terminals.

The frontal lobe is another brain area involved in memory. It is involved with meta-memory, prospective memory, and memory for context, temporal order or spatial order (Cohen, 1997; Cytowic, 1996). The basal forebrain has extensive connections to other brain regions such as the hippocampal formation, amygdala, limbic structures, and

the temporal, frontal and parietal cortices (Cytowic, 1996; Delis & Lucas, 1996). Memory deficits occur after extensive damage to this area rather than to any particular structure (Delis & Lucas, 1996).

Neurotransmitters and hormones involved in memory include norepinephrine, dopamine, serotonin, acetylcholine, GABA, ACTH, vasopressin, oxytocin, and alpha-melanocyte stimulating hormone (Cytowic, 1996). Acetylcholine is one of the major neurotransmitters associated with memory. It is the major system in the hippocampus, and cholinergic producers in the basal forebrain have been implicated in Alzheimer's disease (Delis & Lucas, 1996).

### **SHORT-TERM MEMORY (STM)**

Information initially enters the memory system through the sensory memory store. This holds information for a few seconds at most before it either decays or is sent to short-term memory. The limited capacity of short-term memory means that only a certain amount of information can be transferred from sensory stores to STM at any one time. Rehearsal can maintain information in STM for about two minutes before it is transferred into long-term storage, and this activity increases the likelihood of information being transferred into LTM (Cytowic, 1996). Information will quickly decay unless it is rehearsed or moved into long-term storage.

Information is thought to be temporarily maintained in reverberating neural circuits (Lezak, 1995). This electrochemical activity needs to develop a more stable biochemical organization for more long-term storage. . The multiple components of working memory may all involve areas of the dorsolateral prefrontal cortex, but receive information from different areas of the brain (Cohen, 1997). The dorsolateral prefrontal cortex has neurons that are well suited for maintaining information over a short delay (Cohen, 1997).

The term STM is commonly misused. The general public often uses it when referring to recently acquired long-term memories. This selective difficulty with recent memory suggests difficulty in the acquisition or storage of new information, but intact over-learned and more remote LTM (Vanderploeg, 2000).

Working memory provides storage of information while it is being processed, allowing cognitive processes such as reasoning and learning (Cytowic, 1996). The central executive system is a component of working memory, along with its slave subsystems, the visuo-spatial sketchpad and the phonological loop. The central executive is responsible for controlling attention, organizing the subsystems and deciding whether their contents should be maintained for active processing, sent to long-term memory storage, or discarded by redirecting resources from them (Vanderploeg, 2000). The visuo-spatial sketchpad allows the manipulation of visual images, and the phonological loop allows the storage and rehearsal of speech information.

For information to enter short-term memory, it must first be attended to. The primary STM system, which holds a limited number of items, is seen as being more attention-dependent than working memory (Morris & Baddeley, 1988, as cited in Lezak, 1995).

### *Encoding*

Encoding involves information being transformed into a stored perceptual or conceptual mental representation (Kramer & Delis, 1998; Vanderploeg, 2000). The degree and depth of processing in this stage influences how well the information is learned. Processing depends on the amount of time spent, the amount of organization and the way the information is organized, and the number of associations made with previously learned information (Kramer & Delis, 1998). Processing is also influenced by preexisting knowledge. New memory traces are integrated with the individual's previous knowledge (León-Carrión, 1997). More experienced individuals with a larger knowledge base will be able to make more links with previous information, and therefore have a stronger memory trace. The primary and secondary association cortices in the temporal, parietal and occipital lobes are thought to be the location of the perceptual and conceptual analyses involved in encoding (Vanderploeg, 2000).

## **LONG-TERM MEMORY (LTM)**

After encoding has taken place, information is stored in LTM, and subsequently retrieved. Asking the individual to recall information that exceeds the capacity of short-term memory is the general method of assessing LTM. Commonly used measures are immediate and delayed story recall, and multi-trial word list learning (Rao, 1996).

### ***Storage***

The storage of information in LTM involves neurochemical changes in the neuron, neurochemical changes in the synapse (affecting neurotransmitter release or uptake), and dendritic expansion increasing the number of connections with other cells (Lezak, 1995). The hippocampus plays a large role in the consolidation process (Squire and Zola-Morgan 1991, as cited in Vanderploeg, 2000).

Information is gradually stored in LTM through the process of consolidation. This involves the strengthening of information in long-term storage until it becomes a relatively permanent record. This process may be rapid, or may continue over long periods without any active involvement (Squire, 1987, as cited in Lezak, 1995). LTM storage is susceptible to distortion and decay. Memories will gradually decay through disuse if they are not reactivated or strengthened through associations with new material.

### ***Retrieval***

Retrieval is the active search through information previously consolidated and stored in LTM (Kramer & Delis, 1998; Vanderploeg, 2000). There are three main types of retrieval that are investigated in neuropsychological tests. Free recall involves search the memory stores using only a general cue. In cued recall, the individual is provided with a direct cue to aid retrieval. Recognition involves either judging if an item was presented previously, or distinguishing among previously presented information and memory foils. Recognition is the easiest as it places less demands on memory retrieval. Studies using PET images have revealed that successful retrieval involves a memory

search mediated by the prefrontal cortex, and the activation of memory from posterior cortical stores (Kapur et al., 1995, as cited in Vanderploeg, 2000). Memory search may be another function of the central executive. The medial temporal lobe is involved in reactivating stored information, but it does not appear to be involved in the retrieval attempt (Vanderploeg, 2000).

## **DECLARATIVE AND PROCEDURAL MEMORY**

One division that is made in LTM is declarative and procedural memory. These two systems are based on different cerebral organization (Cytowic, 1996). Declarative memory is knowledge that is based on data and can be stated (Vanderploeg, 2000). It is further divided into episodic and semantic memory. Episodic memory consists of memory for autobiographical events, including the context of time and place. Semantic memory is knowledge of facts. It is more conceptual in nature and the contextual aspects of the learning experience are no longer accessible (Vanderploeg, 2000). Semantic memory is rarely impaired due to brain damage.

Procedural memory is skill-based knowledge, or knowing how to do something. It has been proposed that since procedural memory is rarely affected by TBI, it could be used to help individuals compensate for other memory deficits. This could occur through teaching mnemonic strategies, vocational skills, or training in the use of a memory notebook (Salmon & Butters, 1987; Vanderploeg, 2000).

Another distinction in LTM is between explicit and implicit memory. Episodic memory and semantic memory are both explicit. This entails conscious recollection of previous events or knowledge. Implicit memory occurs without the individual consciously recollecting the knowledge or learning experience. Priming occurs when previous exposure to target stimuli increases the reporting of these stimuli later in tasks such as word-stem completion (Vanderploeg, 2000).

## EVERYDAY MEMORY

Most subjective complaints of individuals after TBI are regarding everyday or functional memory. This is the ability to learn, retain and recall information, and to access it when it is required (Vanderploeg, 2000). Functional memory requires many other interacting cognitive processes besides memory. Deficits in any one of these processes can result in difficulties. As well as the STM and LTM systems, functional memory also requires remembering-to-remember, and then appropriately applying the memories in the correct functional context (Vanderploeg, 2000). The combination of all these steps results in functional memory.

One common complaint is of the individual forgetting things when they enter another room. This is most likely to be a STM or working memory impairment. Entering another room causes a distraction, so information is not effectively encoded in LTM, and therefore not easily retrievable. Cues such as going back to the original room can help retrieve the information from LTM (Vanderploeg, 2000). This shows how difficulties in one system can result in a functional difficulty.

Kersel, Marsh, Havill, and Sleigh (2001) found that while the ability to learn verbal information improved from testing at 6 months post-injury to one year post-injury, there was no significant improvement in retention of this information. Retention has a greater contribution to long-term functional performance, so verbal memory abilities would not be expected to improve over time.

Prospective memory stores intentions and plans. This type of memory is used frequently in everyday activities, so deficits of prospective memory can be severely incapacitating (Cohen, 1996). Prospective memory tasks include remembering to keep appointments, remembering to take medication etc. Prospective plans tend to be self-generated, and involve remembering a plan of action, and remembering to carry out the action at the appropriate time. Failures of prospective memory can be contributed to by poor motivation (Cohen, 1996). An individual who does not want to go to the doctor is less likely to keep this appointment.

Shimamura, Janowski, and Squire (1991) have identified prospective memory deficits in frontal lobe damage. Individuals with frontal damage may have normal test

performance, but have poor organization and planning when involved in everyday activities.

## **MEMORY IMPAIRMENT**

Memory impairment can have a variety of sources, including TBI, surgery, CVA, encephalitis, dementia, and Korsakoff's syndrome (Wilson, 1987). Damage to any of a number of brain areas can impair memory, with the nature of the deficit depending on the site of the damage.

Damage to the dorsomedial nucleus of the thalamus can also result in amnesia. This area is damaged in 88% of individuals suffering from Wernicke-Korsakoff's syndrome (Wilson, 1987). The mammillary bodies are also implicated in Korsakoff's syndrome and amnesia from tumors or surgery. They are among the most important structures for memory, but memory impairment can occur without the involvement of this area (Wilson, 1987). The dorsomedial nucleus of the thalamus and mammillary bodies cause mild to moderate memory difficulties if only one structure is involved, and more difficulties if both areas are damaged (Cohen, 1997). The fornix has been implicated in memory damage, but there is less evidence of its involvement compared with the previously mentioned structures (Wilson, 1987).

## **MEMORY QUESTIONNAIRES**

Tests provide standardized presentation of stimuli in terms of number, duration and timing, with a fixed delay between presentation and recall. In everyday situations, there is no control over the number and duration of encounters with the stimuli, the effectiveness of encoding or the events that occur between encoding and retrieval. This lack of control limits the ability to generalize results (Cohen, 1996). However, this lack of ability to generalize can also be said of formal tests that only test memory under strictly defined conditions. Everyday memory performance is embedded in a context of ongoing events. The assessment of memory through formal neuropsychological tests

deliberately excludes the numerous factors that can influence memory performance in an everyday setting.

In some questionnaires, individuals are asked to assess the frequency of certain specified memory lapses by rating the frequency of occurrence. Self-assessments are based on direct, first-hand experience of success and failure in a wide range of everyday tasks over a long period. It seems reasonable that an individual should know the most about their own memory performance and be able to assess it accurately, but there are some serious doubts about the validity of self-ratings (Sunderland, Harris, & Baddeley, 1983). When correlated with objective psychometric tests of memory ability (digit-span/free recall of word-lists), correlations are usually low or non-existent. The extent of the correlation may depend on the degree to which the questionnaire and the test are measuring the same aspect of memory (Cohen, 1996; Sunderland et al., 1983).

The low correlation between self-ratings and objective memory tests may be contributed to by other factors. Individuals differ in the number of opportunities they have to make memory errors. Soon after the injury, and sometimes for much longer, relatives may shelter the individual from cognitively demanding situations. Even with severe test difficulties, an individual will make few errors if there are very few memory demands in their environment (Sunderland et al., 1983). Individuals who have returned to work are likely to experience many more memory failures than more severely injured individuals. Another factor contributing to the low correlation may be the use of memory aids such as notebooks or reminder notes. Again, this reduces the memory demands of the environment, giving less opportunity for error.

For those with little or no memory impairment, there is a good relationship between self-ratings and ratings made by a significant other (Gilewski & Zelinski, 1986). Individuals with more severe memory difficulties tend to underestimate their impairment. A close relative or friend may be in a better position to describe memory difficulties, especially if the brain-injured individual has poor awareness or memory difficulties to the extent that they do not remember instances of memory failure. Sunderland et al. (1983) found that the strongest relationship between questionnaires and test performance was for ratings made by relatives. However, relative ratings still have difficulties in that different relatives vary in the amount of time they spend with an individual and how observant



they are of memory lapses. This means that some relatives are more reliable sources of information than others are.

There are a variety of reasons that self-ratings may not be accurate. Firstly, individuals may under-report instances of memory failure to avoid embarrassment caused by their difficulties or to appear more competent to the researcher or clinician. In addition, a meta-memory paradox exists. This results in the individuals who experience the most memory failures being the least able to report them as they forget they have occurred (Cohen, 1996).

## **CONCLUSION**

The current experiment aims to investigate the relationship between everyday memory as assessed by questionnaire, and formal memory tests. Both patient and relative ratings will be investigated, as they each provide a different perspective on the everyday difficulties experienced by the brain-injured individual. However, based on past research and the memory demands involved in reporting memory failures, it was expected that relative ratings would provide a more accurate assessment of everyday functioning.

## CHAPTER 5

### FORMULATION

#### OBJECTIVES

Memory difficulty is a common problem after TBI, and as previously stated, difficulties in this area can be debilitating educationally, socially and vocationally (Gilandas et al., 1984; Mateer & Sohlberg, 1988). Knowledge of the type of memory difficulty being experienced is necessary for rehabilitation to be tailored to the abilities of the individual.

As reviewed in chapter 4, memory consists of several components: STM, LTM, and the processes of encoding, storage and retrieval. Deficits in any of these systems can result in low memory test scores. The Rey Auditory-Verbal Learning Test (AVLT) is widely used as it measures multiple components of learning and memory it provides and is easy to administer (Wiens, Crossen, & McMinn, 1988). This test provides information on STM, interference, learning curves, recall and recognition. On average, individuals with TBI have intact STM, but lower scores on the AVLT learning trials, low recall, but intact recognition (Lezak, 1995). However, due to the wide range of deficits that result from TBI, performance on this test varies, and individuals can be categorized into subgroups based on their pattern of performance. These subgroups will be investigated for any demographic or injury-related characteristics that could be contributing to their pattern of test performance.

Memory can be evaluated by means of formal neuropsychological tests, or by self-report or the report of a significant other. The relationship between these two methods of measurement is variable (Sunderland et al., 1983). Results of formal testing do not provide a reliable estimate of everyday memory abilities as some individuals who have low scores on tests have few everyday difficulties and vice versa.

A review of the literature (in chapters 2, 3 and 4) confirms the variable nature of outcomes after TBI, and the questionable validity of self-report, especially for memory. The present study will compare relative ratings of everyday memory performance to

formal test results to examine the relationship between these two measures of memory abilities. The influence of other demographic and injury related variables on these two measures will also be investigated.

The present research will consist of two studies. In study one, the AVLT performance of a large sample of individuals with TBI will be examined. The contributions of age, gender, education, general intelligence and injury severity to AVLT performance will be investigated. Individuals will be categorized as low STM and/or low delayed-recall. These two groups will be further divided into subgroups based on their performance pattern on the other trials of the AVLT. In study two, a smaller group of individuals will be drawn from the study one sample, based on the availability of PCRS data. The everyday memory and test performance of this group will be compared.

## **HYPOTHESES**

Based on the preceding review of the literature, the following hypotheses were predicted:

### *Study 1*

#### *Hypothesis 1*

Individuals with TBI will score at lower levels than the normative group over all AVLT trials

Rationale: Individuals with TBI generally have lower recall on each trial, but do tend to show a learning curve. Little gain is usually found on long-delay recall (Bigler, Rosa, Schultz, Hall, & Harris, 1989; O'Donnell, Radtke, Leicht, & Caesar, 1988). Therefore, it is expected in the present study that the mean scores of the TBI group will be lower than those of the normative group on every trial of the AVLT.

### *Hypothesis 2*

Higher ratings of TBI severity will be associated with lower scores on the AVLT

Rationale- Mildly injured individuals have variable difficulties, with test performance generally returning to normal levels within three months (Lucas, 1998; McAllister, 1994; Ponsford, 1995). Severely injured individuals have more lasting and a higher level of difficulty. Dikmen et al. (1995) found severely injured individuals (>2 weeks coma) to have large impairments on all measures.

### *Hypothesis 3*

Higher education will be associated with higher AVLT scores.

Rationale- The effects of education show up on almost every neuropsychological test (Lezak, 1995). Education has been found to have the most pronounced effect on measures with a strong verbal component, including the AVLT (Selnes et al., 1991). Selnes and colleagues found significant correlations between education and AVLT performance for trials 5, interference, 6 and 7. Geffen, Moar, O'Hanlon, Clark, and Geffen (1990) found education to account for a significant amount of variance on trials 2, 3, 4, and 5.

### *Hypothesis 4*

In the TBI group, females will have higher mean AVLT scores than males on all trials

Rationale- Females have been found to have higher word recall than males both normative groups (Geffen et al., 1990), with mean differences ranging up to 3.2 words. Higher means for females would also be expected in the TBI group.

### *Hypothesis 5*

Controlling for severity, education and gender, AVLT performance will decline with age.

Rationale- Age effects are prominent in the AVLT as they are in all learning tests (Ivnik et al., 1992). Geffen et al. (1990) found older individuals to have more difficulty on the recall measures of the AVLT. With general aging, recall performance is worse than that of recognition, and delayed recall increases age differences in performance (Ivnik et al., 1990). Ivnik and colleagues found that AVLT performance is not strongly related to age in younger adults, but becomes stronger at older ages. Significant correlations between age and AVLT performance have been found for trials 5, interference, 6 and 7 (Selnes et al., 1991). Wiens et al. (1988) found slight decreases on all trials except trial 1 with increasing age.

### *Hypothesis 6*

Higher Verbal IQ will be associated with higher AVLT scores on all trials.

Rationale- General intelligence has been found to have significant correlations with AVLT performance. (Poon, 1985, as cited in Geffen et al., 1990; Wiens et al., 1988). Verbal IQ was expected to be more associated with AVLT performance than Full-scale IQ or Performance IQ as the AVLT is a test of verbal memory.

### *Hypothesis 7*

Individuals with low STM performance will show differing patterns of performance on subsequent AVLT trials.

Rationale- The nature of memory difficulties varies widely between individuals, with factors such as the extent and location of brain damage contributing to the specific problems of the individual. Some individuals are expected to continue to show low test performance after an initial low score, whereas others are expected to exhibit difficulty on trial 1 only, then recover to normal levels.

### *Hypothesis 8*

Individuals with low delayed-recall performance on the AVLT will show different patterns of performance on earlier trials.

Rationale- TBI individuals are generally expected to show average STM performance, with lower learning and recall (Lezak, 1995). Some individuals are expected to follow this pattern, however the specific memory problems experienced by individuals vary. Others are expected to perform at low levels on all trials, or have isolated delayed recall difficulties.

### *Hypothesis 9*

The low STM group will have low performance on digit span and the low recall group will have low performance on logical memory.

Rationale- Subgroups are expected to differ in their performance on other neuropsychological tests in a way that corresponds with their AVLT performance. The low STM group (group 2) is expected to have low performance on digit span. Digit span performance is strongly associated with AVLT trial 1, and they are usually no more than a few points apart (Lezak, 1995). The low recall group (group 3) is expected to have low scores on logical memory recall.

### *Study 2*

#### *Hypothesis 10*

Memory test performance will have a low association with everyday memory performance.

Rationale- Gilewski and Zelinski (1986) state that recall of word lists is less likely to be related to memory complaints than memory for texts or nonverbal tasks. As recall for a list of words, and abilities assessed in the PCRS such as keeping an appointment on time are very different tasks, the relationship between them would be expected to be low.

*Hypothesis 11*

Higher ratings of TBI severity will be associated with lower scores on the PCRS (everyday memory performance).

Rationale- along with the lower test performance that is associated with more severe injuries, more everyday difficulties are expected. Although severely individuals can have either good or bad outcomes, the general pattern is of persisting complaints of everyday difficulties, including vocational, cognitive and emotional (Karol, 1989, as cited in Lezak, 1995)

*Hypothesis 12*

Correlation between patient and relative PCRS ratings will be low.

Rationale- The self-report of memory performance is a memory task in itself. Those with low memory ability could not be expected to accurately recall how often they experienced memory difficulty. Relative's ratings have in general been found to be more accurate than self-report (Sunderland et al., 1983). Also, any difficulties in awareness (associated with frontal damage) reduce the accuracy of self-report.

*Hypothesis 13*

Group 1 (L/L) and Group 2 (A/L) will differ on the PCRS items they have difficulty with, as reported by a relative.

Rationale- Groups 1 and 2 has been both classified as having low everyday memory performance, but this classification only involved reported memory difficulties on two or more of the five PCRS memory items. It was expected the groups would differ on the particular items they had low performance on, and would therefore exhibit different types of everyday difficulties.

*Hypothesis 14*

Group 1 (L/L) would have a higher number of reported difficulties on the PCRS than Group 2 (A/L).

Rationale- It would be expected that group 1 would be more severely impaired, and thus have a higher number of reported difficulties on the PCRS. Since difficulty on only 2 out of five memory items was required for a low PCRS performance rating, it was possible that all of group 1 (L/L) had five items with reported difficulty, while group 2 (A/L) could have just two items of difficulty.

#### *Hypothesis 15*

The low AVLT and PCRS performance group (L/L) will score significantly lower than the average AVLT, low PCRS performance group (A/L) on *all* AVLT trials

Rationale- Group allocation was made on the basis Trial 7 scores only. It is possible that Group 2 could have difficulties on other AVLT trials in spite of average performance on Trial 7. For example, STM difficulties could occur without subsequent recall problems, and these difficulties could then affect everyday functioning.

#### *Hypothesis 16*

More recent injuries would be associated with higher PCRS performance.

Rationale- soon after an injury, individuals are often restricted in terms of social activities and have fewer cognitive demands placed on them. Few memory errors are made in environments where the memory demands are low (Sunderland et al., 1983).

#### *Hypothesis 17*

Participants who are currently employed will have higher everyday memory performance than those who are currently unemployed.

Rationale- Individuals are often impatient to return to work after a TBI, so unemployment is likely to be enforced by the nature of their everyday abilities.



Individuals who are experiencing low everyday memory performance are unlikely to be employed. Also, if previously unrecognized difficulties become apparent in the work environment, the individual is unlikely to stay employed.

## CHAPTER 6

### METHOD

#### PARTICIPANTS

Participants in both Studies were drawn from a database of 454 individuals who had attended the Psychology Clinic at the Massey University, Palmerston North campus. All individuals on this database had sustained a TBI. As a referred sample the participants are not representative of brain-injured individuals as a whole, but rather of those who were more moderate to severe, or those with mild TBI, but who were experiencing difficulties. All participants had received formal neuropsychological assessment. Table 6.1 provides a summary of the characteristics of both samples.

##### *Study 1*

Study 1 involved the data of 353 individuals for whom AVLT results were available. The sample was predominantly male (69.97%) and European (80.17%). The male to female ratio was 2.3:1, which is consistent with earlier findings (Annegers et al., 1980; Klauber et al., 1981). The average age was 32.16 (Median 30.00, SD11.77). Approximately half of the sample (46.18%) was unemployed at the time of assessment.

The injuries of the sample were more severe than generally found in a brain-injured population. Even Tate et al. (1998), who gave the estimate most similar to the current sample (62.2% mild, 20.3% moderate, and 13.6% severe) was vastly different to the distribution of Study 1 participants (21.25% mild, 28.05% moderate, and 43.62% severe). The most common cause of injury was MVA (41.08%), which is consistent with the findings of previous studies (Tate et al., 1998). The sample was not representative of the frequency of severity levels in TBI, as a large number of mild injuries were not included as would be expected in a clinical sample. The higher severity of this sample means more individuals would be expected to experience functional problems as a result of their brain injury. The mean years of post-primary education was 3.88 (Median 3.00, SD 1.92), which translates to near the end of Form Six (year 12). The interval between the TBI and assessment had a mean of 55.54 months (Median 32.50, SD 66.49).

Table 6.1. Characteristics of samples.

Characteristics	Study 1 (N=353)		Study 2 (N=82)	
	N	%	N	%
<b>Gender</b>				
Male	247	69.97	59	71.95
Female	106	30.03	21	25.61
<b>Ethnicity</b>				
European	283	80.17	61	74.39
Maori	59	16.71	15	18.29
Polynesian/Asian	3	.85	0	0.00
Unknown	8	2.27	6	7.32
<b>TBI Severity</b>				
Mild	75	21.25	18	21.95
Moderate	99	28.05	22	26.83
Severe	154	43.62	33	40.24
Unknown	25	7.08	9	10.98
<b>Cause of TBI</b>				
MVA	145	41.08	37	45.12
Fall	49	13.88	13	15.85
Assault	19	5.38	2	2.44
Collision	33	9.35	8	9.76
Other	20	5.67	4	4.88
Unknown	87	24.65	18	21.95
<b>Multiple TBI</b>	111	31.44	23	28.05
<b>Occupation (at time of injury)</b>				
Student	65	18.41	12	14.63
Labourer	54	15.30	11	13.41
Tradesperson	64	18.13	14	17.07
Technician	24	6.80	8	9.76
Sales worker/clerk	34	9.63	9	10.98
Professional	24	6.80	7	8.54
Tutor	2	0.57	0	0.00
Unemployed	17	4.82	0	0.00
Unknown	69	19.55	21	0.26
<b>Age</b>	Years	SD	Years	SD
Mean	32.2	11.8	33.8	13.7
Range	15-76		16-76	
<b>Education</b>				
Mean post-primary	3.9	1.9	3.0	1.7
<b>Assessment Interval</b>	Months		Months	
Mean (Median)	55.5	66.5	41.4	51.9

## *Study 2*

The 82 participants in Study 2 were a sub-set of the 353 individuals in Study 1 for whom Patient Competency Rating Scale- Relatives and Patient Forms, as well as AVLT results were available. As in Study 1, participants in Study 2 were predominantly male (71.95%) and European (74.39%). The male to female ratio was slightly higher at 2.8:1, but was also consistent with findings of previous studies (Klauber et al., 1981; Tate et al., 1998) as was the percentage unemployed at the time of assessment (43.9%). Average age (Mean 33.81, Median 32.00, SD 13.71) and years of post-primary education (Mean 3.71, Median 3.00, SD 1.67) were similar to sample 1. The assessment interval was somewhat shorter, occurring an average of 41.35 months after the TBI (Median 25.00, SD 51.88).

Severity of injury was distributed as 21.95 % mild, 26.83% moderate, and 40.24% severe, which is similar to sample 1. A higher proportion of TBI's (45.12%) were the result of a MVA in sample 2, which is also consistent with previous findings (Kraus et al., 1984).

## MEASURES

### *Rey Auditory-Verbal Learning Test (AVLT)*

The AVLT is a list-learning test assessing verbal learning, immediate memory span, interference, and recognition (Lezak, 1995). On trial I, a list of 15 unrelated words (List A shown in Appendix A) is presented at a rate of one word per second. The individual is then asked to repeat as many words as possible. Their responses are recorded in the order in which they are recalled. This is repeated until the list has been presented 5 times. An interference list (List B shown in Appendix A) of 15 words is then presented and the individual is asked again to recall as many words as possible from it. They are then asked to recall List A again without a further presentation of this list (trial 6). After 20-30 minutes during which other activities are undertaken, free recall of List A is tested again (trial 7). A recognition test is also presented in which the individual must identify the words of List A from 50. The recognition list contains all words from lists A and B, along with semantically associated words and phonetically associated words.

Trial 1 and the interference trial are measures of short-term memory. The pattern of Trials 1-5 scoring reflects learning ability which is expressed as a the total number of words recalled over these trials, or as a learning index score in which the trial 1 score is subtracted from trial 5. The remaining trials (6 and 7) measure both short and long-term recall. The interference trial score generally falls in the same range as trial 1 as both are measuring immediate recall. Comparatively poor performance on the interference trial indicates proactive interference (interference from previously learned information). Lower performance on the short-delay recall trial indicates retroactive interference (information learned later interfering with previously learned information).

As the everyday memory tasks under consideration involved long-term memory functions, the long-term recall trial was selected as the test of memory function. For the purposes of the current study, participants were rated as low on the AVLT if their long-term recall score was more than one standard deviation below their age-corrected norm. The norms used were those of Geffen et al. (1990). AVLT users have typically chosen from three sets of norms (Stallings, Boake, & Sherer, 1995). The other two are those of Savage and Gouvier (1992, in Stallings et al., 1995) and Wiens et al. (1988). Stallings and colleagues investigated all three of these norm sets and found differences in rates of impairment for each set. The norms of Wiens et al. classified significantly more as impaired than those of Savage and Gouvier. The norms of Geffen et al. fell between these two in terms of classification rates.

The norms of Geffen et al. (1990) provide separate norms for males and females. Females have been found to perform significantly better than males on the AVLT, especially on total recall of trials 1-5 and the recall trials (Geffen et al., 1990), justifying the use of separate norms. The norms used in this study also cover a wider age range than previous norms, covering ages 16-84. This was important for the present study as ages ranged up to 76 years old. Although these norms are from a relatively small sample, they are based on an Australian sample, which will be more similar to a New Zealand sample. There are some words in the two lists that may have different levels of familiarity for New Zealand and American samples, such as 'turkey' and 'ranger', which are more commonly used in America. However, the word 'farmer' may be more familiar to a New Zealand sample.

Test-retest reliability of the AVLT after one year ranges from .38 for trial B to .70 for trial V (Snow et al., 1988, as cited in Lezak, 1995). Trials VI, VII and recognition correlate significantly (0.5-0.7) with other measures of learning (Macartney-Filgate & Vriezen, 1988, as cited in Lezak, 1995).

As well as gender, general intelligence has been found to significantly influence AVLT performance. Recall performance has also been found to be predicted by both verbal IQ (Poon, 1985, as cited in Geffen et al., 1990) and the vocabulary subtest of the WAIS-R (Wiens et al., 1988).

Geffen et al. (1990) found age has a significant effect on the total of trials 1-5, with individuals age 60 and over recalling at least eight words less than younger age groups. Age groups also significantly differ on trials 6 and 7, with individuals over 70 recalling about 2 words less than those 50-59, 3 less than 20-49 and 4 less than 16-19. No significant age differences were found in the learning index (trial 5 – trial 1). Overall, recognition was relatively stable, while recall declined with age.

People have different patterns of performance on AVLT, e.g. low STM, interference, poor learning, poor recall, or a combination of these. Individuals with TBI are generally thought to have relatively normal STM, and substantially lower recall (especially after a long delay). The learning curve has been found to be similar for both TBI groups and controls, but TBI groups generally perform at a lower level on all items (Lezak, 1995; O'Donnell et al., 1988). However, within this group there is a wide amount of variation. There has not been much investigation of why individuals exhibit a particular pattern of performance. It is generally expected that individuals with STM difficulties on the AVLT will show such difficulties on other neuropsychological tests of STM.

One explanation for the lower performance of brain-injured individuals is the lower strategy use and awareness associated with frontal damage. As previously noted in chapter two, frontal damage is common after TBI. Individuals seem to focus on words they did not recall in the previous trial, making a trade-off between maintaining old words and learning new words (Blachstein, Vakil, & Hoofien, 1993).

### *Patient Competency Rating Scale (PCRS)*

This 30 item self-report measure of everyday functioning includes items covering cognitive, interpersonal and emotional competencies as well as activities of daily living (ADL). There are both patient and relative's forms. Ratings are based on a 5-point scale ranging from 1 ("can't do" to 5 ("can do with ease").

Five items on this measure are related to memory. On the relative's form these are Item 7 "How much of a problem do they have in keeping appointments on time?", item 10 "How much of a problem do they have in remembering what they had for dinner last night?", item 11 "How much of a problem do they have in remembering names of people they see often?", item 12 "How much of a problem do they have in remembering their daily schedule?", and item 13 "How much of a problem do they have in remembering important things they must do?". The patient's form is identical, apart from being phrased "How much of a problem do you have...?". These difficulties are easily seen in everyday settings, and significantly impair the ability of the individual to return to premorbid functioning (Sunderland et al., 1983).

There are several measures available for assessing everyday performance, many of them more recent than the PCRS (e.g. the Neuropsychology Behaviour and Affect Profile, or NBAP). The PCRS was selected for inclusion in this study because it has been used at the clinic in question for several years, and therefore had the most available data.

## **PROCEDURE**

### *Study 1*

The records of 353 individuals who completed the AVLT as part of their neuropsychological assessment were examined. These individuals were divided into groups according to certain criteria outlined in Table 6.2. There were also 115 individuals with TBI who scored at average levels or above on all trials of the AVLT.

Table 6.2. Distribution of individuals with TBI based on AVLT performance

	Group 1	Group 2	Group 3 <sup>1</sup>
	Total sample N=353	Low T1 N=168 (47.59%)	Low T6 & T7 N=214 (60.62%)
Low all trials	120 (33.99)	120 (71.43)	120 (56.07)
Low T1	168 (47.59)	26 (15.48)	22 (10.28)
Low T6 & T7	159 (45.04)	22 (13.10)	39 (18.22)
Low Int, T6 & T7	153 (43.34)	-	33 (15.42)

<sup>1</sup> 144 individuals are categorized in both groups 2 and 3

The 168 individuals who scored at low levels on trial 1 of the AVLT (see Group 2 in Table 6.2) were examined in terms of their performance on the subsequent trials. They were divided into groups based on identified performance trends. The 214 individuals who showed low performance on trials 6 and 7 (see Group 3 in Table 6.2) were then examined to identify the patterns of performance that led to low recall scores. These individuals were also divided into groups based on their pattern of performance. The subgroups are presented in Table 6.3.

The subgroups were examined for differences on other neuropsychological tests. In previous studies, education, verbal ability (vocabulary subtest on WAIS-R) and general mental ability have been found to significantly affect AVLT performance (Selnes et al., 1991; Wiens et al., 1988). The TBI group as a whole was investigated for the contributions of age, gender, education and injury severity to AVLT performance.



**Table 6.3.** Composition of subgroups based on AVLT performance for Study 1.

<b>Low Interference trial only</b>		
<b>Group</b>	<b>AVLT Performance<sup>1</sup></b>	<b>Code</b>
1a	Low all trials.	All low
1b	Low Trials 1 only	Low 1
1c	Low Trials 1, 6 and 7 only.	Low 1/6/7
2a	Low all trials	All low
2b	Low Trials 6 and 7 only	Low 6/7
2c	Low Interference and Trials 6 and 7	Low I/6/7
2d	Low Trials 1, 6 and 7	Low 1/6/7

<sup>1</sup> 1 SD below age-adjusted norm

### ***Study 2***

Neuropsychological test performance has been found to have a variable relationship with everyday functioning (Sunderland et al., 1983). The artificial nature of tests is designed to measure optimal performance, and deliberately excludes the distractions and unpredictability that characterize everyday tasks. Study 2 examined the relationship between formal memory test results (as measured by the AVLT) and everyday memory functioning (as measured by the PCRS). Individuals were selected for this study on the basis that both patient and relative data on the PCRS was available.

Ratings of neuropsychological test performance were based on the long-delay trial (trial 7) of the AVLT only. Individuals were classified as having low test performance if they were over 1 SD below their age-adjusted norm. All other individuals were classified as having high memory test performance.

Table 6.4. Composition of Groups based on AVLT performance and PCRS for Study 2.

<b>Group</b>	<b>AVLT Performance<sup>1</sup></b>	<b>PCRS Rating</b>	<b>(Code)</b>	<b>N</b>
1	Low Trials 6 & 7 only	Low	L/L	29
2	Average or higher Trial 7	Low	A/L	22
3	Low Trials 6 & 7 only	High	L/A	17
4	Average or higher Trial 7	High	A/A	14

<sup>1</sup> 1 SD below age-adjusted norm

Evaluation of everyday memory performance was based on relative's ratings only of the PCRS. Sunderland et al. (1983) found that relative's ratings of memory difficulties were significantly correlated with six of the 14 memory tests used, but there were no significant correlations of patient ratings with these tests. Individuals were classified as having low everyday memory performance if there were ratings of 1 ('can't do'), 2 ('very difficult to do'), or 3 ('can do with some difficulty') on two or more of the five memory questions. All other individuals were classified as having high everyday memory performance. Some 51 individuals were classified as having low everyday memory performance, and 31 were classified as having high everyday memory performance.

Possible interactions with other variables such as employment, severity and time since injury were investigated.

## CHAPTER 7

### RESULTS

In order to confirm equivalency of participant groups in Studies 1 and 2, analyses regarding AVLT performance were conducted for both samples. The results of the study 2 sample are presented throughout the Study 1 data as grey shaded columns in the relevant tables. As these data are only presented to establish equivalency, the main focus of these tables should be the unshaded information.

#### STUDY 1

*Hypothesis 1-* Individuals with TBI will score at lower levels than the normative group over all AVLT trials

The difference between the normative and TBI groups remained constant over the five learning trials (Trials 1-5), ranging from 1.03 for Trial 1 to 1.84 points difference for Trial 4. As seen in Table 7.1, the mean scores of the TBI group on the learning trials significantly differ from those of the normative group, however, the TBI mean still falls within 1 SD of the norms. The lowest mean difference was found on the interference trial (M diff=.72), followed by Trial 1 (M diff=1.03). The greatest mean difference between the two groups was seen on trials 6 (M diff=3.54) and 7 (M diff=4.28). It is only on these two trials that the TBI mean falls outside the normal range (1.62 SD and 1.81 SD respectively). The TBI group shows a small drop in performance from trial 6 to 7 (not significantly different), while the norms show a small rise in mean scores.

The pattern of performance of Group 1 relative to controls is shown in Figure 7.1. The TBI group has a similar shaped learning curve to the norms, but at a lower level.

Table 7.1. T-test comparison of mean AVL T trial scores for TBI group and norms

	TBI (N=353)		Norms		t value
	M	SD	M	SD	
Trial 1	5.57	1.83	6.60	1.86	-10.56*
Trial 2	7.42	2.36	8.84	2.31	-11.23*
Trial 3	8.96	2.79	10.24	2.40	-8.59*
Trial 4	9.66	2.88	11.50	2.35	-11.99*
Trial 5	10.26	2.90	11.79	2.21	-9.90*
Interference	4.94	1.92	5.66	1.57	-7.06*
Trial 6	7.88	3.78	10.42	2.18	-17.50*
Trial 7	7.66	4.26	10.94	2.36	-17.59*

$p < .001$

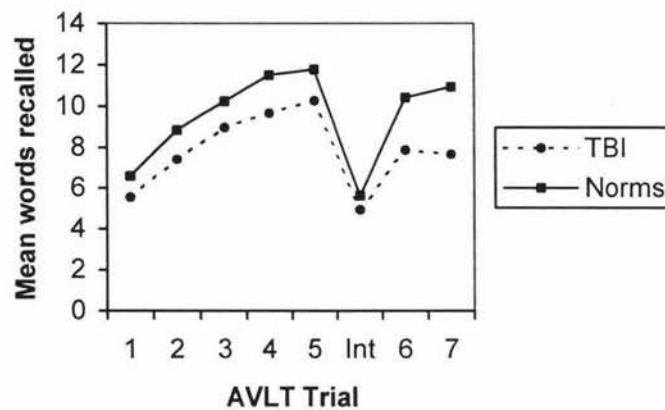


Figure 7.1. Comparison of mean AVL T scores of TBI group and norms.

**Hypothesis 2** - Higher ratings of TBI severity will be associated with lower scores on the AVL T

A one-way between-groups MANOVA procedure was conducted to investigate the relationship between group severity and AVL T performance. Relationships were

considered for both sets of participants, i.e., Study 1 & 2 partly to ensure that the samples were identical.

Eight dependent variables were used: Trials 1-7 and the interference trial of the AVLT. The independent variable was severity, as measured by length of PTA (mild, moderate or severe). As is shown in Table 7.2, the correlations (Pearson product-moment correlation coefficient) between severity and AVLT scores, were identical, and accordingly, the results reported will be generally for Study 1 only. All of these correlations, higher injury severity was associated with lower AVLT scores.

Table 7.2: Correlations of severity and AVLT scores

	Study 1 (N=328) <sup>1</sup>	Study 2 (N=82)
Trial 1	-.053	-.113
Trial 2	-.151**	-.253*
Trial 3	-.143*	-.256*
Trial 4	-.171**	-.307*
Trial 5	-.155**	-.206
Interference	-.110*	-.068
Trial 6	-.169**	-.231*
Trial 7	-.187**	-.264*

\*  $p < .05$

\*\*  $p < .005$

<sup>1</sup> 25 cases of missing data

As shown in Figures 7.2 and 7.3, the mean scores of the mild and moderate groups were very similar, and differed most from the norms on the recall trials. The mean scores of the severe group were generally lower than those of the mild and severe groups, and were especially low on the recall trials.

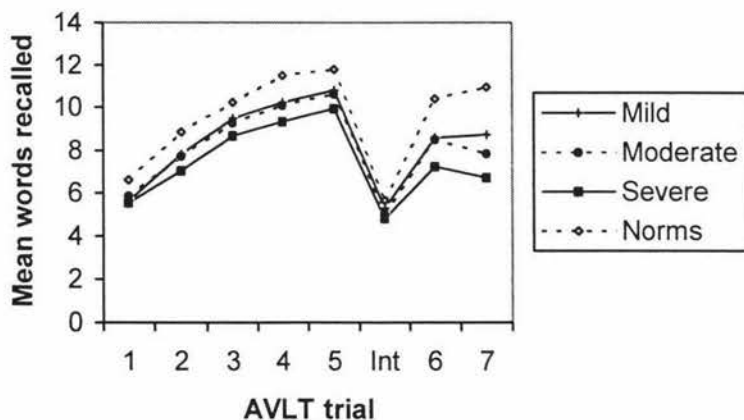


Figure 7.2: Comparison of AVLT scores by severity group for the Study 1 sample

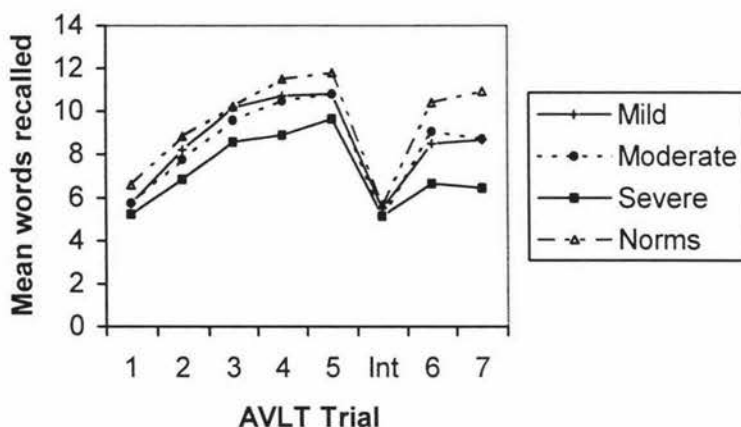


Figure 7.3: Comparison of AVLT scores by severity group for the Study 2 sample

A significant difference was found between severity groups on the combined independent variables:  $F(8, 270)=557.59, p=.0005$ , Wilks' Lamda=.057, partial eta squared=.943. Separate investigations of the dependent variables revealed significant differences between severity groups on trial 2 [ $F(2, 277)=3.32, p=.038$ ], trial 6 [ $F(2, 277)=4.27, p=.015$ ], and trial 7 [ $F(2, 277)=5.05, p=.007$ ]. Post-hoc tests using the Tukey HSD test revealed significant differences on trial 6 between mild ( $M=8.60, SD=3.47$ ) and severe ( $M=7.23, SD=3.82$ )  $p=.043$ , moderate ( $M=8.51, SD=3.83$ ) and severe  $p=.039$  and on trial 7 between mild ( $M=8.74, SD=5.29$ ) and severe ( $M=6.74, SD=3.79$ )  $p=.006$ .

One-way ANOVAs were then carried out for these trials to identify which of the three severity groups differed on these trials. The ANOVA for trial 4 had a moderate effect size of .11. The Tukey HSD test revealed a significant mean difference ( $p=.038$ ) between the mild ( $M=10.72$ ,  $SD=2.52$ ) and severe ( $M=8.91$ ,  $SD=2.42$ ) groups. The moderate group ( $M=10.50$ ,  $SD=2.50$ ) was not significantly different from either the mild or severe group. The ANOVA conducted for trial 6 also had a moderate effect size of .086. The Tukey HSD test showed a significant difference ( $p=.047$ ) between the moderate ( $M= 9.09$ ,  $SD=3.80$ ) and severe ( $M=6.64$ ,  $SD=3.49$ ) groups. The ANOVA for trial 7 had a moderate effect size of .09. However, the Tukey HSD test revealed no significant mean difference between any of the severity groups.

**Hypothesis 3-** Higher education will be associated with higher AVLT scores.

The relationship between years of post-primary education and memory test performance (as measured by the AVLT) in Study 1 & 2 participants was investigated using Pearson product-moment correlation coefficient. Significant positive correlations are presented in Table 7.3. These results indicate that on the significant trials, higher education was associated with higher AVLT performance in both groups.

Table 7.3: Correlations of education and AVLT scores

	Study 1 (N=328) <sup>1</sup>	Study 2 (N=73)
Trial 1	.215**	.158
Trial 2	.325**	.246*
Trial 3	.325**	.319*
Trial 4	.354**	.395**
Trial 5	.308**	.239
Interference	.246**	.274*
Trial 6	.258**	.194
Trial 7	.165**	.216

\*  $p<.05$

\*\*  $p<.001$

<sup>1</sup> 25 cases of missing data

A one-way analysis of variance revealed that the mean years of post-primary education significantly differed across the groups [ $F(6, 321)=3.80, p=.001$ ], with a moderate effect size of .07. However, the assumption of homogeneity of variance was not met, so a stricter significance level of .01 was used. The Tukey HSD test revealed a significant difference ( $p=.0005$ ) between Group 1 ( $M=3.33, SD=1.67$ ) and Group 7 ( $M=4.44, SD=1.99$ ). A chi square analysis revealed no significant difference between the groups on time since injury, gender, or marital status.

**Hypothesis 4-** In the TBI group, females will have higher mean AVLT scores than males on all trials

An independent sample t-test was conducted to examine the extent of the mean differences between males and females. As can be seen in table 7.4, the mean scores of males and females significantly differed on every trial except interference, with females having consistently higher scores.

Table 7.4. Male and female means across AVLT trials

	Males (N=248)		Females (N=105)		t value
	M	SD	M	SD	
Trial 1	5.43	1.81	5.90	1.85	2.20*
Trial 2	7.20	2.32	7.94	2.39	2.71*
Trial 3	8.58	2.75	9.85	2.70	3.97***
Trial 4	9.20	2.76	10.73	2.89	4.70***
Trial 5	9.91	2.90	11.08	2.75	3.50**
Interference	4.85	1.81	5.13	2.14	1.26
Trial 6	7.44	3.65	8.90	3.89	3.35**
Trial 7	7.00	3.85	9.20	4.76	4.25***

\*  $p<.05$

\*\*  $p<.001$

\*\*\*  $p<.0005$



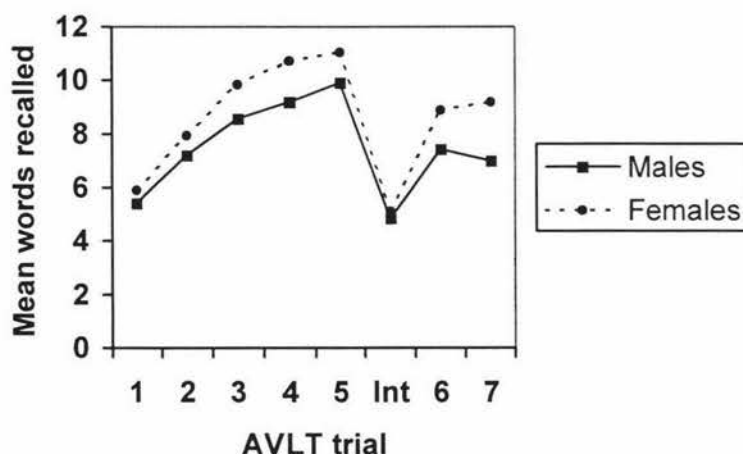


Figure 7.4. Mean AVLT scores across trials for males and females

As shown in Figure 7.4, the pattern of AVLT performance for males and females was quite different. Males had a slower learning curve, and dropped in performance between trials 6 and 7. Further investigations however revealed that females had on average one more year of post-primary education than males. As shown in hypothesis 3, education was found to have significant correlations with all trials of the AVLT. No significant differences were found between the gender groups on age or injury severity. Controlling for education, age, and injury severity (which are all factors that impact on AVLT scores) significant correlations of AVLT scores and gender, with a female advantage, were found only on trials 3 ( $r=-.13$ ,  $p=.038$ ), 4 ( $r=-.14$ ,  $p=.023$ ), and 7 ( $r=-.18$ ,  $p=.004$ ).

**Hypothesis 5-** Controlling for severity, education and gender, AVLT performance will decline with age.

The mean AVLT scores across age groups in the current study, as well as two other normative studies are presented in Table 7.5. All of these studies show a general decrease in AVLT scores with increasing age.

Table 7.5. Mean AVLT scores across age groups for three studies

	Current Study			Geffen et al (1990)			Wiens et al. (1988)		
	16-29	30-49	50+	16-29	30-49	50+	16-29	30-49	50+
	162	150	34	23	21	31	126	71	12
Trial 1	5.83	5.40	5.06	7.7	6.2	5.0	7.4	7.4	-
Trial 2	7.86	7.00	7.24	10.3	8.5	6.9	10.4	9.9	-
Trial 3	9.49	8.49	8.50	11.4	9.8	8.7	12.2	11.6	-
Trial 4	10.17	9.25	9.0	12.5	11.2	9.2	13.0	12.4	-
Trial 5	10.74	9.88	9.65	12.4	11.2	9.6	13.4	12.6	-
Interference	5.23	4.60	4.85	6.7	5.7	4.5	6.8	6.6	-
Trial 6	8.59	7.43	6.74	11.2	9.7	7.7	12.1	11.4	-
Trial 7	7.88	7.61	7.06	11.0	10.5	7.6	-	-	-

As shown in Table 7.6, significant negative correlations were found for all trials of the AVLT except trial 7, with higher age associated with lower AVLT performance.

Table 7.6. Correlations of age and AVLT performance controlling for severity, education and gender.

	Study 1 (N=305) <sup>1</sup>	Study 2 (N=65)
	r	r
Trial 1	-.17**	-.22
Trial 2	-.16**	-.19
Trial 3	-.19**	-.30*
Trial 4	-.17**	-.32**
Trial 5	-.17**	-.25*
Interference	-.16*	-.21
Trial 6	-.21**	-.26*
Trial 7	-.09	-.20

\*  $p < .05$

\*\*  $p < .01$

<sup>1</sup> 48 cases of missing data

**Hypothesis 6-** Higher Verbal IQ will be associated with higher AVLT scores on all trials.

The relationship between verbal IQ (VIQ) and AVLT performance was investigated using a Pearson product-moment correlation coefficient. As shown in Table 7.7, significant positive correlations were found for all trials of the AVLT, thus higher VIQ was associated with higher AVLT scores. Some 21-34% of the variance in AVLT scores was predicted by VIQ.

**Table 7.7.** Correlation between VIQ and AVLT performance

	Study 1 (N=104) <sup>1</sup>	Study 2 (N=16) <sup>2</sup>
	r	r
Trial 1	.52**	.35
Trial 2	.54**	.29
Trial 3	.54**	.48
Trial 4	.58**	.60*
Trial 5	.56**	.49
Interference	.50**	.32
Trial 6	.46**	.64*
Trial 7	.47**	.71*

\*  $p < .05$

\*\*  $p < .0005$

<sup>1</sup> 249 cases of missing data

<sup>2</sup> 66 cases of missing data

**Hypothesis 7 -** Individuals with low STM performance will show differing patterns of performance on subsequent AVLT trials.

In the TBI sample, 168 individuals had low scores on trial 1 of the AVLT. These individuals were divided into three groups based on their pattern of performance on the remaining seven AVLT trials. These were Group 1a (low on all trials), Group 1b (low trial 1 only) and Group 1c (low trials 1, 6 and 7).

### Group 1a: low on all trials

The majority of individuals had generally low AVLT performance, with 120 (71.43%) continuing to score more than 1 SD below the normative group on the remaining trials. As can be seen in figure 7.5, these individuals had a flat learning curve. Delayed-recall dropped almost to the level of trial 1, indicating either low retention or difficulty retrieving information. While an average of 3.31 words were learned over the five learning trials, this small gain was not maintained on the delayed-recall trials.

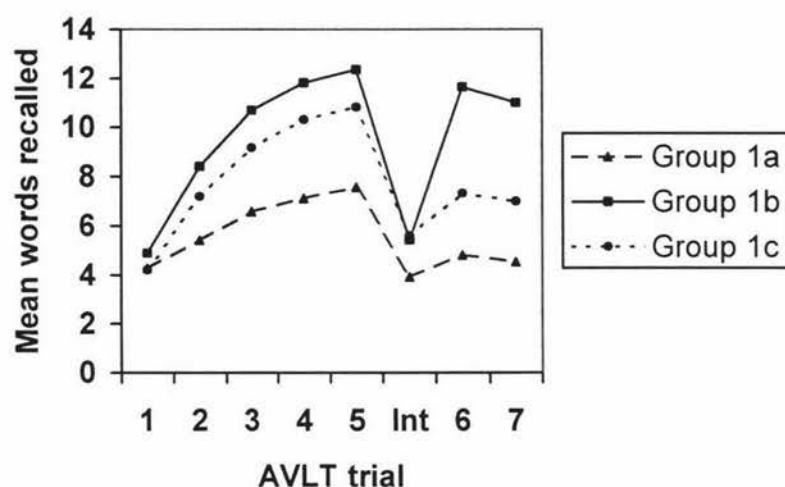


Figure 7.5. Patterns of AVLT performance for individuals with low STM scores<sup>1</sup>.

<sup>1</sup> See Table 6.2 in method for further information on groups 1a-1c.

### Group 1b: low on trial 1 only

For 26 individuals (15.48%), no other difficulties were experienced on the remaining AVLT trials. These individuals displayed a learning curve steeper than that of the normative group, and from trial 2 onward were scoring at a similar level or higher than the normative group (see Appendix C). The largest gain over the normative group was on trial 6.

### Group 1c: low trials 6 and 7

This group of 22 individuals (13.10%) showed a learning curve similar to that of the normative group, but at a slightly lower level (see Appendix C). However, while the

learning trial scores were lower than those of the normative group, they fell within the normal range. The most pronounced difference between Group 1c and the normative group was on the delayed-recall trials, especially trial 7 with a mean difference of 3.94 words.

**Hypothesis 8-** Individuals with low delayed-recall performance on the AVLT will show different patterns of performance on earlier trials.

In the TBI sample as a whole, 214 individuals had low trial 6 and 7 performance. These individuals were divided into four groups based on their performance on trials 1-5 and the interference trial.

#### Group 2a: all low

Of those with low delayed-recall performance, 120 (56.07%) had low performance on all the preceding trials. Figure 7.5 shows the relatively flat learning curve of this group. The lowest recall scores were recorded for this group, with the average number of words recalled being very similar to the average scores on trial 1.

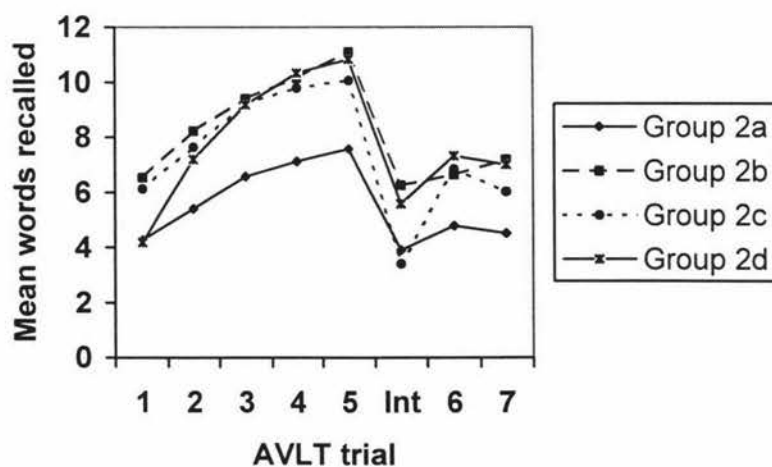


Figure 7.6. Patterns of AVLT performance resulting in low delayed-recall scores<sup>1</sup>.

<sup>1</sup> See Table 6.2 for further information on groups 2a-2d.

#### Group 2b: low trials 6 and 7 only

Some 39 individuals (18.22%) had isolated difficulty on the delayed recall trials. The average performance of Group 2b on all other AVLT trials followed the learning curve of the normative group (see Appendix C). The mean delayed-recall scores of these individuals were the highest of the four groups.

#### Group 2c: low interference and recall only

Of those with low delayed-recall scores, 33 individuals (15.42%) were low on the interference trial and recall only. As can be seen in figure 7.5, the learning curve of this group is similar to that of Group 2b, with a sharp drop in performance on the interference trial.

#### Group 2d: low trial 1 and recall only

Low delayed recall performance accompanied by low performance on trial 1 was observed for 22 individuals (10.28%). This group started the lowest of the four groups, however they exhibited a steep learning curve, almost reaching the mean score of Group 2b. The interference trial performance was also normal for this group.

**Hypothesis 9** – The low STM groups will differ on digit span performance and the low recall groups will differ on Logical Memory performance.

Table 7.8. Mean digit span age-corrected scaled scores across the three low STM groups.

	M	SD	N
Group 1a	7.38	2.72	102
Group 1b	8.96	2.27	23
Group 1c	8.33	2.63	21

A one-way analysis of variance was carried out, revealing that digit span performance significantly differed across the subgroups [ $F(2, 143)=3.89, p=.023$ ], with a small effect size of .05. The Tukey HSD test revealed a significant difference ( $p=.029$ ) between Group 1a (all low) ( $M=7.38, SD=2.72$ ) and Group 1b (low 1) ( $M=8.96,$

SD=2.27). The discrepancy between the sample sizes shown in table 7.8 and 7.9 and the samples reported in hypotheses 7 and 8 is due to missing data.

Table 7.9. Logical Memory recall performance across the four low delayed-recall groups.

	Logical Memory Recall A			Logical Memory Recall B		
	M	SD	N	M	SD	N
Group 2a	5.29	4.29	70	5.92	3.95	66
Group 2b	9.83	3.89	23	8.39	2.90	23
Group 2c	5.81	4.90	21	6.35	4.18	20
Group 2d	5.00	3.16	14	7.64	4.25	14

A one-way analysis of variance revealed that Logical memory A recall performance significantly differed across the subgroups [ $F(3, 124)=7.17, p=.0005$ ], with a large effect size of .15. The Tukey HSD test revealed a significant difference ( $p=.0005$ ) between group 2a (all low) ( $M=5.29, SD=4.29$ ) and group 2b (low 6/7) ( $M=9.83, SD=3.89$ ). The mean scores of group 2b and group 2d (low 1/6/7) ( $M=5.00, SD=3.16$ ) were also found to be significantly different ( $p=.005$ ).

Logical memory B recall performance also significantly differed across the subgroups [ $F(3, 119)=2.70, p=.049$ ], with a small effect size of .06. The Tukey HSD test revealed a significant difference ( $p=.045$ ) between group 2a (all low) ( $M=5.92, SD=3.95$ ) and group 2b (low 6/7) ( $M=8.39, SD=2.90$ ).

## STUDY 2

The mean everyday memory performance (as measured by the PCRS) of the 82 individuals with TBI are presented in Table 7.10 below. Mean ratings for both relatives and patients ranged from 3.33 to 3.73, indicating high everyday memory performance on average. Table 7.11 below shows the mean PCRS ratings in each subgroup for both patients and relatives ratings.

Table 7.10. Mean PCRS ratings for the TBI group

	Relative Form (N=82)		Patient Form (N=82)	
	M	SD	M	SD
Item 7	3.68	1.17	3.60	1.05
Item 10	3.35	0.99	3.43	1.07
Item 11	3.73	1.06	3.45	1.12
Item 12	3.49	1.13	3.38	1.06
Item 13	3.43	1.08	3.33	1.06

Table 7.11. Mean PCRS ratings across subgroups.

	Group 1 (L/L) (N=29)		Group 2 (A/L) (N=22)		Group 3 (L/A) (N=17)		Group 4 (Ave) (N=14)	
	M	SD	M	SD	M	SD	M	SD
Relative form								
Item 7	3.17	1.17	3.29	1.23	4.41	0.62	4.43	0.76
Item 10	2.89	0.89	3.00	0.84	3.94	1.00	4.07	0.62
Item 11	3.41	1.05	3.09	0.87	4.47	0.72	4.50	0.65
Item 12	2.96	0.96	3.00	1.11	4.41	0.71	4.21	0.80
Item 13	2.90	0.94	3.00	1.16	4.24	0.56	4.21	0.58
Patient form								
Item 7	3.31	1.00	3.50	1.14	3.88	1.05	4.0	0.88
Item 10	2.86	1.04	3.32	1.00	4.18	0.81	3.86	0.86
Item 11	3.17	1.07	3.05	0.90	4.12	1.17	3.86	1.10
Item 12	3.25	1.01	2.95	0.97	4.00	1.00	3.50	1.09
Item 13	3.34	1.05	2.86	0.85	3.88	1.22	3.34	0.93



**Hypothesis 10-** Memory test performance will have a low association with everyday memory performance.

The relationship between memory test performance (measured by the Rey Auditory-Verbal Learning Test- Delayed recall trial) and everyday memory performance (as measured by the Patient Competency Rating Scale) was investigated using Pearson product-moment correlation coefficient. As shown in Table 7.12, no significant correlation was found between these two variables.

**Table 7.12.** Correlations between AVLT performance and PCRS ratings of everyday memory performance

	Relative form		Patient form	
	r	p	r	p
Item 7	.14	.22	-.02	.88
Item 10	.20	.08	.20	.07
Item 11	.03	.80	.02	.83
Item 12	.10	.36	-.08	.50
Item 13	.18	.10	-.13	.26

When this analysis was conducted for each of the four groups, only one significant finding emerged. For group 1 (low everyday and test performance), there was a moderate positive correlation between AVLT 7 and PCRS-P 10 ( $r=.414$ ,  $N=28$ ,  $p<.05$ ), with higher scores on AVLT 7 associated with fewer problems on PCRS-P item 10 (remembering what was for dinner last night).

**Hypothesis 11-** Higher ratings of TBI severity will be associated with lower scores on the PCRS (everyday memory performance)

The relationship between severity (as measured by length of PTA) and everyday problems (as measured by ratings on the PCRS) was investigated using Pearson product-

moment correlation coefficient. As seen in Table 7.13, results showed one significant positive correlation for relative ratings, and three for patient ratings. On these items, higher severity was associated with fewer reported memory difficulties.

**Table 7.13.** Correlations between injury severity and PCRS ratings of everyday memory performance

	Relative form		Patient form	
	r	p	r	p
Item 7	.104	.39	.359**	.002
Item 10	.070	.57	.291*	.01
Item 11	.264*	.02	.065	.06
Item 12	.131	.27	.192	.11
Item 13	.197	.09	.266*	.02

\*  $p < .05$

\*\*  $p < .01$

**Hypothesis 12-** Correlation between patient and relative PCRS ratings will be low

The relationship between relative and patient ratings on the PCRS were investigated using Pearson product-moment correlation coefficient. Significant positive correlations were found between patient and relative ratings for all items: item 7 ( $r=.399$ ,  $p=.0005$ ), item 10 ( $r=.365$ ,  $p=.001$ ), item 11 ( $r=.468$ ,  $p=.0005$ ), item 12 ( $r=.474$ ,  $p=.0005$ ), and item 13 ( $r=.386$ ,  $p=.0005$ ).

**Hypothesis 13 -** Group 1 (L/L) and Group 2 (A/L) will differ on the PCRS items they have difficulty with, as reported by a relative.

The PRCS performance of Group 1 and 2 was compared by means of chi-square analysis. A significant difference was found for only one item- PCRS-Patient form item

10. A greater percentage of group 1 reported difficulty on this item. As shown in Table 7.14, 82.1% of Group 1 had problems, while only 50.0% of Group 2 reported problems.

A one-way ANOVA was conducted to investigate group differences on PCRS items. The results showed that the four groups were not significantly different in the relative ratings made for items 7, 10, 11, 12 or 13.

Table 7.14. Percentage of sample with reported everyday memory difficulties in Groups 1 and 2

	Group 1 (L/L)	Group 2 (A/L)	Total Sample (groups 1-4)
<i>Relative form</i>			
Item 7	62.07	61.90	41.46
Item 10	85.19	71.43	55.13
Item 11	55.17	68.18	41.46
Item 12	64.29	77.27	49.38
Item 13	72.41	72.72	47.56
<i>Patient form</i>			
Item 7	48.28	50.00	42.68
Item 10	82.14	50.00	51.85
Item 11	65.52	72.72	52.44
Item 12	60.71	76.19	57.50
Item 13	55.17	80.95	60.49

**Hypothesis 14-** Group 1 (L/L) would have a higher number of reported difficulties on the PCRS than Group 2 (A/L).

It was expected that Groups 1 and 2 would differ on the number of PCRS problems that were reported on the bases that average test performance would offer some advantage. Table 7.15 shows that the number of problems was similar for both groups.

Table 7.15. Percentages showing number of PCRS-R problems for Groups 1 and 2

Number of problems	Group 1	Group 2
2	34.48	27.27
3	17.24	22.73
4	27.59	22.27
5	20.69	22.73

**Hypothesis 15-** Group1 (L/L) would score significantly lower than Group 2 (A/L) on all AVLT trials

Table 7.16. T-test comparison of AVLT means for Groups 1 and 2

	Group 1		Group 2		t value
	M	SD	M	SD	
Trial 1	4.83	1.58	5.86	1.81	-2.18*
Trial 2	6.31	2.16	8.68	1.86	-4.12**
Trial 3	7.62	2.16	10.50	2.18	-4.70**
Trial 4	8.03	1.88	11.91	2.09	-5.15**
Trial 5	8.56	1.90	12.00	1.63	-6.62**
Interference	4.34	1.61	5.23	1.80	-1.84
Trial 6	5.24	2.66	10.59	2.87	-6.88**
Trial 7	5.03	2.29	10.45	2.46	-8.10**

\*  $p < .05$

\*\*  $p < .0005$

An independent sample T-test was conducted to examine any differences between group 1 and 2 in AVLT trial means. As seen in Table 7.16, significant differences were found on every trial except interference. In all of these cases, the mean scores of group 1 were significantly lower than those of group 2.

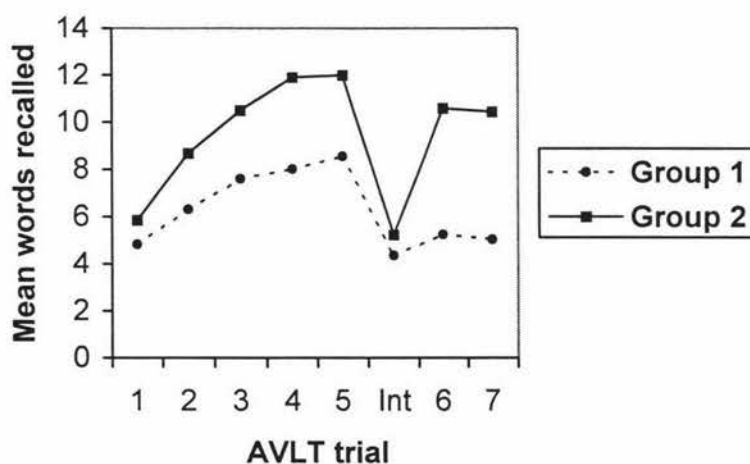


Figure 7.7. Comparison of mean AVLT scores of Groups 1 and 2

**Hypothesis 16** - More recent injuries would be associated with higher PCRS performance

A one-way between-groups analysis of variance was conducted to investigate the impact of time since injury on everyday memory performance, as assessed by the PCRS. Individuals were divided into three approximately equal groups based on the interval between their injury and assessment (Group 1: 0-12 months; Group 2: 1-3 years; Group 3: over 3 years). This analysis revealed a significant difference on PCRS-R item 11 [ $F(2, 74)=4.95, p=.01$ ]. The effect size (eta squared) was moderate at .12. Post-hoc comparisons (using the Tukey HSD test) showed that the mean scores of Group 1 ( $M=4.26, SD=.92$ ) and Group 3 ( $M=3.39, SD=1.17$ ) were significantly different. Group 2 ( $M=3.76, SD=.83$ ) did not significantly differ from group 1 or 3. For the task of remembering names of people one sees often, higher performance was reported in the first year of injury than three years after.

**Hypothesis 17**- Participants who are currently employed will have higher everyday memory performance than those who are currently unemployed.

A chi square analysis was conducted to investigate distributions of employment status at the time of assessment across groups. For the purpose of this analysis,

employment status was divided into two groups- employed and unemployed. The results showed a significant difference ( $p=.039$ ) among the four groups. Table 7.17 shows that more individuals were employed in group 2 (low everyday and high test performance) and group 3 (high everyday and low test performance). The results for group 2 confirm this hypothesis, however the results of group 3 do not fit the expected pattern.

Table 7.17. Distribution of employment status across groups

Group	N	Employed (%)	Unemployed (%)
1. low everyday and test	26	34.6	65.4
2. low everyday and high test	18	72.2	27.8
3. high everyday and low test	16	62.5	37.5
4. high everyday and test	12	33.3	66.7

A one-way between-groups MANOVA procedure was conducted to investigate if overall PCRS memory ratings differed as a function of employment status. Five dependent variables were used: PCRS-R item 7, PCRS-R item 10, PCRS-R item 11, and PCRS-R item 12, PCRS-R item 13. The independent variable was employment status (consisting of the categories employed and unemployed). A significant difference was found between employment status groups on the combined independent variables:  $F(5, 62)=255.02, p=.0005$ , Wilks' Lamda=.046, partial eta squared=.954. An investigation of the separate results of the dependent variables revealed no statistically significant differences on any individual item.

## CHAPTER 8

### DISCUSSION

#### STUDY 1

##### *Hypothesis 1*

Individuals with TBI will score at lower levels than the normative group over all AVLT trials

Based on previous research, it was expected that the TBI group would have lower scores in general than the normative group. Other studies have reported intact STM, a learning curve over trials 1-5 that is at a lower level than normative group, and little gain shown on the long-delay recall trial (Bigler et al., 1989; O'Donnell et al., 1988). Like these earlier studies, the TBI group in the present study showed consistently lower performance than controls across all the learning trials, although the learning curve was similar in shape. The largest difference between the groups was on the delayed recall trials, with TBI group mean scores on trials 6 and 7 more than 1 SD from the mean of the normative sample.

The mean score of the TBI group was significantly lower on trial 1 of the AVLT, although it was still within 1 SD of the normative mean. This contradicts previous findings that TBI patients generally have intact STM. There is a high attentional component to STM, and trial 1 generally has similar results to digit span forwards (Lezak, 1995). This finding may indicate the presence of attention problems as well as memory difficulties in a proportion of brain-injured individuals.

Another possible explanation for the low trial 1 scores is executive dysfunction. As previously mentioned in chapters 2 and 3, damage in the frontal lobe is common after a TBI. Executive dysfunction is characterized by slowness changing response sets, little organization of material to be learned, difficulty with novelty, and difficulty using learning strategies. Any one of these problems could produce low STM performance. The central executive system of working memory is thought to control the allocation of attentional resources.

### *Hypothesis 2*

Higher ratings of TBI severity will be associated with lower scores on the AVLT

The severity of injuries was measured by the length of PTA. This measure has been found to correlate with return to work and late outcome (Jennett, 1990), and has been found to closely relate to evidence of tissue damage (Golden et al., 1983), i.e., higher PTA rating means more tissue damage. As multiple areas of the brain are involved in memory (Cohen, 1997; Wilson, 1987), it follows that the more damage that there is, the higher the likelihood that memory processes will be disrupted. Individuals with a higher level of tissue damage are also more likely to have other difficulties such as attention or executive dysfunction. In this case, a combination of factors are likely to be negatively influencing test performance.

Analyses of individual trials showed significant differences on trials 4, 6 and 7, with higher severity groups having lower AVLT scores. Generally there was an overlap in outcome for individuals with mild and moderate TBI. In this clinical sample, all of those with mild TBI would be experiencing a reasonable amount of functional difficulty for the referral to have been made. The more impaired nature of this mildly injured group would increase the overlap between the mildly and moderately injured groups (Morse & Montgomery, 1992).

Significant positive correlations between AVLT performance and severity were found for trials 2, 3, 4, 6 and 7. As expected, on each of these trials higher severity was associated with lower AVLT scores. These show that severity mostly impacts on learning and recall. No significant correlations were found for trial 1 and the interference trial, indicating that severity does not significantly contribute to STM performance.

### *Hypothesis 3*

Higher education will be associated with higher AVLT scores

Education influences all neuropsychological tests, especially verbal tests such as the AVLT (Lezak, 1995). Education is beneficial in terms of test taking (lower levels of anxiety) and using learning strategies. The current results show significant positive correlations for trials 2, 3, 4, 5 and interference. These findings are similar to those of Geffen et al. (1990), who found education to account for a significant amount of variation on trials 2, 3, 4, and 5.



The relationship between education and AVLT scores was not significant for trial 1, as this is more a measure of attention. The interference trial was enhanced by education, and this could be due to greater experience in reducing interference from previously learned material.

The advantage of higher levels of education was significant for the learning trials. Neither the current study, nor Geffen et al. found any significant advantage of higher education on the delayed recall trials (trials 6 and 7). This suggests that the advantage of education on the learning trials is cancelled out by the effects of TBI by trials 6 and 7. In fact, higher education is likely to be associated with an even higher drop-off in words recalled from trial 5 to trial 6 as this group was higher than those with lower education on trial 5, but performed at a similar level on trials 6 and 7. Education does not seem to provide any practical advantage in learning ability, since increased learning speed is not of use in everyday life unless the information is maintained in memory.

#### *Hypothesis 4*

In the TBI group, females will have higher mean AVLT scores than males on all trials

The results supported this hypothesis, with females recalling significantly more words on all AVLT trials except interference. The drop in performance between trials 6 and 7 that was characteristic of individuals with TBI was only found in the male group. Females on average increased their performance across these trials. Correlations still existed for three trials (trials 3, 4, and 7) when age, education and injury severity were controlled for, indicating a remaining advantage for females on these trials. These findings support those of Geffen et al. (1990) who found higher scores for females in a normative group on all AVLT trials. However, Wiens et al. (1988) found no significant differences between males and females.

#### *Hypothesis 5*

Controlling for severity, education and gender, AVLT performance will decline with age.

Significant correlations between age and AVLT performance, controlling for severity, education and gender, were found for all AVLT trials except trial 7. The lack of correlation

for trial 7 was unexpected, as long-delay recall is generally one of the trials most affected by age. The other delayed recall trial (trial 6) showed the highest of the significant findings, consistent with expectations.

Geffen et al. (1990) found that delayed recall on both trials 6 and 7 declined with age, as did Selnes et al. (1991), and Query and Berger (1980). Ivnik et al. (1990) studied individuals aged 55 and older, and found that AVLT performance was strongly related to age. They proposed the relationship with age is likely to be stronger at older ages. Wiens et al. (1988) found only slight differences with age, but their sample was under 50 years old.

Overall, the lack of a decrease on trial 7 with age is inconsistent with the results of previous studies. The older age group in the current study was much smaller than the two younger age groups, as can be seen in Table 7.5, and this small sample may have included outliers.

For the study 2 sample, correlations of age and AVLT scores were found to be statistically significant for only four trials. This group had a sample size of 65, so differences may be due to a small N in the older age group. The samples of the two studies may differ somewhat in their test performance.

### ***Hypothesis 6***

Higher Verbal IQ will be associated with higher AVLT scores on all trials.

Significant positive correlations were found between VIQ and AVLT performance for all trials, thus confirming the hypothesis. This result confirms the findings of previous researchers, such as Wiens et al. (1988) who found a significant influence on general intelligence on AVLT performance.

In the study two sample, significant correlations were only found for three AVLT trials. As VIQ data was only available for 16 individuals from this sample, the small N may have limited the confidence that can be had in the results.

### *Hypothesis 7*

Individuals with low STM performance will show differing patterns of performance on subsequent AVLT trials.

Group 1b (low trial 1) showed a sharp rise in performance to equal the performance of the normative group. Lezak (1995) suggests that this pattern is due to slowness establishing a new response set, and after trial 1 acquisition is usually greater than would be expected. This was particularly true for Group 1b, which had a steeper learning curve than the normative sample. Overall, the low trial 1 performance of this group did not have a detrimental effect on their subsequent learning and retention. Group 1c (low 1/6/7) however, performed at low levels on the delayed recall trials in spite of a near normal learning curve. This suggests difficulty with free recall rather than encoding as learning was shown to occur over the first five trials. The low delayed recall performance of this group may have been a retroactive interference effect, with the interference trial reducing the ability to recall previously learned information.

Post-hoc analyses of PCRS ratings showed that of the three subgroups, Group 1a had the lowest everyday memory performance, with 17 individuals (68.0%) categorized as having low everyday memory performance, and 8 (32.0%) categorized as high. Groups 1b and 1c were too small to accurately determine their relationship with PCRS ratings, with samples of 7 and 8 individuals respectively.

### *Hypothesis 8*

Individuals with low delayed-recall performance on the AVLT will show different patterns of performance on earlier trials.

Individuals with low delayed-recall were divided into subgroups to investigate whether any learning patterns could account for low recall performance. Group 2b (low 6/7) had isolated difficulties on the delayed recall trials. As mentioned earlier, this may have been an isolated retrieval deficit, or susceptibility to retroactive interference. Group 2c (low 1/6/7) showed low performance on the interference trial as well as delayed recall. Low interference trial scores suggest the presence of proactive interference. Given this susceptibility to

interference, the low delayed recall trials were also likely to have resulted from interference effects. Group 2d (low 1/6/7) showed low trial 1 performance also, and consisted of the same individuals as Group 1c.

Post-hoc investigations of PCRS ratings for each subgroup revealed the lowest everyday memory performance for group 2a, which had 17 categorized as low and 8 as high. It was thought that recall would relate to PCRS performance, and Group 2a (all low) showed the expected results. However, the sample sizes of Group 2b (7), Group 2c (7) and Group 2d (8) were too small to make conclusions about the relationship of these groups with everyday memory performance.

### ***Hypothesis 9***

The low STM group will have low performance on digit span and the low recall group will have low performance on logical memory.

#### Digit Span

Digit span performance was highest for Group 1b (low trial 1) and lowest for Group 1a (all low). Although AVLT trial 1 mean scores for the three groups had a range of only .74 words, digit span scores were more varied and a significant difference was found between Groups 1a and 1b, with Group 1b having higher mean scores.

The difference in digit span performance between group 1a and group 1b suggests a different basis for the memory difficulties of these two groups. Digit span scores are generally found to have a high agreement with the AVLT. Lezak (1995) states that large differences in favour of the digit span tend to occur in patients with intact immediate memory and concentration, but are confused when they are presented with too much information. This finding suggests that group 1b may have had this difficulty.

#### Logical memory recall

The lowest performance on both Logical Memory Recall A and B were found for group 2a (all low) and group 2c (low 1/6/7), as would be expected from the lower AVLT recall performance in both of these groups. Overall, performance differed most between Group 2a (all low) and Group 2b (only low recall), indicating a different memory problem in

each of these groups. It may be that Group 2b was most vulnerable to interference, and their low delayed-recall scores on the AVLT were a reflection of this difficulty.

## STUDY 2

### *Hypothesis 10*

Memory test performance will have a low association with everyday memory performance.

The association between memory tests and everyday ratings was not found to be significant. This suggests that the two measures are examining different aspects of memory. List learning is a different task from remembering to keep an appointment on time or remembering a person's name. Others have suggested that the extent the two measures measure the same aspects of memory is the main contributor to the degree of association between them (Cohen, 1996; Sunderland et al., 1983).

Results on the AVLT may be artificially high due to the lack of distractions that impact on everyday memory performance. In a clinical testing situation, the individual is provided with a limited number of stimuli, and maximum attention is focused on these items. However, there are also factors that negatively impact on test performance, such as anxiety or low education.

The lack of a relationship between test performance and everyday memory performance may be partly due to the influence of other cognitive abilities on performance of everyday activities. Individuals can often experience distractibility or other attentional difficulties as a memory problem (Lezak, 1995). This would lead to ratings of low everyday memory performance, but test results are not likely to be affected.

The PCRS asks for subjective ratings of how much difficulty is experienced and individuals may differ in what they define as difficulty. The same level of performance may be viewed as very problematic to one person and only slightly so to another person. These subjective perceptions depend on factors such as the standards set for the individual by themselves and others, and the frequency with which they do the task in question. For

example, individuals who are meeting new people all the time are likely to experience more name recall failures than an individual who only has contact with their caregiver.

### *Hypothesis 11*

Higher ratings of TBI severity will be associated with lower scores on the PCRS (everyday memory performance)

This hypothesis was not supported. Of the ten possible relationships between severity and PCRS ratings from both patients and relatives, only four were significant. Lower scores were not obtained by more severely injured individuals on any of the comparisons, in fact all the significant relationships were in the opposite direction to what was expected.

Length of PTA was only related to Item 11 on relative ratings. This item referred to the ability to remember names. There was a positive correlation, so higher severity was associated with higher ratings on item 11, thus less problems. This finding was small and quite against what would be expected.

Severity (length of PTA) was significantly correlated with items 7 (appointments), 10 (dinner) and 13 (important things to do) on patient ratings. All of these involved higher severity associated with higher ratings of performance, so those with more severe injuries reported less difficulty on everyday memory tasks. Lack of awareness is a common problem in self-report, and the frequency of this problem is expected to increase with increasing severity. Frontal damage is common after TBI (Jennett, 1990; Miller et al., 1990; Walsh, 1991), and this is often associated with low awareness.

Leathem, Murphy, and Flett (1998) found severely injured individuals underestimated their difficulties, while the ratings of moderately and mildly injured individuals were consistent with relative reports. The discrepancy between patient and relative ratings indicated a greater frequency of awareness difficulties in the severely injured group.

### *Hypothesis 12*

Correlation between patient and relative PCRS ratings will be low

The correlations between patient and relative ratings were moderate in size, but were low in the context of inter-rater reliability. This low agreement supports the use of relative ratings only in assigning cases to groups. Awareness difficulties are quite common after TBI, especially in the case of frontal injury. Lack of awareness is typically defined as a discrepancy between relative and patient ratings of performance, with patient ratings being higher (Heaton & Pendleton, 1981; Leathem et al., 1998; Prigatano, Altman, & O'Brien, 1990). Factors such as social desirability influence the answers given on self-report measures, as well as problems remembering the activities in question.

It is generally found that relative's ratings are more accurate for brain-injured individuals. This is due to the awareness difficulties that often accompany brain damage, and the fact that asking about memory difficulties is a memory test in itself. Individuals with a high level of memory difficulty would not be expected to accurately recall situations in which they had memory problems. However, relatives rating can also be called into question since they may not be living with the individual and may not notice incidences where memory difficulties occur.

#### *Hypotheses 13 & 14*

13. Group 1 (L/L) and Group 2 (A/L) will differ on the PCRS items they have difficulty with, as reported by a relative.
14. Group 1 (L/L) would have a higher number of reported difficulties on the PCRS than Group 2 (A/L).

Since Group 1 had memory test problems and Group 2 did not, it was thought they may differ on the particular PCRS items that the individuals in the group had reported difficulty with. The results showed that Groups 1 and 2 did not significantly differ on any of the PCRS items, suggesting that the types of memory difficulties experienced were similar for each group. The number of reported difficulties for groups one and two were also very similar. Both groups had similar everyday problems (in both the number and type of difficulties) regardless of whether or not they had test problems. A significant number of individuals had everyday memory difficulties not picked up by the AVLT alone. If formal

memory tests only conducted with these individuals they would seem to have no difficulty, when in fact they do.

***Hypothesis 15***

Group1 (L/L) would score significantly lower than Group 2 (A/L) on all AVLT trials

Only AVLT trial 7 was used in the classification of individuals as having high or low test performance. This was chosen due to the long-term memory required for successful performance of everyday memory tasks, so groups 1 and 2 were only split on the basis of their trial 7 performance. It was possible that the groups may have had other AVLT differences that accounted for the everyday memory difficulties reported for Group 2. For instance, group 2 may have had low STM performance compared to group 1 that could also lead to high everyday memory difficulties. However, the results show group 2 means were significantly lower than those of group 1 on all trials of the AVLT, confirming the hypothesis. This suggests that there is not some other factor such as poor STM causing the everyday difficulties of group 2.

***Hypothesis 16***

More recent injuries would be associated with higher PCRS performance

It was expected that more recent injuries would be associated with less reported everyday difficulties. Soon after the injury, the individual is likely to be in hospital or cared for at home. The cognitive demands placed on them are less than normal, so they may not have an opportunity to experience any difficulties. When the individual returns to their everyday activities, cognitive difficulties become apparent. Individuals who are dependent on their caregivers are less likely to experience memory difficulties, because they are not often in a situation where they must rely on their memory. Individuals who have returned to work, or who perform many memory-related activities are likely to experience the most memory problems, because they have more opportunity for problems to occur.

The finding that longer time since injury was significantly associated with more reported difficulties on PCRS-R item 11 partially supports this hypothesis. There were no significant



differences for any of the other groups. Item 11 refers to the memory for names of individuals that are seen often. It may be that soon after the injury, when the individual is relatively sheltered, they have only a few visitors, resulting in fewer names to remember. Once the individual returns to work or increases the time spent in the company of others, they have more names to remember, so the opportunity for them to forget names would increase.

### *Hypothesis 17*

Participants who are currently employed will have higher everyday memory performance than those who are currently unemployed.

It was expected that unemployed individuals would experience more everyday memory problems than employed individuals as high levels of everyday memory difficulties would be expected to reduce the ability to work. The results show that more employed individuals were found in groups 2 and 3. Group 2 had low everyday and high test performance. This group may be able to cope well in the distraction-free testing environment, but experience everyday difficulties in distracting environments. The work setting provides numerous opportunities for memory failures to occur. The increased demands of employment may bring out everyday memory difficulties that are not experienced in a distraction-free environment (Prigatano, 1995). It is possible that a proportion of this group actually have attention difficulties only that they experience as memory problems. Everyday difficulties may be a function of the increased distractions in the work environment rather than increased memory demands.

Group 3 had high everyday and low test performance. This group showed fewer everyday memory difficulties than would be expected from their AVLT performance. This group may have underlying memory difficulties that show on formal tests, but have effective compensation strategies in place that allow them to work effectively and cope well in everyday settings.

The high number of unemployed individuals in group 4 (high everyday and test performance) was unexpected. This group appeared to have few difficulties, so should have been capable of returning to work. This analysis had a sample size of 12 for group 4, so this result may be due chance effects related to the small size of the sample. Also, this group may

have had other deficits such as executive function or physical difficulties that limited their ability to work.

## CONCLUSIONS

Memory is a common area of difficulty after TBI, and its effects can be extremely debilitating in the everyday life of the affected individual. Memory is comprised of several systems and involves several areas of the brain, each of which produces a different type of memory difficulty. This study examines some of the many types of memory difficulty experienced after TBI. The AVLT is a useful memory test, as it lends itself to categorization of scores as STM, recall, learning and so on. In the present study, AVLT scores were used to divide brain-injured individuals into subgroups based on their performance trends either following low trial 1 scores, or preceding low recall scores.

Memory tests and questionnaires have been found to have varying degrees of correlation. The degree of association is thought to depend on the extent to which the test and questionnaire examine the same memory processes. This study compared performance of brain-injured individuals on the AVLT and ratings made by their relatives on the PCRS. No significant correlation was found, indicating that these two measures examine different aspects of memory, or other variables are impacting on everyday or test performance that are not examined on these measures. Education and age were found to have significant correlations with AVLT performance, but not PCRS ratings.

The sample of this study was drawn from a database of existing test results. This limited the study, as further information could not be gained from the individuals. In future research, information could be obtained from brain-injured individuals and their relatives on such points as strategies used in test performance, social support systems of the individual, and compensation strategies used in everyday activities. The use of compensatory strategies, both on tests and in daily life was not investigated in the present study due to the unavailability of this information. Strategy use is likely to have a large effect on the relationship between test and everyday memory performance. Individuals who have low everyday memory performance may be able to obtain high test performance through the use of learning strategies such as linking the words to be remembered as a story. Likewise, those with low test performance may compensate effectively in everyday life through making lists or using a memory notebook. Social support is also an important factor in the relationship between memory deficits and

functional performance. Family support has been found to be an important predictor of outcome, possibly through enhancing the motivation of the individual and assisting them with compensation strategies. However, the extent of social support can also be influenced by the level of difficulty being experienced by the individual. Those with many interpersonal difficulties and a slow rate of improvement are less likely to receive social support.

The investigation of the relationship between PCRS results and the subgroups with either low trial 1 performance or low trial 6 and 7 performance was limited. Only two of the seven subgroups (both were low on all trials) had enough PCRS data available for investigation. A larger sample would allow a more thorough investigation of any differences in the functional outcome of these subgroups.

The results of this study suggest caution when inferring everyday memory ability on the basis of formal memory tests such as the AVLT. Tests take place in a distraction-free environment to measure the optimal performance of the individual. In real life, there are a multitude of distractions that increase the memory and attention demands on the individual, and can result in difficulties becoming apparent that were not present in the testing situation.

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**APPENDIX A****REY AUDITORY-VERBAL LEARNING TEST**

	List A	List B
1	drum	desk
2	curtain	ranger
3	bell	bird
4	coffee	shoe
5	school	stove
6	parent	mountain
7	moon	glasses
8	garden	towel
9	hat	cloud
10	farmer	boat
11	nose	lamb
12	turkey	gun
13	colour	pencil
14	house	church
15	river	fish

(Lezak, 1995, p 439).

**Patient Competency Rating  
(Relative's Form)**

**APPENDIX B**

**Instructions**

Patient's Name: \_\_\_\_\_

The following is a questionnaire which asks you to judge this person's ability to do a variety of very practical skills. Some of the questions may not apply directly to things they often do, but you are asked to complete each question as if it were something they "had to do." On each question you should judge how easy or difficult a particular activity is for them and mark the appropriate box.

	Can't do	Very difficult to do	Can do with some difficulty	Fairly easy to do	Can do with ease
1 How much of a problem do they have in preparing their own meals?	_____	_____	_____	_____	_____
2 How much of a problem do they have in dressing themselves?	_____	_____	_____	_____	_____
3 How much of a problem do they have in taking care of their personal hygiene?	_____	_____	_____	_____	_____
4 How much of a problem do they have in washing the dishes?	_____	_____	_____	_____	_____
5 How much of a problem do they have in doing their laundry?	_____	_____	_____	_____	_____
6 How much of a problem do they have in taking care of their finances?	_____	_____	_____	_____	_____
7 How much of a problem do they have in keeping appointments on time?	_____	_____	_____	_____	_____
8 How much of a problem do they have in starting conversation in a group?	_____	_____	_____	_____	_____
9 How much of a problem do they have in staying involved in work activities even when bored or tired?	_____	_____	_____	_____	_____
10 How much of a problem do they have in remembering what they had for dinner last night?	_____	_____	_____	_____	_____
11 How much of a problem do they have in remembering names of people they see often?	_____	_____	_____	_____	_____

	Can't do	Very difficult to do	Can do with some difficulty	Fairly easy to do	Can do with ease
12 How much of a problem do they have in remembering their daily schedule?	_____	_____	_____	_____	_____
13 How much of a problem do they have in remembering important things they must do?	_____	_____	_____	_____	_____
14 How much of a problem would they have driving a car if they had to?	_____	_____	_____	_____	_____
15 How much of a problem do they have in getting help when they are confused?	_____	_____	_____	_____	_____
16 How much of a problem do they have in adjusting to unexpected changes?	_____	_____	_____	_____	_____
17 How much of a problem do they have in handling arguments with people they know well?	_____	_____	_____	_____	_____
18 How much of a problem do they have in accepting criticism from other people?	_____	_____	_____	_____	_____
19 How much of a problem do they have in controlling crying?	_____	_____	_____	_____	_____
20 How much of a problem do they have in acting appropriately when they are around friends?	_____	_____	_____	_____	_____
21 How much of a problem do they have showing affection to people?	_____	_____	_____	_____	_____
22 How much of a problem do they have in participating in group activities?	_____	_____	_____	_____	_____
23 How much of a problem do they have in recognising when something they say or do has upset someone else?	_____	_____	_____	_____	_____
24 How much of a problem do they have in scheduling daily activities?	_____	_____	_____	_____	_____

		Can't do	Very difficult to do	Can do with some difficulty	Fairly easy to do	Can do with ease
25	How much of a problem do they have in understanding new instructions?	_____	_____	_____	_____	_____
26	How much of a problem do they have in consistently meeting their daily responsibilities?	_____	_____	_____	_____	_____
27	How much of a problem do they have in controlling their temper when something upsets them?	_____	_____	_____	_____	_____
28	How much of a problem do they have in keeping from being depressed?	_____	_____	_____	_____	_____
29	How much of a problem do they have in keeping their emotions from affecting their ability to go about the day's activities?	_____	_____	_____	_____	_____
30	How much of a problem do they have in controlling their laughter?	_____	_____	_____	_____	_____

## APPENDIX C

