Patterns of Performance: Implications for The Rey Auditory Verbal Learning Test.

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Murdoch University Western Australia 2001

This Dissertation is presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Psychology
I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary educational institution.

Marie Hardman  

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ABSTRACT

Three studies investigated patterns of performance as demonstrated by the serial position on the Rey Auditory Verbal Learning Test (RAVLT). Patterns of performance were explored in a sample of genuine traumatic brain injured subjects who were litigating (TBI-LIT; N = 22) and compared to a sample of genuine traumatic brain injured subjects who were not in litigation (TBI-NONLIT; N = 22). Comparisons were also made to a sample of subjects who were depressed but not neurologically compromised (PSY-DEP; N = 24). Results demonstrated that when time for loss of consciousness was controlled for, no difference existed between the litigating and non-litigating groups on any serial position. With this in mind the TBI-LIT and TBI NON-LIT groups were collapsed to form one traumatic brain injured group (TBI; N = 44). Patterns of performance were then compared between the TBI group, the PSY-DEP group and a normal control (NC; N = 68) group. No differences were demonstrated between the TBI and PSY-DEP groups on any serial position however, the NC group demonstrated significantly different primacy effects than the TBI group and significantly different recency effects than both the TBI and PSY-DEP groups (Study 1). Patterns of performance relative to the serial position were also compared in a group of Alzheimers Disease (AD; N=20) and dementia (DEM; N=20) subjects. Results indicated that the DEM group demonstrated a greater primacy effect than the AD group with both groups demonstrating a greater recency effect when compared to the primacy effect but no significantly so. Patterns of performance was also explored in a group of Huntington’s Disease subjects (HD; =14) with this group demonstrating a significantly reduced primacy effect as compared to a recency effect (Study 2). In the third study patterns of performance
were compared in a group of subjects having sustained frontal lobe (FL; N=21) and posterior lobe (PL; N=21) lesions to the brain. Subjects with PL lesions demonstrated a significantly greater primacy effect as compared to the FL group with both groups demonstrating a reduced recency effect. Comparisons were also made between the PL and FL groups with normal control groups (FL-NC; N = 21: PL-NC; N = 21) and results indicated that the FL group demonstrated a significantly reduced primacy and recency effect when compared to the normal control group. When comparisons were made between the PL and a normal control group, the PL group demonstrated a significantly reduced recency effect as compared to normal controls. Patterns of performance were also explored in a small sample of subjects with diffuse (DIFF; N=6) damage to the brain and results demonstrated that this group displayed a reduced recency effect as compared to the primacy effect (Study 3). Overall, when examining the serial position effects across all experimental groups, subjects who had sustained a traumatic injury to the brain or who were depressed all demonstrated a greater primacy effect as compared to the recency effect by recalling more words on that position. This contrasted the pattern of performance which emerged with various dementing processes where more words were recalled in the recency position as compared to the primacy position. Results for all studies were analyzed using MANOVA followed by the Sheffe procedure.
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<th>Term</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Traumatic Brain Injured</td>
<td>TBI</td>
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<tr>
<td>Traumatic Brain Injured Litigating</td>
<td>TBI – LIT</td>
</tr>
<tr>
<td>Traumatic Brain Injured Not Litigating</td>
<td>TBI – NONLIT</td>
</tr>
<tr>
<td>Psychiatric Depressed</td>
<td>PSY – DEP</td>
</tr>
<tr>
<td>Normal Control</td>
<td>N/C</td>
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<tr>
<td>Neurosciences Unit</td>
<td>NU</td>
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<tr>
<td>Alzheimers Disease</td>
<td>AD</td>
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<tr>
<td>Huntington’s Disease</td>
<td>HD</td>
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<tr>
<td>Dementia</td>
<td>DEM</td>
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<tr>
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<tr>
<td>Posterior Lesions</td>
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<td>Posterior Lesions Normal Control</td>
<td>PL – N/C</td>
</tr>
<tr>
<td>Mild Traumatic Brain Injury</td>
<td>MTBI</td>
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<tr>
<td>Glasgow Coma Scale</td>
<td>GCS</td>
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<tr>
<td>Closed Head Injury</td>
<td>CHI</td>
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<tr>
<td>Control</td>
<td>C</td>
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<tr>
<td>California Verbal Leaning Test</td>
<td>CVLT</td>
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CHAPTER 1

GENERAL INTRODUCTION

1.1 THE CONTEXT

Over the past decade the area of neuropsychology has expanded and grown in an attempt to meet the ever increasing demands of professionals engaged in the provision of health services to those who have acquired a traumatic brain injury, those who are learning disabled and those who suffer from various types of dementia. Essentially, the area of clinical neuropsychology is ‘an applied science concerned with the behavioral expression of brain dysfunction’ (Lezak, 1995, p. 7).

In examining the history of neuropsychology, one of the first major neuropsychological programs to be implemented was that which followed the war when assessment and diagnoses of soldiers who had been both traumatized and brain injured was required in order that rehabilitation programs could be implemented (Lezak, 1995). Programs such as this enabled researchers to explore more fully the impact of damage to the brain on behaviour. One of the more famous brain – behaviour relationships was that established by Broca when it was noted that damage to the second and third left frontal convolutions of the brain resulted in what was termed nonfluent aphasia (Gasquoine, 1998). Nonfluent aphasia of this nature today is known as Broca’s aphasia. Another well know example in the literature of the relationship between brain and behaviour is that of Phineas Gage who suffered severe injuries to the frontal lobes of his brain as a result of an explosion which sent a metal bar through Gage’s skull (Coon, 1992). Apparently, prior to the accident Gage had been ‘known as a decent, conscientious man (Western, 1999, p. 115), however, following the accident his behaviour changed and became ‘childish and irreverent’ (p. 115). Research has since established that damage to the frontal lobes of the
brain may result in behaviour which is childish, lewd and tactless (Ron, 1989). Frontal lobe damage may also result in a lack of insight where the patients themselves do not have an appreciation of their own behaviour, or the impact of their behaviour upon those around them (Russell & Roxanas, 1990).

It is often the resultant behaviour of persons who have sustained some form of brain trauma which prompts the treating practitioner to request a neuropsychological assessment. Essentially, the purpose of the neuropsychological assessment is to identify deficits to the brain which subsequently alters behaviour (Miller, 1994). The aim of such assessments is usually to implement interventions which may for example, assist the dementing person with a memory dysfunction to cope with every day living such as grocery shopping, cooking, cleaning and self care.

In the case of the person who has acquired a brain injury as a result of an accident, programs may be implemented based on the results of a neuropsychological assessment which may assist in eventually returning the brain injured person to his/her former employment, or to retrain the person so that they may participate in a form of employment of which they are capable (Paniak, Shore, Rourke, Finlayson, Moustacalis, 1992).

As a result of the numerous cases of compensable traumatic brain injury (TBI) which occur each year, there has been an increase in the number of studies conducted in order to identify patterns of performance which may be demonstrated when a person is deliberately performing poorly. However, for the most part, it has been common practice to utilize convenience samples with subjects who have been instructed to mangle. Problems of generalisability are obvious and it simply cannot be assumed that the pattern of performance on results obtained from normal subjects instructed to 'fake' a poor performance as a result of TBI are representative of results which would be obtained from
persons who had sustained a genuine TBI and who were trying to deliberately perform poorly.

Patterns of performance have been explored on such tests as the Rey Memory Test, The Dot Counting Test and the Rey Auditory Verbal Learning Test (Rey, 1964 [RAVLT]). The measure of interest insofar as this study is concerned is the RAVLT and as such, the primary focus of the literature review will be on the RAVLT. As far as the RAVLT is concerned, research has generally explored patterns of recall performance relative to the serial position (i.e., primacy and recency effects) in simulated malingerers (Bernard, 1991), Alzheimer’s Disease (Haddad, & Nussbaum, 1990; Tierney, Nores, Snow, Fisher, Zoritto & Reid, 1994), multiple sclerosis (Godoy, Perez, Sanchez-Barrera, Muela, Mari-Befa & Puente, 1995) and TBI (Shum, Harris & O’Gorman, 2000) however, such studies have produced conflicting results which may arise from differences between studies in sample size, nature of simulating groups, and comparisons between simulators and groups with differing neurological disorders.

Thus, the purpose of the current study was to contribute to existing research concerning the RAVLT by comparing the serial position effect between genuine TBI litigating and TBI non-litigating samples and differentially compromised neurological groups. Such comparisons will be conducted across several studies; the first study will examine the serial position effect between genuine TBI litigating (LIT - TBI) and TBI non-litigating (NONLIT - TBI) samples and comparisons made to normative data (NC) concerning the RAVLT. In view of the impact that depression may have on performance regarding neuropsychological measures, a psychiatric group (PSY – DEP) formally diagnosed by psychiatrists as suffering with anxiety and or depression, but with no neurological impairment, will also be compared to the above. The second study will
patterns of performance will be explored between groups consisting of Probable Alzheimer's Disease (AD), Dementia (DEM) and Huntington's Disease (HD). In reviewing the literature, there seems to exist a paucity of research concerning the serial position in relation to location of damage to the brain thus, the third study will consist of subjects grouped according to location of lesion to the brain. For example, frontal (FL) vs. posterior (PL) vs. diffuse (DIFF) damage to the brain. Comparisons will also be made between the FL, PL and DIFF groups and normal control (N/C) groups. Specific hypotheses and justification for each study will be presented following a presentation of definitions of terms relevant to this study, a general introduction to malingering and TBI research and a review of the literature surrounding the RAVLT as it relates to each study.
1.2 DEFINING THE TERMS.

A common problem concerning research regarding brain injury or insult to the brain is the clear lack of definitions surrounding the terms used to describe such (Hsiang, Yeung, Ashley, & Poon, 1997). For example, terms such as postconcussive syndrome (Silver & McAllister, 1997), mild head trauma, mild traumatic brain injury, traumatic brain injury and head injury all appear to be used interchangeably (Williams, 1997). It is possible that this lack of clarity contributes to at least some of the conflicting findings regarding brain injury research and the lack of understanding regarding cognitive deficits which result (Essleman & Uomoto, 1995).

The Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine (1993) suggests that the definition of mild traumatic brain injury (MTBI) include at least one of the following;

1. any period of loss of consciousness;
2. any loss of memory for events immediately before or after the accident;
3. any alteration in mental state at the time of the accident (e.g., feeling dazed, disorienated, or confused); and
4. focal neurological deficit(s) that may or may not be transient; but where the severity of the injury does not exceed that following: loss of consciousness of approximately 30 minutes or less; after 30 minutes an initial Glasgow Coma Scale (GCS) of 13 – 15; and posttraumatic amnesia (PTA) not greater than 24 hours (p. 86).

The above definition is somewhat ambiguous and includes symptoms from feeling ‘dazed’ to permanent focal deficits (Essleman & Uomoto, 1995) and this impreciseness becomes
obvious in the literature. For example, many studies utilize the suggestion of a GSC score of between 13 – 15 at first examination (Alexander, 1995) to classify an individual as having sustained a MTBI (see Barth, Macciocchi, Giordani, Rimel, Jane, & Boll, 1983; Bohnen, Jolles & Twijnstra, 1992; Levin, Mattis, Ruff, Eisenberg, Marshall, Tabaddor, High & Frankowski, 1987), often regardless of other clinical features (Hsiang et al, 1997).

In view of the confusion surrounding the terms used to describe MTBI, Hsiang et al (1997) undertook a study which incorporated some 1,360 subjects who had been admitted to the neurosurgery service of the Prince of Wales Hospital during the years 1994 – 1995 for the purposes of ‘redefining’ the definition of MTBI. After documenting data such as GCS score, skull x-ray film and CT findings, neurosurgical intervention and 6-month outcome postinjury, these researchers found that 967 patients with GCS scores of 15 and no abnormalities demonstrated on radiographic investigations exhibited a good outcome however, 108 patients with GCS scores of 13 or 14 with no acute radiographic abnormalities demonstrated a poor outcome. The researchers concluded that ‘patients with lower GCS scores tended to have suffered more serious injury’ (p. 234).

Other research has suggested that whilst the GCS may be adequate in predicting initial survival of patients, it may not be ‘sophisticated enough to differentiate long-term higher level variations in cognitive performance’ (Haut & Shutty, 1992, p. 56).

An additional problem seen to exist with current research and one which also possibly contributes to the variability of results seen in the literature is the classification of subjects primarily based on a GCS score. In most circumstances the GCS is usually only administered through emergency departments, emergency medical centres and trauma centres. This procedure in effect ‘misses’ the individuals whom either present to their
general practitioner as a result of an accident involving the trauma to the head or, who simply do not present for medical treatment. When the same individuals then begin to experience cognitive difficulties as a result of the injury sustained and are referred for NPA, there is minimal medical evidence to support a classification as to degree of severity regarding the injury. In these cases, often other factors such as time of loss of consciousness and posttraumatic amnesic period (McAllister, 1994) are used to classify the severity of the injury.

Whilst the above meets certain aspects of the symptomology required for a diagnosis of ‘mild’ TBI, there exists the possibility that there is an intrinsic difference between subjects classified according to the GCS and those who have been classified on the basis of time of loss of consciousness and/or post traumatic amnesia. As a result, when new research is conducted, comparisons to existing research where subjects have been classified according to GCS scores becomes problematic simply because such samples may not be equitable.

Similarly, problems exist with applying the term ‘postconcussive syndrome’ to patients presenting with symptoms of brain trauma such as dizziness, visual disturbances, headache, irritability and fatigue. Often such patients are classified as having sustained a mild brain injury however, Silver and McAllistor (1997) indicate that;

‘Mild TBI is not synonymous with terms such as postconcussive syndrome. The former simply refers to the less severe end of the spectrum of brain injury; the latter describes the cluster of signs and symptoms (usually including one or more difficulties from somatic, cognitive, and behavioral domains) that can be seen after TBI of any severity’ (p. 103).
These researchers go on to recommend that patients experiencing postconcussive symptoms exceeding 12 months be classified as having either 'chronic or persistent’ postconcussive syndrome. Misclassification of patients presenting with postconcussive syndrome as having a MTBI, or vice versa, not only contributes to confusion regarding the literature in brain injury research, but also contributes to confusion regarding diagnoses should the presenting patient pursue a claim for compensation (Silver & McAllister, 1997).

With the above contradictions in mind, for the purposes of this research, the term Traumatic Brain Injury (TBI) will be applied to every group participating in the study where a brain injury has been sustained. Analysis of data will examine the potential impact of time of loss of consciousness on RAVLT performance in studies where appropriate (e.g., time of loss of consciousness is not applicable to comparisons of person’s suffering from various types of dementia).
1.3 INTRODUCTION: STUDY 1.

TRAUMATIC BRAIN INJURY (TBI)

There are millions of cases of TBI occasioned across the world each year and, whilst statistics may indicate prevalence and incidence rates of TBI, they do not demonstrate the ‘human face’ of living with a brain injury. Common residual deficits associated with TBI may include cognitive, physical and emotional consequences. Physically, the individual may suffer from seizures, visual problems ranging from low vision to blindness, loss of olfactory senses, headaches and fatigue (Jakobsen, Baadsgard & Thomsen, 1987). The cognitive deficits are demonstrated by short-term memory loss, slowed speed of information processing (Gronwell, 1977), attention and concentration difficulties, spatial and organisational problems and communication problems (Lezak, 1995). The emotional consequences of TBI can be observed by the person demonstrating inappropriate social behaviour (Weddle, Oddy & Jenkins, 1980), decreased motivation (Bernstein & de Ruiter, 2000), emotional lability (Albin, 1999), aggression, mood swings and depression (Baker – Price & Persinger, 1996; Prigatano, 1992).

The aftermath of any form of TBI for an individual can be devastating with the more severely injured requiring institutionalisation. However, even what is termed to be a mild TBI can alter an individual’s life and severely impact upon family members who often became the primary caregivers of the injured person. Often, significant emotional adjustments must be made by immediate and extended family as they watch a loved one, who, after incurring a TBI seems ‘not to be the same person’ (Persinger, 1993).

It appears as though not only do families have to cope with the loss and grief associated with a member incurring a TBI, but both they and the person concerned must cope with the stress of consulting a legal representative in an attempt to ascertain if injuries
sustained are compensable and then making a decision as to whether to pursue a claim. Whilst it may be said that the physical care of the person concerned is attended to by medical professionals and the legal aspects managed by forensic specialists, the psychological care of the individual often falls to Clinical Psychologists. In all probability this involves neuropsychological assessment and/or long term therapy. In instances where a claim is lodged and monetary compensation is sought there is, in the majority of cases, some form of communication between the forensic, medical and psychological practitioners involved in the management of the person concerned. In this, it seems as though the traumatic brain injured individual and his/her family are met by a myriad of conjecture, speculation and suspicion in regard to claims relating to cognitive deficits reportedly sustained as a result of injuries received.

Insofar as the legal profession is concerned, there is the advantage of the legislative process which outlines appropriate laws dependent upon the nature of the offence committed with some flexibility surrounding the execution of such laws. This is simply not the case in the psychological domain. The study of the human mind is based on individual differences and whilst certain patterns of behaviour may suggest a certain type of disorder, essentially there is maximum flexibility insofar as diagnoses is concerned. As far as the traumatic brain injured individual, neuropsychological assessment and litigation is concerned, it is too simplistic to state that 'all patients with financially compensable injuries must be assessed for the possibility of malingering' (italics added; Binder & Willis, 1991, p. 180). Rather, each person should be assessed as an individual by the clinician with hypotheses forming and changing dependent upon emerging results. For the families involved and specifically for the individual who presents as a victim of TBI, the clinician has a ‘duty of care’ to approach the NPA with an open mind, clear of suspicions
simply because the client’s status is one of litigation. For psychologists involved with the
evaluation of such individuals, the focus should not necessarily be on how long the
individual lost consciousness for as a result of the injury, or how long the post-traumatic
amnesic period lasted because these issues overall, become redundant. Rather, the
emphasis should be on the identification of what deficits the individual is left with, how
such deficits will possibly impact upon daily life and the minimization of such impact
(Lezak, 1995).
1.3.1 TBI: Prevalence Rates

Traumatic Brain Injury (TBI) is acquired as a result of external forces impacting upon the skull such as when the head strikes the windscreen of a vehicle or when the head is struck by a blunt object. In these circumstances the brain is damaged when the force of impact causes it to smash against the bony surface of the skull. Neurological damage may also occur as a result of ‘whiplash’ injury which causes the head to snap forward and backward rapidly resulting in acceleration/deceleration forces causing shearing or stretching of the nerve fibres (Bigler & Snyder, 1995). The brain may also be injured as a result of a penetrating force such as when a bullet enters the skull or when the skull is hit with such power as to cause fracturing. In most instances the former type of injury is referred to as a ‘closed brain injury’ whilst the latter is referred to as a ‘penetrating brain injury’ and both types of injury may result in localized and diffuse damage (de Kruijk, Twijnstra & Leffers, 2001).

The number of persons sustaining a TBI cannot be understated and it is estimated that in America one person every 15 seconds sustains some form of TBI, with approximately 50,000 people losing their life each year as a result of TBI (Thurman, Alverson, Browne, Dunn, Guerrero, Johnson, Johnson, Langlois, Pilkey, Sniezek, & Toel, 1999). Approximately 1.5 million persons suffer from a TBI each year who do not require hospitalisation, and the same number of persons incur brain injury which has resulted in loss of consciousness and hospitalisation but does not require institutionalisation.

The average prevalence rate for what could be termed ‘mild’ TBI is approximately 618 per 100,000. It is estimated that between 80,000 and 90,000 people experience long term disability as a result of brain trauma (Kraus & MacArthur, 1996), and
culminating, 5.3 million men women and children live with a permanent disability as a result of TBI (Thurman et al., 1999).

When examining groups most at risk, young people between the ages of 15 – 24 years are the most vulnerable with males being disproportionately represented (Kraus & MacArthur, 1996) and excluding mild TBI, it is estimated that 62.3 per 100,000 adults over the age of 15 in America live with enduring functional impairments due to TBI (Moscato, Trevisian, & Willer, 1994).

In Australia, during 1996 – 97 there were approximately 27,437 persons diagnosed with TBI and as in America, males between the ages of 15 – 19 years represented the highest rate of TBI (418 per 100,000). It is estimated that 80% of these persons were admitted to hospital with ‘mild’ TBI, 10% with moderate TBI and 10% with severe TBI. Approximately 6.4% of persons admitted to hospital died as a result of the severity of TBI and approximately 24 per 100,000 suffer a long-term disability (Fortune & Wen, 1999).

The implications of the above statistics is that more individuals are seeking or pursuing compensation claims as a result of persisting cognitive or behavioural deficits incurred as a result of having sustained a TBI. Conversely, the number of persons referred through forensic practitioners for an individual to attend a NPA has also increased.
1.4 THE NEUROPSYCHOLOGICAL ASSESSMENT (NPA)

Essentially, the primary purpose of the NPA in most cases is to attempt to identify behavioral and cognitive deficits which have resulted as a consequence of injuries sustained to the brain. However, the cognitive sequelae following TBI are not clearly defined and remains confusing (Raskin, Mateer & Tweeten, 1998). Whilst it appears as though the majority of persons sustaining a TBI go on to make a full recovery within three months of the injury, there remains a significant number who demonstrate a number of symptoms over a much longer period (Bohnen, Jolles, & Twijnstra, 1992). In this group, there remains individuals who will continue to exhibit symptoms of TBI for periods extending 6 – 12 months after sustaining the injury (Silver & McAllister, 1997). Persisting deficits include headache, dizziness and fatigue (Levin et al, 1987), emotional distress (Diamond, Barth & Zillmer, 1988), attentional problems (Kay, 1992) depression (Robinson, Starr & Price, 1984; Robinson, Bolduc & Price, 1987) and difficulties on tests assessing executive functions (Leninger, Gramling, Farrell, Kreutzer & Peck, 1989). Often as a result of persisting deficits arising from TBI, the number of referrals to psychologists for a NPA to be conducted has increased as individuals pursue legal claims for compensation. The implication of this is that psychologists are being repeatedly called upon to act as expert witnesses in order to testify as to the possibility of exaggerating or faking cognitive deficits which are alleged to have occurred as a result of injuries sustained (Goebel, 1983; Rogers, 1977).

This appears to have led to multiple complications for the assessing psychologist in that often, testimony by psychologists as to the extent of TBI and the implications of such, is met with skepticism by those in the forensic arena, particularly where the evidence of a
psychologist results in an increased monetary payout. This skepticism is obvious in the words of Lees – Haley (1994):

‘The evolution of minor into a massive psychological claim is frequently the end result of a testifying psychologist who asserts that neuropsychological testing has proved brain damage. The defense attorney must learn to analyze this evidence and explain it to the fact finder in order to disclose it’s weak underpinnings’ (p. 131).

Whilst Lees – Haley’s (1994) statement that the analysis of NPA tests results will reveal ‘weak underpinnings’ may be a questionable one, the identification of a malingering performance on neuropsychological tests remains both problematic and difficult as previous research suggests that various factors such as motivation and litigation have been found to impact upon performance during a NPA.
1.4.1 NPA AND MOTIVATION

Motivation (Bernstein & de Ruiter, 2000; Binder & Willis, 1991), depression (Baker–Price & Persinger, 1996; Fann, Katon, Uomoto & Esselman, 1995; McCleary, Satz, Forney, Light, Zaucha, Asarnow & Namerow, 1998) and monetary compensation (McMahon & Satz, 1981; Mittenberg, DiGiulio, Perrin & Bass, 1992) amongst other factors, may influence a person’s performance during a NPA.

In a study designed to explore motivational factors upon neuropsychological performance, Binder and Willis (1991) used the Portland Digit Recognition Test (PDRT) to compare and assess motivation in some 139 subjects who were divided into 6 groups; ‘minor head trauma litigating clients’ (MHT – Comp); ‘well documented’ brain dysfunction clients not litigating (BD – NoComp); affective disorder patients not litigating (AD NoComp); nonpatients instructed to simulate the effects of a compensable minor head injury in order to obtain financial gain (Nonpt – Comp) and nonpatients (Nonpt – NoComp [p. 176]).

Results for the study demonstrated that compensable patients performed worse than non compensable patients on the PDRT with the Nonpt – NoComp group performing superior to all groups. Interestingly, the Nonpt – Comp (simulator) group performed significantly worse than any other group, regardless of compensable status, perhaps questioning the suitability of using simulator groups in malingering research (emphasis added). Additionally, whilst the pattern of performance on the PDRT of affective disordered patients may be interesting, it could not be assumed that similar results would emerge from a depressed, litigating TBI sample simply because the depression which results from trauma may be different in nature to that experienced as a result of psychosocial factors (Baker–Price & Persinger, 1996). Binder and Willis (1991) also
suggested that sensorimotor measures may also be impacted upon by patients who 'fake bad'. This may well be possible, however, performance on sensorimotor measures may also be affected as a result of a client experiencing depression and/or fatigue (Alexander, 1995).

Similar problems appear to exist with this study as they do with the majority of studies concerning simulated or analogue research; a lack of generalisability. In most studies subjects are drawn from university populations and are without brain dysfunction (Rogers, 1977). Whilst it could be said that most of the current literature accurately reflects results obtained from persons who 'grossly exaggerate', one could question as to whether the same results are reflective of such behaviour in the 'real world'.

Whilst research supports that it is not unusual for persons to 'exaggerate or deliberately perform poorly' during neuropsychological assessments, it seems that such conclusions are based on a number of assumptions. For example, the case of 'normal' subjects being instructed to 'act like malingers' and to 'pretend to be seeking compensation for an injury'. In this, there is the inadvertent assumption that somehow on instructing 'normal' subjects to imagine a scenario and pretend that they are involved in litigation and to act accordingly, those same subjects will also develop such insight as to be able to understand the extrinsic and intrinsic motivations of the true 'malingering'.

Another assumption concerns the recruitment of university students to act as 'simulators'. The practice of studying patterns of behaviour in a population of students instructed to mangle leaves a myriad of questions unanswered and the generalisability of such studies in doubt. Realistically, results and findings of such studies merely represent the behaviour of 'normal' students who have been instructed to mangle. In the context of simulation research there is no doubt that subjects are indeed malingering; there is an intent to
deliberately fake, or exaggerate some sort of alleged cognitive deficit. However, whether such results can be said to reflect true malingering patterns in a population of potentially neurologically compromised persons seems to be questionable.
1.4.2. NPA AND THE DETECTION OF DECEPTION

In the search for instruments which may reliably identify malingerers, studies have been conducted across tests commonly used in the NPA such as the California Verbal Learning Test (CVLT; Millis, Putman, Adams & Ricker, 1995; Coleman, Rapport, Millis, Ricker & Farchione, 1998), the Rey Memory Test (RMT; Bernard & Fowler, 1990), the Rey Auditory Verbal Learning Test (RAVLT; Bernard, 1991), and more recently devised tests such as the Test of Memory Malingering (Rees, Tombaugh, Gansler & Moczynski, 1998) which according to its creators, ‘holds considerable promise for detecting exaggerated or deliberately faked memory impairment in clinical situations’ although, the authors of this test do recommend that it be used in conjunction with other measures (Tombaugh, 1997, p. 260) and tests proposed for further research but which are postulated to be sensitive to malingering such as the Wildman Symptom Checklist (Wildman & Wildman, 1999).

In an attempt to investigate the potential of the CVLT in differentiating between TBI patients classified as having either ‘mild’ or ‘severe’ head injuries, Millis et al (1995), compared patterns of performance between 23 mild head injury subjects (MHI), and 23 severe head injury subjects (SHI) matched for age and education (within 2 years). Variables from the CVLT were selected which were apparently sensitive to incomplete effort. According to Millis et al (1995), incomplete effort by subjects on memory examinations might be demonstrated by the subject denying the gaining of new knowledge during such examinations. Thus, the variables selected from the CVLT included trials 1 – 5, recognition discriminability, recognition hits and long – delay cued recall. Essentially, over the five acquisition trials subjects were instructed to recall as many words as possible, which was followed by target and distracter words being presented. This presented the
subjects with the opportunity to deny having learned the target words during the acquisition trials and resulted in a low recognition discriminability score and a low number of recognition hits. Semantic prompting during the recall trials provided additional opportunity for subjects to deny having gained knowledge during the acquisition trials.

As predicted, Millis et al (1995) found that the MHI group demonstrated significantly lower scores in the CVLT total, recognition discriminability, recognition hits and long delay cued recall. Insofar as the CVLT being able to differentiate between patients who had mild or severe head injury, linear discriminant function analysis classified 91% of subjects with a sensitivity of 91% and specificity of 91%. In the above study, sensitivity was defined as ‘...the test’s ability to identify incomplete effort or exaggerated impairment...’ (Millis et al, 1995, p. 466). Specificity referred to the test’s ability to correctly identify MHI participants without illness or diagnosis as MHI participants.

Based on the above results, the investigators concluded that the CVLT held considerable promise as a means of detecting incomplete effort during neuropsychological assessment. However, the investigators caution that a single test score on its own does not necessarily indicate the presence of incomplete effort and, that psychosocial factors unrelated to brain injury but associated with incomplete effort ‘likely’ influenced the MHI groups performance. Interestingly, prior to the commencement of the study the investigators stated that whilst they couldn’t establish with ‘absolute certainty’ that the MHI subjects were malingering, they felt that characterising them as giving ‘incomplete effort’ was ‘conservative’. This opinion was based on the fact that MHI subjects were involved in litigation – and that all members of the group had performed at or below chance level on one test - that being the Recognition Memory Test. Unfortunately, whilst
the investigators administered ‘...a fixed or core battery of tests’ (p. 465) it is unclear as
to whether measures indicative of affective state were included in the test battery. There
exists the possibility that anxiety (Lezak, 1987), depression (Brooks, Campsie,
Symington, Beattie & McKinlay, 1987; Jorge, Robinson, Arndt, Forrester, Geisler &
Starkstein, 1993) or even fatigue may have impacted upon results obtained. Additionally,
despite matching subjects which contributes to statistical power, there were only 23
participants in each group. The problems associated with research conducted on small
samples is documented in (Goodwin, 1995) and results obtained may have been different
if the sample size had been larger. It also seems somewhat presumptuous to ‘characterize’
TBI clients as demonstrating incomplete effort based on the fact that such clients were
involved in litigation at the time of the study and performed poorly on one type of memory
measure. Whilst Millis et al (1994) acknowledge that replication of their study is
necessary it could be argued that their statement "certainly, it is never more true than in
this case that absence of evidence of malingering is not evidence of absence of
malingering" (p. 469) in regards to the findings of the study could simply be rewritten to
read “certainly, it is never more true than in this case that [alleged] presence of evidence
of malingering is not evidence of the presence of malingering”.

Beeter and Williams (1995) used various instruments such as Rey’s Dot-Counting
Test, a Forced-Choice Symptom Validity procedure and the Memory Assessment Scales
to differentiate performance in subjects who had been 'instructed' to malinger and a control
group. Results demonstrated that the 'malingering' group performed worse than the control
group across most dimensions assessed. For example, the malingering groups response
times on tests were slower, recognition tasks were performed more poorly than recall tasks
and response style on recognition tasks was 'characteristic' of intentional wrong and
random responding' (p. 57). However, insofar as the Forced Choice Symptom questionnaire was concerned, malingers did not demonstrate an expected worse-than-chance performance. It should be kept in mind that the 60 subjects who participated in the study were University students and whilst it is not clear as to what discipline they were enrolled in, they had been approached whilst working in the 'medical library computer laboratory' (p. 62). This suggests that the subjects had some knowledge of medicine and perhaps a greater knowledge than what would be expected from non University attendees thus possibly rendering the results not applicable to the 'wider population'.

Research concerning malingering has, for the most part, involved 'groups' however, results from single case studies have also been reported. For example Binder and Pankratz (1987) presented a single case study of a female patient who had been complaining of severe memory loss and was seeking a disability pension. Various neuropsychological instruments were administered including the Wechsler Adult Intelligence Scale, the Wechsler Adult Intelligence Scale Revised, the Trail Making Test B, the RAVLT, the Babcock Story Recall Immediate/Delay and the Purdue Pegboard Motor Test. Only selected results from the study were presented as researchers conducting the study were of the opinion that certain results were 'noncontributory' and could have resulted from 'dementia, lifelong subnormal intellectual ability, poor motivation, or a combination of all three (p. 168). On the basis of testing which suggested that the subject was poorly motivated or faking, a Symptom Validity Test was devised 'on the spot' and consisted of presenting the subject with a yellow or black pen. The subject viewed the pen before its removal and then counted from 1 to 20 before being asked to recall the presented object. Results indicate that of 100 trials conducted the subject made 63 errors and on this basis 'her response pattern...was so statistically improbable that faking bad was more than
a clinical hunch - it was a compelling, logical conclusion' (p. 167). This may well be so but the subject in this case study had been diagnosed previously with 'inadequate personality disorder and depression' (p. 168). It is quite possible that such a disorder combined with depression could have impacted upon test results. Additionally, whilst the subject may not have had a history of head injury and consequently was not disabled as a result, there certainly seems to exist the possibility of a disabling psychiatric history.

An additional measure used frequently in TBI research is the RAVLT which has proven useful as a device in the classification of subjects based on performance across trials, particularly in relation to the serial position.
1.5 THE REY AUDITORY VERBAL LEARNING TEST (RAVLT).

The RAVLT is an easily administered measure that consists of 15 nouns which are read aloud at the rate of one per second for five consecutive trials. In this, the measure is referred to as a supraspan word list learning task. Each trial is read aloud by the examiner and upon completion of each trial the client is asked to remember as many words as possible in any order. Upon completion of the fifth trial, an interference trial utilising a different set of 15 words is conducted. The client is again asked to remember as many words as possible. A free recall trial is then conducted in which the client is asked to remember as many words as possible from the original list without the list being read out by the examiner. A recognition trial can be conducted following either a 20 or 30 minute delay (Groth-Marnet, 1997). It should be kept in mind that in examining the serial position effect for this study, the delayed recall and recognition trials are not included in the analysis. Overall, the RAVLT appears to measure immediate memory, efficiency of learning, effects of interference and recall and recognition (Rey, 1964).

Performance on the RAVLT has been evaluated as a measure of learning and memory in numerous studies across a diverse range of subjects and it has been rated of one of the most useful diagnostic tests for dementia (Tuokko et al, 1995). In all probability this relates to the simplistic manner in which the RAVLT can be administered and the volume of information demonstrated by results obtained. It is one of the more common measures included in a neuropsychological assessment battery and will provide information relating to memory in the way of learning strategies and learning curves demonstrated by the serial position (Mungas, 1983).

The versatility of the measure is demonstrated by the diverse range of studies which have implemented the device in order to study the serial position curve. Insofar as
TBI and litigation research is concerned, the RAVLT has been used to detect malingering as research suggests that 'malingers' demonstrate different serial position curves. In addition, the RAVLT has been implemented in studies of Alzheimer's Disease, multiple sclerosis and Huntington's Disease in order to study the serial position effect in these populations.
1.5.1 RAVLT and NEUROLOGICAL CLASSIFICATION.

Patterns of performance across numerous populations, including litigating samples, have been explored by way of the serial position effect which according to Rundas (1971) is the ‘U’ shaped curve resulting from the recall of words. The ‘U’ shaped curve emerges as a result of better recall of words presented from the beginning and the end of a wordlist (Tan & Ward, 2000). Insofar as the RAVLT is concerned, words presented later in the list tend not to interfere with the learning of words presented at the beginning of the list (Mungas, 1983).

The versatility of the RAVLT has been demonstrated in the literature and it has been implemented as a research tool across a broad variety of studies in order to classify subjects according to deficits and, to evaluate the serial position effect in subjects with Huntington’s Disease (Butters, Wolfe, Granholm & Martone, 1986), Alzheimer’s Disease (Haddad & Nussbaum, 1990) and multiple sclerosis (Bravin, Kinsella, Ong & Vowels, 2000; Godoy, Perez, Sanchaz-Barrera, Muela, Mari-Beffa, & Puente, 1996) and to differentiate between normal aging and the effects of Alzheimer’s and Parkinson’s dementia (Tierney, Nores, Snow, Fisher, Zorzitto & Reid, 1994) and between control and closed head injury groups (Vakil, Blachstein, 1991).

In a study designed to assess the effectiveness of the RAVLT in differentiating between neurologically impaired and non-neurologically impaired patients, Powell, Cripe and Dodrill (1991) compared 50 ‘mixed’ neurologically impaired subjects with 50 control subjects with no neurological history. The neurologically impaired group selected to represent a cross section of impairment, consisted of head injured subjects (18), penetrating head wound (3), idiopathic epilepsy (10), infectious encephalopathy (8), brain tumor (4), hemorrhagic lesion (3), anoxia (2), stroke (1) and degenerative dementia (1).
Results demonstrated that the neurologically impaired group performed significantly worse than the non-neurologically impaired group on all RAVLT trials (1 – VII) and on the total number of words recalled (trials 1 – V). These researchers determined that a cutoff score of 12 and less on trial vindicated a performance outside normal limits and that a cutoff score of 13 and more indicated a performance within normal limits. Using this criteria the RAVLT identified 75% of the neurologically impaired sample and performed more accurately than the Halstead-Reitan or Dodrill batteries and the Halstead Impairment Index.

Insofar as frontal lobe lesions are concerned, Dimitrov, Granetz, Peterson, Hollnagel, Alexander and Grafman (1999), reported that these patients invariably exhibit diminished performance on tests of recognition, cued recall and free recall with the latter being disrupted the greatest, and recognition being disrupted the least. However, a study by Shimamura, Janowsky and Squire (1990), using a condensed version of the RAVLT consisting of a one-trial free recall test, immediately followed by a yes/no recognition test, did not support these results.

In the Shimamura et al study, comparisons were made between four patients with unilateral frontal lobe lesions, two patients with bilateral lesions and normal subjects matched on age and education. The frontal lesions group recalled 13% less words on the recall trial however, the difference was not significant. Similarly, there was no significant difference in scores on the recognition test. However, patients with frontal lobe lesions were impaired on reproducing the sequential order of the fifteen words thus suggesting damage to this area contributes to a deficit in memorizing temporal order.

Similarly, Rosenberg, Ryan and Prifitera (1989) implemented a study involving 92 psychiatric and neurological patients designed to assess the efficacy of the RAVLT in
discriminating between subjects who had been classified as having a memory impairment and those who did not. In order to establish who of the 93 subjects were memory impaired, every subject was administered the Wechsler Adult Intelligence Scale (WAIS), the Wechsler Memory Scale and the RAVLT. Subjects scoring 12 lower than their full scale intelligence quotient and whose memory quotient was lower than 85 were classified as memory impaired. According to this criteria, 47 patients were classified as impaired whilst the remaining 45 receive a classification of normal. Results demonstrated that memory impaired subjects performed worse than unimpaired group for each of the RAVLT trials (I – VI) including the recognition trial. The researchers concluded that ‘the RAVLT is a valid indicator of verbal learning and memory in a mixed patient sample (p. 787).

In a similar study also designed to assess the efficacy of the RAVLT in discriminating between subjects with differing diagnoses, Mungas (1983) administered the RAVLT to amnesics, severe head trauma victims, patients with Attention Deficit Disorders, Schizophrenics and nonpsychotic psychiatric patients. In this study, the RAVLT was able to discriminate between the groups on all trials with the exception of trial 1.

The research pertaining to the RAVLT however appears to be somewhat conflicting and results obtained by Crockett, Hadjistavropoulos and Hurwitz (1992) using a sample of 22 subjects with lesions located posteriorly to the central sulcus, 31 with anteriorally – situated lesions, and 52 psychiatric patients with no evidence of structural damage demonstrated that there were no significant differences between any of the groups insofar as primacy and recency effects were concerned. However, Crockett et al (1992) did suggest that the above finding might have been due to a higher number of patients with
specific hippocampal damage in the study. This finding also indicates a need to study groups of subjects who have damage to specific areas of the brain.

The predictive ability of the RAVLT has also been explored with patients diagnosed with Alzheimer's Disease in a study conducted by Haddad and Nussbaum (1989). In this study 57 elderly persons with a mean age of 70.6 years and all diagnosed with AD had taken part in an intensive cognitive stimulation/social communication skills training group therapy program for a period of 8 weeks. At the commencement and conclusion of the program all subjects were administered a variety of behaviour scales with the exception of the RAVLT which was only administered at the commencement of the program. Subjects were then divided into two groups based on pre/post behaviour rating scales and a semi-structured interview with ward staff and pre therapy RAVLT scores were evaluated in order to establish differences between groups. Results demonstrated groups to be significantly different on all trials with the exception of trials 1 and delayed recall. This lead Haddad and Nussbaum (1989) to conclude that the RAVLT appeared to 'have the potential for locating those persons who, from a pool of impaired elderly, benefit from intervention (p. 59).
1.5.2 RAVLT and THE SERIAL POSITION

Previous research has also been conducted to explore the sensitivity of the RAVLT to "faking bad" in a study by Bernard (1991). In this study comparisons were made between a closed head injured group (CHI), a control group (C), one malingering group given financial incentive and one malingering group without financial incentive. The malingering groups received instructions to pretend they had been in a car accident and had received a head injury and to simulate 'as serious memory problems you can but in a believable way' (p. 83). Interestingly, statistical analysis revealed no difference between the two malingering groups on any RAVLT trials including the interference, recall and recognition trials. As a result, the two groups were combined. The CHI group was drawn from the database of a rehabilitation hospital and all had sustained a closed head injury in a motor vehicle accident whilst subjects for the malingering and control groups were University attendees. Subjects were matched on age, sex and education. Results demonstrated a significant serial position by group interaction effect with the malingering group performing significantly worse that the control group but significantly better than the CHI group. Results also demonstrated that the pattern of performance for the CHI group was different to the malingering group in that the malingering group demonstrated a primacy effect (approximately 65% of words recalled) that was below the recency effect (approximately 74% of words recalled) by contrast to the CHI groups pattern of performance where 56% of words were recalled in the first serial position (primacy effect) and 47% recalled in the last position (recency effect).

In view of the above results, Bernard (1991) suggested that the shape of the recall learning curve was distorted by subjects faking bad in that the 'U' shaped curve demonstrated a suppressed primacy effect and a normal recency effect. This led Bernard (1991) to
conclude that persons attempting to fake bad suppressed words from the first third of the list and that ‘performance pattern may be a good indicator of deliberate poor performance on the RAVLT rather than the pattern of scores themselves’ (p. 87).

The above results contrast with those of a later study conducted by Bernard, Houston and Natoli (1993) when both the control group and malingering group produced normal recency and primacy effects. It should be kept in mind however that there were fewer subjects in the malingering group for the 1993 study (31) compared to the number of subjects in the 1991 study (57) and this may have had some statistical impact by way of Type I error in the second study. In addition, Bernard et al (1993) makes the point that the results for the 1993 study are only indicative of the serial position effect in a simulated sample and thus, may not generalise to a genuine clinical TBI sample.

The serial position effect has also been examined in patients diagnosed with multiple sclerosis. In a study mentioned previously, Godoy et al (1996) examined the serial position effect in a study designed to test acquisition-retrieval deficits in multiple sclerosis patients. This study implemented an experimental group and a control group (CG) which consisted of subjects with similar demographic and cultural characteristics as the experimental group. Performances between both groups on the RAVLT were compared with results indicating that whilst the control group demonstrated a primacy and recency effect, the MS group did not. The researchers concluded that as the primacy effect is an indicator of long term memory, and the recency effect is hypothesized to be indicative of short term memory, then the absence of a recency effect may be suggestive of a deficit in the ‘explicit recovery of information’ (p. 95).

The serial position effect was also examined in a study to determine differing patterns of performance in subjects diagnosed with Parkinson’s Dementia, Alzheimer’s
Disease and normal aging (Tierney, Nores, Snow, Fisher, Zorzitto & Reid, 1994). Subjects in this study were divided into four groups; (1) normals, (2) AD – moderate, (3) AD – severe and (4), Parkinson’s Disease. Results demonstrated a significant main effect of group and serial position. In this, the normal group recalled more words at each position than all other groups. The moderately impaired Alzheimer’s Disease group and Parkinson Disease group performed similarly with both groups recalling more words than the severe Alzheimer’s Disease group for primacy, middle and recency serial positions. Both the normal and Parkinson Disease groups demonstrated a similar proportion of words recalled from the beginning and end of the list demonstrating similar recency and primacy effects however, the moderate and severe Alzheimer’s Disease groups recalled significantly more words from the end of the list than from the beginning which resulted in a greater recency effect. This led to the conclusion that the serial position demonstrated by the RAVLT may be a useful measure in establishing the severity of dementia regardless of etiology (Tierney et al, 1994).

The RAVLT was also implemented in a study designed to illustrate ‘the use of a trial – to – trial decomposition method which is designed to yield measures of both gained items and lost items across adjacent study – test trials’ (Woodward, Dunlosky & Salthouse, 1999, p. 667). In other words, the above study examined the amount of information lost from one trial to the next trial by exploring how much information was encoded and consolidated across trials in a group of 6 subjects diagnosed with Alzheimer’s Disease compared to normal controls. In examining the serial position both the AD subjects and the matched controls demonstrated a primacy and a recency effect. However, it was also found that the AD subjects experienced ‘impaired encoding and impaired consolidation between adjacent trials’ (p. 674). This indicated that AD subjects were not
only unable to encode information efficiently, they were equally unable to access previous information which had been encoded.

It should be kept in mind that the 'recency' and 'primary' effects as they relate to the RAVLT are a reflection of pooled trials across the five trials. This contrasts with traditional memory research which establishes the serial position effect following the presentation of a single word list where typically more words are recalled from the beginning and the end of the list as a result of separation of long term and short term memory processes across three trials (Rundas, 1971). Insofar as the current study is concerned, the serial position, as demonstrated by recency and primacy effect, will reflect pooling across the five trials to reflect total percentage of words recalled in each serial position. The author of the normative data for the RAVLT maintains that maximum information concerning learning and memory is gained when the serial position is examined across five trials as compared to that which emerges when serial position effects are examined across three trials (see Lange, Senior & Sutton, 1997). Table 1a provides an illustration as to how the serial position is calculated. The numbers in each cell represents the order and number of words recalled on each trial (this may not always add to 15).
Table 1a: Illustration of the calculation of the Serial Position.

<table>
<thead>
<tr>
<th>List A</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>Serial Positions</th>
</tr>
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<tbody>
<tr>
<td>Drum</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Curtain</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>Serial Position 1 = 15</td>
</tr>
<tr>
<td>Bell</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>(Primacy Effect)</td>
</tr>
<tr>
<td>Coffee</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td></td>
<td>Serial Position 2 = 12</td>
</tr>
<tr>
<td>Parent</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td></td>
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<tr>
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<td>Garden</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>Serial Position 3 = 6</td>
</tr>
<tr>
<td>Hat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Farmer</td>
<td>4</td>
<td>11</td>
<td>10</td>
<td>12</td>
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<tr>
<td>Nose</td>
<td>3</td>
<td></td>
<td>13</td>
<td>15</td>
<td></td>
<td>Serial Position 4 = 10</td>
</tr>
<tr>
<td>Turkey</td>
<td></td>
<td></td>
<td>12</td>
<td>12</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Colour</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>House</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td>Serial Position 5 = 14</td>
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<td>River</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>(Recency Effect)</td>
</tr>
</tbody>
</table>
1.5.3 RAVLT and Educational Influence.

Previous research has found that education has some effect on performance on the RAVLT with small positive correlations being demonstrated. For example, Query and Megran (1983) studied a number of influences which may have impacted upon performance on the RAVLT in a large sample of 677 male inpatients aged 19 - 81. In order to establish the impact of education upon performance, Query and Megran (1983) selected data from the main pool of subjects in the study for analysis. Higher education enhanced learning for the younger group whilst it was significantly associated with recall for the older group. In the 30 – 34 year old age group a correlation of .29 with learning emerged and, in the 50 – 54 year old age group a correlation of .33 was demonstrated on trial IV scores and .29 with recognition memory scores. Other research also supports that education may impact upon RAVLT performance with results from a study by Selnes, Jacobson, Machado, Beeker, Wesch, Miller, Visscher & McArthur (1991) involving a sample of seronegative homosexual and bisexual males. Small but significant correlations with education were demonstrated across all RAVLT trials including delayed recall.
1.5.4 RAVLT and AGE

Age effects have also been demonstrated on RAVLT performance with a ‘steady decline’ noted on RAVLT scores as age increased in the previously mentioned study by Query & Megran (1983). The number of mean words recognised by the younger group (15 – 24) was demonstrated as being 5.35 whilst the mean number of words recognised for the oldest group (70 +) was 2.72. An increase in learning was noted in the 35 – 39 year old age group which decreased over time indicating that as age increased, less words were recognised.

Savage and Gouvier (1992) also found age effects in a sample of 134 undergraduate psychology students representing ages 16 – 59 and, senior citizens recruited from within the community representing ages 60 – 76. Results demonstrated no effect for age on trials I or II however, significant effects for age were found on trials III, IV and V with subjects in the 20 – 59 age group scoring within one word of each other and the oldest group scoring between 2 and 6 words fewer. It should be kept in mind however, that previous research suggests small correlations with performance and education on the RAVLT and subjects representing the younger groups (16 – 59) in the above study were recruited from undergraduate psychology courses indicating a higher level of education than the older group which may have influenced results.

Vakil and Blachstein (1997) also conducted a study to investigate the impact of age on RAVLT performance in a sample of 528 subjects with an age range of 21 – 91 years with the oldest group including participants aged 70 – 91 years. Results for trials I – V indicated significant differences between age groups with the younger groups learning more words and demonstrating a steeper learning rate. Insofar as the delayed recall and recognition trials are concerned, significant age differences were also noted. This led to
the conclusion that 'until the age of 60 years, the changes in verbal memory are moderate, as compared to the changes observed from the age of 60 onward' (p. 367).
1.5.5 RAVLT and GENDER EFFECTS.

Research concerning the question of gender differences and performance on the RAVLT has produced inconsistent results. For example, Savage and Gouvier (1992) found that although females gained a higher score than males on trials I – V, the difference was not significant. In fact overall, gender had no effect on any of the RAVLT trials. Similarly, Senior and Rickertand (1998) found no effect for gender on the RAVLT.

These results contrast with results obtained by other researchers such as Vakil and Blanchstein (1997) who found that females demonstrated a significant advantage over males for the majority of the verbal memory measures. Geffen, Moar, O’Hanlon, Clark and Geffen (1990) also found that females performed better than males and recalled an average of 2.8 more words than men. Bleeker, Bolla-Wilson and Agnew, (1988) also reported gender differences on the RAVLT with females recalling approximately 1.9 words more than males across most trials.
1.6 JUSTIFICATION AND PURPOSE OF STUDY 1.

Previous literature reviewed (see Section 1.4 – 1.5) suggests that certain patterns of performance on the RAVLT, namely the serial position effect, differentiates simulated malingerers from those who apply genuine effort however, the problems with generalisability are obvious in that in the majority of studies reviewed, both conditions (malingerers and non-malingerers) have employed subjects who have been instructed to ‘pretend’ having sustained a traumatic brain injury as a result of an accident and to ‘perform poorly’ in order to gain monetary compensation. Additionally, the majority of such subjects are selected from a University population.

Problems with generalisability are obvious in that whilst it is possible to pretend having sustained a traumatic brain injury, it would not be possible for persons who did not sustain a traumatic brain injury to pretend having suffered the effects of being rendered unconscious, experienced post traumatic amnesia, depression or any other effects which often accompany such an injury. In this, it could be said that results from simulated research are extremely limited, if useful at all.

As far as the literature is concerned, there appears to be a paucity of studies which examines the serial position effect in genuine TBI litigating subjects compared with non-litigating TBI subjects and comparisons made with a non neurologically compromised samples. Therefore, the purpose of the first study is to compare patterns of performance demonstrated by the serial position effect in a genuine sample of litigating TBI patients (LIT – TBI) to non litigating TBI patients (NONLIT – TBI) and a control group of normal subjects (NC). It should be kept in mind that there is no suggestion that the LIT – TBI subjects in the current study are deliberately performing poorly.
Research will also support that depression is common following a traumatic brain injury (see Lezak, 1995) therefore, in an attempt to examine the influence of depression upon performance on the RAVLT, a group of non-neurologically compromised psychiatric subjects diagnosed by treating psychiatrists as suffering from an anxiety and/or depressive disorder were also included in the study in order to compare patterns of performance with subjects who had sustained a traumatic brain injury. The normal control group were selected from the database for the Australian Normative Data relative to the RAVLT and was kindly made available by Dr Graeme Senior, the author of the normative database. A full description of such is available from Dr Senior (see Senior & Rickertand, 1998).
**Hypotheses**

Previous research has found relationships between the serial position and litigation status however, such conclusions are usually based upon results obtained from simulated samples. As the current study utilizes genuine litigating and nonlitigating traumatic brain injured subjects the goal was to evaluate patterns of performance relative to the serial position in the above populations. In addition, there appears to be a limited number of studies which have examined the serial position across five positions as this study does. As such, the study could be said to be exploratory in nature. In this, relationships which will be explored are;

1) The primacy and recency effect as demonstrated across five serial positions in genuine litigating and nonlitigating traumatic brain injured persons.

2) The impact of time of loss of consciousness upon performance.

3) Comparisons of traumatic brain injured persons’ pattern of performance to a normative sample.

4) Evaluation of the impact of depression in a sample of non-neurologically compromised persons performance on the serial position and,

5) Comparison of such performance to persons having sustained a traumatic brain injury.
1.7 METHOD: STUDY I.

1.7.1 SUBJECTS:

1.7.1.1 LIT – TBI GROUP:

Subjects data for the LIT-TBI group was accessed through the database of the Neurosciences Unit (see 1.8).

1.7.1.2 SCREENING OF TBI – LIT SUBJECTS:

All subjects in the LIT-TBI group had been referred through their lawyers following work or motor vehicle related accidents which resulted in TBI. In excess of 150 files were identified and extracted from the main system. Once files had been identified consent letters were sent to each of the clients in order to seek permission for NPA data to be extracted from the main system. This did not include details that might identify the client for reasons of confidentiality. On receiving permission to access NPA results, the information was extracted from the main database and a new database was created with details relevant to the current study entered. It should be noted that the above process took in excess of three months. Of 50 subjects contacted, 22 gave permission for their results to be extracted from the database.

1.7.1.3 NON – LIT TBI GROUP:

Subjects for the NONLIT-TBI group were also selected from the Neurosciences Unit (NU) database with the above procedure being followed. Thirty five letters seeking consent to extract neuropsychological results from the database were sent to subjects and the first 22 replies giving consent were used in the study.

1.7.1.4 PSYCHIATRIC DEPRESSED GROUP:

Subjects for the Psychiatric – Depressed group were also selected from the NU database (see above). Subjects in this group had been diagnosed as depressed by their
treated psychiatrists and referred to the NU for NPA. The main purpose of assessing this population was to establish baseline cognitive functioning following a diagnosis of depression. It should be kept in mind that none of the subjects in the PSY–DEP group were neurologically compromised. The procedure for this group was as is outlined for both the TBI–LIT and TBI–NONLIT groups. Of 40 consent forms sent to subjects, 24 were received giving permission for results to be accessed from the main database.

**1.7.1.5 CONTROL GROUP:**

Data for the control group was generously provided by Dr Graeme Senior from the University of Southern Queensland. This data was collated and compiled during 1997 and results of this research were presented at the 3rd Annual Conference of the APS College of Clinical Neuropsychologists (see Lange, Senior & Sutton, 1997).

**1.8 SCREENING OF THE NEUROSCIENCES (NU) DATABASE:**

The database for the NU is extensive and includes data for over 1700 clients who have been referred to the Unit over a period of at least 10 years. The NU is a state wide service that provides diagnostic support to tertiary hospitals, secondary level public hospitals and community based facilities. It is a government funded department whose primary role is to provide neuropsychological assessments for the Western Australian public. Referrals for patients to attend the NU come from a variety of sources and include neurologists both in private practice and from major teaching hospitals, psychologists, psychiatrists, medical practitioners, solicitors and other government agencies. The patient pool is varied and includes those suffering from difficulties arising from epilepsy, dementia, tumours, cerebrovascular disease and a variety of accidents including motor vehicle, work related injuries and falls. Once the client has been referred to the NU, qualified psychologists registered with the Psychologists Board of Western Australia,
administer a battery of neuropsychological tests in order to assess brain functioning which includes intelligence, memory, language functioning, frontal lobe functioning, motor and sensory functioning and general cerebral efficiency. During the year 1999/00 the NU provided 18,058 ‘occasions of service’. Data from clients is entered manually into SPSS according to predesignated codes (i.e., 1 = male; 2 = female). Only when data is extracted from the main database is accuracy for entry examined. Consequently, any time data is extracted it must be subject to rigorous screening in order to check for missing or inaccurate entries. Such was the case with this study. Of a total of 110 cases classified as having a TBI and after examining the hard files, only 60 cases were identified as genuine head trauma clients. The same process was followed in obtaining subjects for the PSY – DEP group. As far as the head trauma subjects were concerned, inclusion criteria were that head trauma was to be evident based on results from CT scans and MRI scans.

Once the hard file had been located corrections were made and missing data was entered or, if the client did not have a complete dataset on the RAVLT, they were eliminated from the study. In addition, only right handed subjects were included in the study. Subjects with a history of alcohol or drug abuse were excluded from the study. Data was then screened and checked for outliers. Of the 60 clients identified as having sustained a TBI, after eliminating subjects with either an incomplete data set, who were left handed or who were classified as having extreme scores, only 44 were suitable to be included in the study. In addition, for this first study there was no attempt to differentiate between subjects regarding location of damage to the brain thus, all TBI subjects regardless of location of damage were included. It was felt that this was more a true reflection of the type of clients referred for neuropsychological assessment and also allowed for results to be more generalizable (Johnstone, Vieth, Johnson & Shaw, 2000).
The same process was followed for subjects in the PSY – DEP group. Any subjects with incomplete data, who were left handed or who presented with depression due to brain trauma of any description, including neurodegenerative processes, were eliminated from the study. Only cases where the referring medical practitioner had specifically stated that the subject was not neurologically compromised were included in the study. Of 54 cases identified, only 24 were suitable to include in the study.

1.9 SUBJECT SCREENING AND DEMOGRAPHICS:

Attempts were made to match all subjects in the LIT-TBI and NONLIT-TBI and PSY – DEP groups to subjects in the normative database concerning age and education and while most subjects were matched on these variable within two years of each other this was not possible for all subjects. When this was not possible, subjects were matched to within three years of education. Several subjects from the experimental groups could not be matched with the equivalent from the normative data in regard to gender and in this case, a female/male of the same education and age was matched. Of the LIT-TBI and NONLIT-TBI groups, the majority of subjects (80%) had sustained head injuries in motor vehicle accidents, the remaining 20% had sustained head injuries in falls.

Table 1 provides a summary of subject demographics.
Table 1. Demographic characteristics of the sample by group.

<table>
<thead>
<tr>
<th></th>
<th>LIT-TBI</th>
<th>NONLIT-TBI</th>
<th>PSY-DEP</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>22</td>
<td>22</td>
<td>24</td>
<td>68</td>
</tr>
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<td><strong>GENDER</strong></td>
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<td>49.73</td>
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</tr>
<tr>
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<td>10.46</td>
<td>10.94</td>
<td>12.89</td>
</tr>
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<tr>
<td><strong>EDUCATION (years)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>10.86</td>
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<td>11.74</td>
</tr>
<tr>
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<td>1.58</td>
<td>2.12</td>
<td>2.24</td>
</tr>
<tr>
<td>Range</td>
<td>8-15</td>
<td>8-16</td>
<td>7-16</td>
<td>8-18</td>
</tr>
</tbody>
</table>

Note: LIT-TBI = Litigating Traumatic Brain Injured; NONLIT-TBI = Not Litigating Traumatic Brain Injured; PSY-DEP = Psychiatric Depressed; NC = Normal Control

1.10 MATERIALS

The RAVLT (Rey, 1964) is a 15-item supraspan test of learning and immediate memory that requires recall of a 15-item word list. Total scores range from 15 to 75 (15 words recalled x 5 trials). For the purpose of this study, the score used to determine the serial position was derived by taking the sum of words recalled for each fifth of the word
list across the five trials and dividing by the total possible number of words recalled (75). Using this method, possible percentages for each group ranged from 0% to 20% of words recalled for each fifth of the list. A detailed description of the RAVLT was presented in Section 1.5 and the RAVLT is presented in Appendix A. Table 1a (p.33) provides an illustration as to how the serial position is calculated using pooled trials.

1.11 PROCEDURE

The NU has been providing a service to the public by way of NPA for in excess of 20 years (see Appendix B). During this time as a result of staff movement and different psychologists conducting assessments, it has been necessary to introduce a standardised format in relation to the administration of a neuropsychological test battery. In this, all new psychologists are trained in the administration of the test battery by observing other psychologists during a NPA and familiarising themselves with the administration of the tests. All psychologists use standardised instructions to administer all tests, including the RAVLT (see Appendix C) which are set out in Groth-Marnet (1988) [see Appendix D] thus, the procedure is identical for all clients. Insofar as this study is concerned, the procedure of administering the test battery only as it relates to the RAVLT is reported here.

Clients referred for a NPA are assessed in quiet test rooms and the format for assessment is the same for each case. At the beginning of the assessment a clinical interview is conducted. This will entail asking the client about factors such as medical and educational history (including head injuries) and social and psychological history. Following the clinical interview, the NPA is commenced. As indicated previously, insofar as the RAVLT is concerned, the standardised administration of the RAVLT is followed and is reported in part below;
“I am going to read a list of words. Listen carefully, for when I stop, you are to say back as many as you can remember. It doesn’t matter in what order you repeat them. Just try to remember as many as you can”

The examiner then reads out the 15 list words and records the subject’s responses in order of recall. This is achieved by simply recording the numbers 1, 2, 3, 4… on the scoring protocol in order of recall. Following the subject’s recall of the wordlist the examiner administers the second trial;

“Now I’m going to read the same list again, and once again when I stop, I want you to tell me as many words as you can remember, including words you said the first time. It doesn’t matter in what order you say them, just say as many words as you can remember, whether or not you said them before”.

The above process is repeated for the remaining three trials and remains the same for all clients assessed. In this, the procedure for all subjects in the current research was identical. Results from the NPA are entered into a main database with the client’s permission. When specific research is conducted, consent forms relating to the study are mailed to the client seeking permission to extract results for specific measures administered from the database (see Appendix E). It should be noted that permission to conduct this research was granted by the Murdoch University Ethics Committee.
1.12 RESULTS: STUDY 1.

Preliminary analysis indicated that whilst there were no significant differences between the 4 groups with regards to gender $\chi^2 (1, \ N = 136) = .816, \ p = > .05$.

and level of education ($F (3, 132) = 2.18; \ p > .05$), there were significant differences between the groups insofar as age was concerned ($F (3, \ 132) = 7.82; \ p < .001$). Follow up ANOVA using the Scheffé procedure indicated that the PSY-DEP was significantly older than all other groups. In comparing the LIT-TBI, NONLIT-TBI groups only, no differences were indicated with respect to age ($F (1, \ 42) = 1.71; \ p > .05$), gender $A^2 (1, \ N = 44) = .139, \ p = > .05$), or education ($F (1, \ 42) = .000; \ p > .05$).

To analyze whether there were differences in primacy or recency effects on the RAVLT insofar as the LIT-TBI, NONLIT-TBI groups were concerned, rather than dividing the learning list into three sections as is the case with most research, the list was divided into five sections and summed across trials thereby yielding 5 serial positions as compared to three. Repeated measures ANOVA with one between – subjects factor (the two groups) and one within – subjects factor (the five serial positions) was employed. However, the sphericity assumption was not met so the Huynh – Feldt correction was applied (It should be noted that regardless of the corrective procedure implemented, the result remained significant). Results demonstrated a significant group by trial interaction ($F (3.728, \ 156.571) = 4.371; \ p < .001$) and follow up ANOVAS across groups on each serial position indicated that the LIT-TBI group recalled significantly more words on serial position 2 than the NONLIT-TBI group ($F (1, \ 42) = 3.95; \ p < .05$) but that the NONLIT-TBI group recalled significantly more words than the LIT-TBI group on serial position 4 ($F (1, \ 42) = 4.84; \ p < .05$). Figure 1 provides an analysis of the primacy and recency
effects (see Appendix F for the mean number of words recalled for each group across trials 1 – 5).

![Graph](image)

*Figure 1. Primacy and recency effects on the Rey Auditory Verbal Learning Test in LIT-TBI and NONLIT-TBI groups. Significant differences exist between the groups on the 2nd and 4th serial positions.*

In examining the differences between the two groups and what factors may have impacted upon performance, time of loss of consciousness was examined. In setting up the database, time of loss of consciousness was entered both as a continuous variable and as two dichotomous variables – 1) 24 hours loss of consciousness and less and, 2) 25 hours and greater. To examine the impact of time of loss of consciousness upon
performance on the RAVLT, MANOVA was conducted and time of loss of consciousness entered as a covariate. When time for loss of consciousness was entered as a covariate, no significant interactions or main effects were evidenced. In other words, when time for loss of consciousness was controlled for the two groups did not differ on any serial position. This result suggests that time for loss of consciousness impacted upon performance on the RAVLT rather than litigating status.

To further investigate the impact of loss of consciousness on performance on the RAVLT, MANOVA with one between – subjects factor (the two dichotomous variables – 1) loss of consciousness of 24 hours and less and, 2) loss of consciousness of 25 hours and greater), and one within – subjects factor (the five serial positions) was computed. The sphericity assumption was not met so the Huynh – Feldt correction was applied. Results demonstrated a significant group by trial interaction ($F (3.643, 153.001) = 3.477; p < .05$). Follow up ANOVAS indicated that the group being rendered unconscious for greater than 24 hours recalled more words than the unconscious for less than 24 hours group on the $2^{nd}$ serial position ($F (1, 42) = 6.3161; p < .05$). However, the unconscious for less than 24 hours recalled more words than the unconscious for greater than 24 hours on the $4^{th}$ serial position ($F (1, 42) = 2.9613; p < .05$). These results should be interpreted with caution however, as on dividing the groups into time of consciousness, the less than 24 hour group consisted of 30 subjects whilst the greater than 24 hours unconscious group consisted of only 14 subjects.

In view of the finding that differences between the LIT-TBI group and the NONLIT-TBI groups became nonsignificant when controlling for time of loss of consciousness, the two groups were collapsed to form one TRAUMATIC BRAIN INJURED GROUP (TBI GROUP). Comparisons were then conducted across three
groups; TBI group, PSY – DEP groups and NORMAL CONTROL (NC). As mentioned previously, there was a significant difference demonstrated between the groups with subjects in the PSY – DEP group being older than subjects in the NORMAL CONTROL and the TBI groups thus, initially this variable was entered as a covariate. Subsequent analysis indicated that results did not change with or without age as a covariate and thus, this was dropped from the analysis. The same principle applied to entering loss of consciousness as a covariate - it made no difference to the significance of the result and thus, all analyses was conducted without loss of consciousness as a covariate.

Again, to analyze the serial position effect, MANOVA with one between – subjects factor (the three groups) and one within – subjects factor (the five serial positions) was employed however, the sphericity assumption was not met so the Huynh – Feldt correction was applied. Results demonstrated a significant group by trial interaction \((F(7.534, 497.250) = 4.371; p < .001)\) [It should be noted that regardless of the corrective procedure implemented, the result remained significant]. Follow up ANOVAS using the Sheffe procedure indicated that the NC group recalled significantly more words than the TBI group \((F(2, 133) = 6.1256; p < .01)\) on serial position 1 and serial position 4 \((F(2, 133) = 7.9800; p < .001)\). The NC group also recalled significantly more words than either the TBI or PSY-DEP groups on serial position 5 \((F(2, 133) = 19.1044; p < .0001)\) [It should be noted that identical analysis was conducted with the NC group, the LIT-TBI and the NONLIT-TBI groups prior to collapsing the LIT-TBI and NONLIT-TBI groups to establish the TBI group. The results remained the same therefore, it was considered redundant to report the results twice]. No significant differences emerged on any serial position between the TBI and PSY-DEP groups. Figure 1.1 demonstrates the mean percentage of words recalled for each group across the 5 serial positions.
Figure 1.1 Primacy and recency effects on the Rey Auditory Verbal Learning Test in NC, TBI and PSY-DEP groups. The NC group recalled significantly more words than the TBI group on the 1st and 4th serial positions and significantly more words than either the TBI and PSY-DEP groups on the 5th serial position.
1.13 DISCUSSION: STUDY 1.

Overview:

The major goal of the first study was to assess and explore patterns of performance relative to the serial position in samples of genuine litigating and nonlitigating traumatic brain injured persons. Relationships which were explored included an examination of primacy and recency effects across five serial positions in the above populations; the impact of time of loss of consciousness upon performance in the RAVLT; a comparison of a TBI sample as compared to a normal control group and the impact of depression upon performance relative to the serial position on the RAVLT.

1.13.1 LIT-TBI Group vs. NONLIT-TBI Group:

Results conflicted with previous research in that the LIT-TBI group recalled significantly more words on serial position 2 than the NONLIT-TBI group thereby appearing to demonstrate a greater primacy effect. However, the NONLIT-TBI group recalled significantly more words on serial position 4 than the LIT-TBI group and thus, appearing to demonstrate a greater recency effect.

Previous research conducted by Bernard (1991) indicated that the pattern of performance relative to the serial position on the RAVLT for a malingering group which was compared to a closed head injury group and a control group demonstrated a greater recency effect than the other two groups. This led Bernard (1991) to suggest that the malingering group could ‘fake’ believable deficits by suppressing words from the first third of the word list. Bernard’s (1991) results contrast with those demonstrated in the current study and one possible reason for this is that the malingering group which Bernard utilised was a convenience sample of university students instructed to ‘simulate malingering’. It should also be kept in mind that results from Bernard’s 1991 study
conflicted with those he obtained in a later study in 1993 when both the control group and the malingering group produced normal primacy and recency effects. Again however, the subject pool consisted of university students. Whilst it is acknowledged that it is problematic to study patterns of malingering on neuropsychological tests in genuine brain injured persons, the use of subjects who have been instructed to mangle with financial gain as an incentive perhaps leaves too many variables unaccounted for when comparing patterns of performance to those who have sustained a genuine brain injury.

One such factor which cannot be studied in simulated research is that of time of loss of consciousness. The impact for time for loss of consciousness cannot be ascertained in such studies and whilst it would be easy to conclude that based on results for the current study that litigating traumatic brain injured individuals demonstrated a greater primacy effect than nonlitigating traumatic brain injured individuals, further analysis revealed that this was not necessarily so.

In attempting to identify which factors were contributing to the differences demonstrated between the two groups, time of loss of consciousness was examined. When this factor was controlled for, the groups did not differ on any serial position suggesting that for this group of subjects, time for loss of consciousness rather than litigation status was influencing test performance.

These results are in concordance with results from a study conducted by Crosson, Cooper, Lincoln, Bauer and Velozo, (1993) who also found that litigation status was not predictive of performance on the indices of the CVLT. In that study Crosson et al (1993) compared three CVLT variables for immediate recall, four CVLT variables for short-delay recall and five CVLT variables for long-delay recall between subjects who had sustained head injuries and who were litigating and not litigating. The comparison included analysis
of 20 variables and in no case did a t value reach the .05 significance level. This lead Crosson et al (1993) to conclude that ‘the presence of litigation for particular cases had no systematic effect on neuropsychological data…’ (p. 258). However, it should also be kept in mind that Crosson also found that time for loss of consciousness did not impact upon performance on the CVLT. Leninger et al (1989) in their study investigating neuropsychological deficits following minor head injury also indicated that litigation status did not appear to influence performance as did Suher, Tranel, Wefel and Barrash (1997). It is noted that whilst the above studies by Crosson et al (1993) and Leininger et al (1989) did not examine the serial position, the principal of deliberately attempting to perform poorly by subjects who are brain injured with a view to financial gain remains the same regardless of the measure implemented.

Insofar as patterns of performance on the RAVLT is concerned, results for the current study suggest that it is the time the individual is unconscious for which impacts upon performance on the RAVLT as demonstrated by the serial position rather than litigation status or possible attempts to perform poorly.

1.13.2 The Impact of Time of Loss of Consciousness on Performance:

In further examining the influence of loss of consciousness (i.e., up to 24 hours and 25 hours and greater), subjects who were unconscious for a period of greater than 25 hours recalled significantly more words on serial position 2 than those who had been rendered unconscious for a period of less than 24 hours. However, results also demonstrated that persons who had been unconscious for a period of 24 hours or less recalled significantly more words on serial position 4 than those who had been unconscious for a greater period of time. In this, results suggest that persons sustaining a traumatic brain injury and who are rendered unconscious for a period of greater than 25
hours demonstrated a greater primacy effect than those who were unconscious for a lesser period of time. Conversely, it appears as though persons who sustained a traumatic brain injury and who were rendered unconscious for a period of 24 hours and less demonstrated a greater recency effect than those who were rendered unconscious for a greater period of time. It is possible that LOC greater than 24 hours results in slowed speed of information processing whereby attention is concentrated at the beginning of the word list and then deteriorates towards the end of the word list resulting in loss of information. Conversely, it is possible that LOC of less than 24 hours results in an initial lack of organisation which is reflected in the reduced primacy effect as compared to the recency effect.

As indicated, these results contrast with the majority of previous research concerning patterns of performance and litigation and no research was found which examined the serial position effect which examined the pooled number of words recalled across trials (the majority of research conducted on the RAVLT examines the serial position effect by way of percentage of words recalled on each trial administered which in reality, reflects the pattern of learning rather than the serial position although a primacy and recency effect will still be demonstrated).

In attempting to explain the differences based on loss of consciousness time rather than litigation status, it should be kept in mind that on dividing the groups into time for loss of consciousness there remained 30 subjects in the less than 24 hours unconscious group compared to only 14 subjects in the 25 hours unconscious and greater group. It is quite possible that these results would have been different had the subject pool been greater.
In view of the fact that differences between the groups were not evident when time for loss of consciousness was controlled for, the two groups were collapsed to form one TRAUMATIC BRAIN INJURED GROUP.

1.13.3 Comparisons between TBI, NC and PSY – DEP Groups:

Results for comparisons of performance between the above groups indicated that the normal control (N-C) group demonstrated a greater primacy effect than the TBI group on serial position 1 by recalling significantly more words on that position, and a greater recency effect than the TBI group on serial positions 4 and 5 by recalling significantly more words on those positions. The N-C group also demonstrated a greater recency effect than the PSY-DEP group on serial position 5. It should be noted that the TBI or PSY-DEP groups did not differ significantly from each other on any serial position.

In examining Figure 1.1 it can be seen that all groups demonstrated primacy and recency effects but that performance for the N-C group was significantly different from both the TBI and PSY-DEP groups on serial position 5 indicating that the N-C group demonstrated a greater recency effect than either the TBI or the PSY-DEP groups. Additionally, the finding that the N-C group differed significantly from the PSY-DEP group on serial position 5 suggests that depression impacts upon performance on the RAVLT by way of a reduced recency effect. The finding that neither the TBI or PSY-DEP groups did not differ on any serial position suggests that the pattern of performance for these groups is similar and that depression is manifested by way of a reduced ability to transfer verbal information from short term memory into long term memory or, changes in attention and/or slowing. Whilst it can be seen that the PSY-DEP group did demonstrate a primacy and recency effect, the finding that this group's performance differed significantly from the N-C group suggests that the effectiveness to transfer and retain
verbal information is impacted upon by depression. This also suggests that depression may influence performance on certain neuropsychological tests in a similar manner to that of TBI.

The influence of depression on neuropsychological performance in comparison to persons sustaining a TBI and a N-C group has received little attention in the literature. It is an accepted fact that depression may impact upon performance during a NPA but it is interesting that results for the current study suggest that both TBI individuals and those who are depressed may exhibited similar deficits in relation to memory. Insofar as compensation for TBI is concerned, this finding presents difficulties for the assessing clinician in that it would be difficult to ascertain what was impacting upon poor performance relative to results obtained on the RAVLT. For example, is the poor performance the result of injuries sustained or the result of depression? Research would suggest that most clients who sustain a TBI experience depression or anxiety either as a primary or secondary result of the injury (Lezak, 1995). As data for the current study was obtained from an existing database, it was not possible to ascertain the psychological status of persons who had sustained a TBI. In view of this, it is suggested that future research may compare groups longitudinally in order to ascertain changes in depressive symptomology over time. In this, it would not be unreasonable to expect that performance on neuropsychological tests of non-neurologically compromised clients diagnosed with depression would improve as the depressive symptomology improved and, that the pattern of performance as demonstrated by the primacy and recency effect on the RAVLT would yield different results as compared to initial performance. This may provide further understanding to the assessing clinician as to the impact of depression in conjunction with a TBI relative to performance on the RAVLT.
CHAPTER TWO

2.0 INTRODUCTION: STUDY 2.

SERIAL POSITION EFFECTS IN NON-TRAUMATIC NEUROLOGICALLY COMPROMISED PATIENTS.

As mentioned in the general introduction (and Section 1.5.1, 1.5.2), the serial position effect has been studied relative to patient’s with Alzheimer’s Disease, Parkinson’s Disease, multiple sclerosis and dementia. As indicated, the RAVLT has been utilised as a measure of learning and memory in subjects suffering with multiple sclerosis and Godoy et al (1995) found that MS sufferers failed to display both a recency and primacy effect when compared to a normal control group.

The effect on the serial position demonstrated by the MS subjects contrasts with the pattern of performance demonstrated by patients suffering with Alzheimer’s (AD) and Parkinson’s Dementia (PD). Tierney et al (1994) compared the serial position effect between two groups of subjects suffering from AD (subjects in the AD groups were classified as being either mildly or severely impaired on the 10 item Goldfarb Questionnaire. Severely impaired were classified as such if they obtained a score of 4 or less ) (see Cresswell & Lanyon, 1981). Results demonstrated that the normal control group recalled more words at each serial position than the AD groups or the PD group with the mild AD group and PD group recalling more words than the severe AD group in the primacy and middle positions but not in the recency position. Overall, only the normal and PD groups recalled a similar proportion of words relative to the recency and primacy positions with both AD groups recalling a significantly higher number of words in the recency position than in the primacy position.
In a similar study designed to examine primacy and recency effects on the CVLT, mildly demented (N = 20) and very mildly demented (N = 25) Alzheimer's Disease patients were compared on trial 1 of the CVLT. A group who had received electroconvulsive therapy and were suffering from transient amnesia as a result, were also compared to the very mildly demented AD group. Consistent with past literature, results demonstrated that AD patients exhibited a significantly reduced primacy effect by recalling fewer words on that position and a normal recency effect. This lead the authors to conclude that the reduction in 'the primacy effect, but not the recency effect, is an early and ubiquitous feature of the memory impairment of AD' (Bayley, Salmon, Bondi, Bui, Olichney, Delis, Thomas & Thal, 2000, p. 290).

Insofar as HD is concerned, this disease is an autosomal dominant inherited, neurodegenerative disorder characterised by involuntary movements, changes in personality and behaviour, and cognitive impairment. In about 3% of HD cases, symptoms appear before age 15 and these symptoms are referred to as juvenile-onset HD (Gusella, 1991). Juvenile-onset HD may also result in generalized intellectual decline as evidenced by school problems and personality changes. Antisocial and self-destructive behavior can occur, as well as anxiety and frank psychoses (Gusella, 1991).

The dementia associated with HD is characterized early on by short-term memory disturbances. This may be difficult to detect on objective tests but would explain complaints of difficulties with employment or problems with domestic chores, grocery shopping and driving. Thus, while language skills tend to be preserved, speed of information processing appears to be slowed and deteriorates with time (LaCour, 1990).
2.1 JUSTIFICATION AND PURPOSE OF STUDY 2.

The second study will consist of examining the serial position effect between subjects with differing neurodegenerative disorders as defined by specialist neurologists. It is of theoretical importance that the serial position be examined in subjects diagnosed with a neurodegenerative process as memory and learning are impacted upon so severely with such diseases.

It would be not be unexpected that when a neurodegenerating process is suspected, that the treating specialist would refer the patient for a neuropsychological assessment. Often this is to establish a baseline of cognitive functioning relative to future cognitive decline and, in some cases, to attempt to differentiate between different types of dementia. As far as AD is concerned, diagnosis as early as possible remains one of the most important goals for clinicians in order that pharmacological treatments which may be available be implemented so that the disease process may be slowed (Pepin & Eslinger, 1989).

It is also necessary to differentiate this disease from other dementing processes because of the inheritable factor involved with Alzheimer’s Disease and from this perspective, it is important that neuropsychological tests be implemented which are capable of differentiating between Alzheimer’s disease and other forms of dementia.

The same could be said of Huntington’s Disease. However, the literature relating to the identification of early cognitive deficits concerning Huntington’s Disease is conflicting, with the majority of studies conducted in the later stages of the disease when motor symptoms are present. It is postulated that memory deficits occur early in the disease process (Bamford, Caine, Kido, Plassche & Shoulson, 1989; Caine & Shoulson, 1983) however, as indicated, the research concerning the early identification
of memory deficits has produced conflicting results. The majority of research supports that memory processes are affected very early in the disease process usually prior to any other deterioration in cognitive function (see Butters et al., 1986) and that this deterioration is evident particularly in wordlist learning which implement a recall paradigm.

Research thus far has been relatively inconclusive regarding the exact nature of some of the cognitive impairments involved in AD and HD. It is hoped that the present study will contribute to the identification of possible memory deficits associated with a neurodegenerative process and with the on going care of persons diagnosed with either type of dementia. Insofar as psychological and neuropsychological problems which may emerge as a result of dementia is concerned, early identification of memory deficits which may emerge as part of this research may permit for treatment to be implemented early and aide in the understanding of the impact of these diseases upon family and medical personnel involved in the care of the person concerned. Overall, it is hoped that the information gained from this study will result in a better understanding of the patterns of cognitive functioning and may contribute to improved management of the disease by refining the care and treatment each individual will receive.
Hypotheses:

As with the first study, there does not appear to be any research relating to the serial position across five positions in a sample of subjects who have a neurodegenerative process occurring. Again, the nature of the research is exploratory and the following patterns of performance will be examined:

1) Comparison of performance relative to the serial position in a sample of persons suffering from a neurodegenerative process such as Alzheimer’s Disease and Dementia.

2) An examination of the pattern of performance as is demonstrated by persons suffering from Huntington’s Disease.
2.2 METHOD: STUDY 2.

2.1.1 SUBJECTS:

2.1.1.1 SELECTION OF NON TRAUMATICALLY COMPROMISED NEUROLOGICAL GROUPS:

Subjects for the non-traumatically compromised neurological groups were selected from a large database from within the Neurosciences Unit (NU) (previously described in section 1.8).

2.1.1.2 ALZHEIMER’S DISEASE GROUP:

All subjects diagnosed with probable Alzheimer’s Disease were diagnosed after full investigations by a neurologist. These investigations included blood tests and various scans such as EEG, MRI and CT scans. It should be noted that the subjects in the Alzheimer’s Disease Group were in the early stages of symptomology. Twenty of the 45 subjects contacted gave their permission to access their results for the RAVLT from the database.

2.1.1.3 HUNTINGTON’S DISEASE GROUP:

All Huntington’s Disease patients were diagnosed after receiving a positive result for the disease via genetic testing. All Huntington’s Disease subjects were in the early stages of the disorder and had been referred for NPA in order to establish a baseline for cognitive functioning relative to cognitive decline as the disease progressed. Insofar as the Huntington’s Disease subjects are concerned, the NU has a separate database for patients diagnosed with Huntington’s Disease with in excess of 150 patients listed. As such, it was necessary to manually check every patient’s hard file in order to identify which patients had a complete data set relative to the RAVLT. On identifying these cases, a new database was commenced and data entered for each patient having a complete dataset on
the RAVLT. After eliminating subjects with incomplete data, subjects who were left
handed and those where the RAVLT had not been administered, only 14 subjects were
identified as being suitable to be included in the study and all 14 subjects gave their
permission to access their neuropsychological results.

2.1.1.4 DEMENTIA GROUP:

The Dementia group had also received the diagnosis after full investigations by a
neurologist. Dementia (unspecified) is diagnosed when there is evidence of a
neurodegenerative process occurring but which is not suggestive of a particular type of
disorder. Twenty of the 32 subjects contacted gave their permission to access their results
for the RAVLT from the database.

2.2 SCREENING OF THE NEUROSCIENCES DATABASE:

As indicated previously (see Section 1.8) the database for the NU is extensive and
includes data for over 1700 clients who had been referred to the Unit over a period of at
least 10 years. As the database had been established more than a decade prior to the
current study, a certain number of cases had been coded according to older versions of the
ICD – 9. Thus, in order to select cases from the main database which were suitable for
inclusion in the second study, cases were sorted according to ICD – 9 diagnosis using
SPSSx SORT CASES. As classification codes had been updated to DSM – IV criteria, it
was necessary to identify cases by using the ICD – 9 handbook. As mentioned, once
identified, cases were extracted and a new database was commenced.

As with the first study, the data for the NU had not been entered in a suitable
format to enable calculation of the serial position and as such, all subjects data in the non-
traumatic neurological groups had to be reentered. The total process with regards to
screening, re-entering variables and gathering of new data took in excess of seven months.
2.3 SUBJECT DEMOGRAPHICS;

Demographics for the subject groups are indicated below in Table 2.

Table 2.: Demographic characteristics of the sample by group.

<table>
<thead>
<tr>
<th>GROUPS:</th>
<th>AD</th>
<th>HD</th>
<th>Dementia</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>63.50</td>
<td>45.31</td>
<td>62.23</td>
</tr>
<tr>
<td>$SD$</td>
<td>7.75</td>
<td>10.98</td>
<td>8.03</td>
</tr>
<tr>
<td>Range</td>
<td>50 - 77</td>
<td>21-58</td>
<td>48 - 78</td>
</tr>
<tr>
<td>EDU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>10.55</td>
<td>11.28</td>
<td>10.35</td>
</tr>
<tr>
<td>$SD$</td>
<td>2.16</td>
<td>1.77</td>
<td>1.63</td>
</tr>
<tr>
<td>Range</td>
<td>8-17</td>
<td>10-15</td>
<td>7-15</td>
</tr>
<tr>
<td>GENDER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>17</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: AD = Alzheimer’s Disease; HD = Huntington’s Disease; Dementia = Unspecified Dementia.
2.4 MATERIALS

The RAVLT was again the measure studied and a detailed description of the RAVLT was provided earlier (see Section 1.5).

2.5 PROCEDURE:

The procedure for Study 2 was identical to the procedure for Study 1 and is outlined in Section 1.11.

2.6 RESULTS: STUDY 2.

Preliminary analysis indicated that of the 14 subjects in the Huntington’s Disease group, 9 subjects representing 64% of the sample had extreme scores on the first serial position. With this in mind, the HD group were eliminated from the main analysis thus leaving the AD and DEM groups to be compared. Whilst the HD group was eliminated from the main analysis on the basis of extreme scores, a separate analysis was conducted on this group and results are reported following results for the main analysis. Insofar as the AD and DEM groups were concerned, no significant differences were seen to exist between the groups with regards to education \(F(1, 38) = .7431; p > .05\), age \(F(1, 32) = .6139; p > .05\) or gender \(\chi^2(1, N = 40) = 3.13; p > .05\).

To analyze whether there were differences in primacy or recency effects on the RAVLT insofar as the AD and DEM groups were concerned, as with the first study, rather than dividing the learning list into three sections as is the case with most research, the list was divided into five sections and summed across trials thereby yielding 5 serial positions as compared to three. MANOVA with one between - subjects factor (the two groups) and one within - subjects factor (the five serial positions) indicated a main effect for group \(F(1, 38) = 4.67; p < .05\) with the DEM group recalling significantly more words that the AD group on serial position 1. Paired samples t-tests within the groups
indicated that the number of words recalled on serial position 1 and 5 was not significantly different for either the DEM group ($t(19) = -.85; p > .05$) or the AD group ($t(19) = -.26; p > .05$). Figure 2 provides an analysis of the primacy and recency effects for the AD and DEM groups and Table 2.1 demonstrates the means obtained across the serial positions for both groups.

![Graph showing primacy and recency effects](image)

**Figure 2.** Primacy and recency effects on the Rey Auditory Verbal Learning Test in DEM and AD groups. Significant differences exist between the groups on serial position 1 only ($p < 0.05$).
Table 2.1 Means and standard deviations of words recalled by the AD group and DEM group across the five serial positions.

<table>
<thead>
<tr>
<th></th>
<th>DEM</th>
<th>AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP 1</td>
<td>11.73 (5.22)_a</td>
<td>8.60 (5.30)</td>
</tr>
<tr>
<td>SP 2</td>
<td>10.00 (4.44)</td>
<td>7.20 (6.12)</td>
</tr>
<tr>
<td>SP 3</td>
<td>4.80 (3.36)</td>
<td>3.80 (3.80)</td>
</tr>
<tr>
<td>SP 4</td>
<td>9.27 (3.83)</td>
<td>7.47 (4.70)</td>
</tr>
<tr>
<td>SP 5</td>
<td>12.13 (3.87)</td>
<td>9.73 (3.78)</td>
</tr>
</tbody>
</table>

Note: AD = Alzheimer’s Disease; DEM = Unspecified Dementia. Lower case a indicates significant differences between the groups on that serial position.

* $P = .05$

As mentioned previously, the HD group was dropped from the main analysis in view of the fact that the group size itself consisted of only 14 subjects and of the 14 subjects, 9 demonstrated extreme scores in the first serial position. No attempt was made to drop these subjects from the study because these subjects are what would typically present to the NU for NPA re cognitive functioning. Whilst no comparisons were made to the AD and DEM groups, serial position means for the HD group are presented in Figure 2.1.
Figure 2.1 Primacy and recency effects on the Rey Auditory Verbal Learning Test in the HD group.

In order that simple visual comparisons could be made between the AD, HD and DEM groups, Figure 2.2 demonstrates the mean percentage of words recalled across serial positions 1 – 5. It should be kept in mind that there were fewer subjects in the HD group as compared to the AD and DEM groups and that these groups were not statistically compared although, on visual examination it would be expected that the HD group would
have been significantly different to the AD and DEM groups at least on the primacy position.

Figure 2.2. The serial position effect across the AD, DEM and HD groups.
2.7 DISCUSSION: STUDY 2.

The major goal of the second study was to compare patterns of performance on the RAVLT as demonstrated by the serial position effect in subjects with differing types of dementia. The major comparison was performed between a group diagnosed with probable Alzheimer's Disease (AD) and a group diagnosed with dementia (DEM). Whilst no statistical analysis was performed on a group of subjects diagnosed with Huntington's Disease on the basis of extreme scores on the primacy position, results were presented for this group by way of graphs. Graphs were also presented so that a visual comparison of the performance between the three groups could be made.

2.8.1 Comparison of AD and DEM groups relative to the serial position.

Results for this study indicated that the DEM group recalled significantly more words on serial position 1 than the AD group thereby demonstrating a greater primacy effect. There was no difference between the groups in relation to recency effects. It should be noted that both groups recalled more words on serial position 5 as compared to serial position 1, but the difference between these positions for both groups was not significant. In other words, the number of words recalled on serial position 1 which demonstrates a primacy effect, and the number of words recalled on serial position 5 which demonstrates a recency effect, was not significantly different for either group.

These results are similar to those obtained by Tierney et al (1994) when that study compared patterns of performance relative to the serial position on the RAVLT in groups of subjects with differing types of dementia. Subjects in that study were classified as having either severe or moderate AD and performance was compared on the serial position. Results demonstrated that both groups recalled significantly more words in the recency position as compared to the primacy position. Results for the current study
demonstrated a similar pattern however, whilst subjects in the present study demonstrated a greater recency effect as compared to the primacy effect by recalling more words on that position, the difference was not statistically different.

Results also in part support findings by Bigler et al (1989) who compared performance on the RAVLT relative to the serial position between subjects with closed head injury and Alzheimer’s Disease. That study also demonstrated that the Alzheimer’s group exhibited a significantly different recency effect as compared to the primacy effect by recalling more words in the recency position and whilst the Alzheimer’s group did demonstrate a primacy effect, this was negligible. Results also support a study cited earlier (see Bayley et al, 2000) where AD subjects also demonstrated a greater recency effect as compared to the primacy effect by recalling more words in the recency position.

In examining demographic data of the studies cited, it appears as though the AD group in the current study were younger and in the early stages of the disease which contrasts with the AD subjects used in the Tierney et al (1994) study where the AD subjects were classified as being in either the moderate or severe stages of the disease. Research suggests that AD patients perform differently on memory measures at different stages of the disease (see Hill, Storan dt & La Barge, 1992) and based on the results obtained in the Tierney et al (1994) study where subjects demonstrated a significantly different recency effect as compared to the primacy effect in that more words were recalled in the recency position, and results for the current study which indicated that there was a greater recency effect as compared to the primacy effect in that more words were recalled in the recency position but not significantly so, there appears to be a deterioration of the abilities involved with the encoding and retrieval of information as the disease progresses. Tierney
et al (1994) suggests that this difference is attributable to some sort of storage disorder and results for both studies would appear to support this.

In comparison to the DEM group, the AD group recalled significantly less words in the primacy position (serial position 1) only. The mean percentage of words recalled for both groups indicate that the DEM group recalled more words on every serial position than the AD group but as indicated, significantly more words on serial position 1. Results of ANOVA indicated no interaction which suggests that both groups were producing a similar curve in regards to their recall of the wordlist and this can be seen by inspection of Figure 2.

As mentioned previously, past research suggests that the lack of primacy effect in AD subjects may be due to rapid forgetting of information (Woodard et al, 1999) or a storage disorder (Tierney et al, 1994). Whilst this may be the case, and results from this study indicate that there is a greater recency effect than a primacy effect thereby supporting this suggestion, it seems that the dysfunction in memory, at least between the AD and DEM groups in this study, is similar. Insofar as the neuropsychological assessment is concerned, it appears as though the RAVLT could be used to differentiate between patients in the early stages of AD and patients diagnosed with dementia.

With regards to the HD group, they recalled more words on every serial position with the exception of serial position 1 (SP 1 = 4; SP 2 = 11.33; SP 3 = 6.38; SP 4 = 10.67; SP 5 = 12.57) than either the DEM or AD groups. However, on serial position 1, 64% of the sample were classified as extreme scores demonstrated by the subjects recalling too few words on that position. The research as it relates to memory performance and persons diagnosed with HD is somewhat conflicting with some results suggesting that memory is
the first cognitive process to be impacted upon (see Butters et al., 1986; Lundervold & Reinvang, 1991).

Contrasting with the above were results from a study which compared performance on various memory tasks in two groups of subjects with varying risk of HD (de Boo, Tibben, Hermans, Jennekens-Schinkel, Maat-Kievit & Roos, 1999). Results for that study demonstrated no difference between the low risk vs. the high risk group on measures of verbal and visual memory, word fluency and procedural learning. The overall conclusions of de Boo et al (1999) was that 'memory dysfunction is not a characteristic of presymptomatic individuals at a high risk of HD' (p. 835). It should be kept in mind that the HD subjects in this study had all received a definite diagnosis and were all in the early stages of the disease. In addition, none were demonstrating obvious difficulties with cognitive functioning. However, these results are consistent with research which suggests that memory problems are usually more prominent in the early stages of the disease and that verbal tasks which utilize a recall paradigm are considerably more difficult for HD patients than recognition tasks (Butters et al., 1986). Research also suggests that cell degeneration in the neo-striatum and the caudate nucleus impacts upon memory function in HD (de Boo et al., 1999) however, none of the subjects participating in the current research had been referred for MRI scans at the time of assessment so it was not possible to ascertain what, if any, structures within the brain had been affected.

Although the number of HD subjects equaled only 14 in the current study, it is interesting that of a database of in excess of 150 patients, these 14 subjects were the only patients with a complete dataset on the RAVLT. In addition, as mentioned previously, 64% of the 14 subjects demonstrated extreme scores on the first serial position. It may well be that subjects in this group were somewhat 'atypical' in that they were the only
subjects to have a complete dataset on the RAVLT. However, the results suggest that there are problems with memory in nonsymptomatic patients diagnosed in the early stages of HD which is consistent with current research (see Bamford, Caine, Kido, Plassche & Shoulder, 1989; Lundervold & Reinvang, 1991).

In considering the performance of the three groups (AD, DEM and HD) on the first serial position, although there was no statistical comparisons were performed, it is obvious that the HD group performed considerably worse and in the clinical situation, it appears as though the RAVLT may be capable of differentiating between different types of dementing processes. For example, the extremely poor performance of the HD group on the primacy position; the DEM group performing significantly better than the AD group on the primacy position and the poor performance of the AD group on the primacy position, although not as poorly as the HD group. Patterns of performance such as those demonstrated in the current study may assist treating practitioners to differentiate between various types of dementia early in the disease progress.

Insofar as the AD and DEM groups are concerned, results for the current study appear to support the literature in that AD results in a memory storage problem which is evidenced by a reduced primacy effect as compared to the recency effect. Results also appear to support the literature which suggests that organically impaired patients will exhibit a greater recency effect as compared to the primacy effect (see Wiggins & Brandt, 1988).
CHAPTER THREE

3.0 INTRODUCTION: STUDY 3

SERIAL POSTION EFFECTS ACROSS DIFFERING LOCATIONS OF BRAIN DAMAGE.

There has been limited research on the serial position effect and location of damage to the brain however, animal studies suggest that damage to the frontal lobes has some impact on learning. For example, one such study involved paired associate learning in the rat and examined subsequent behaviour following lesions to the hippocampus, medial prefrontal cortex and parietal cortex. In this study 33 male rats were tested for their ability to learn a list of 4 paired associates (food paired with spatial locations). It was found that subjects correct orientating response increased as a function of the serial position of the paired associate within the list when short intertrial intervals were used between paired associates. Results also indicated that in order to remember a list of paired associates, rats may use a temporal strategy. Twenty two new rats were also trained as above and following medial prefrontal cortex, hippocampus, parietal cortex or cortical lesions it was found that subjects with cortical control lesions continued to display the strategy of temporal order function. However, subjects with medial prefrontal cortex lesions demonstrated a reduced number of correct orientating responses and failed to demonstrate a temporal order function, thus suggesting that insofar as the selection of temporal order strategies are concerned, the medial prefrontal cortex possibly plays a mediating role. Subjects with hippocampal lesions also demonstrated a marked reduction in correct orientating responses but continued to display a temporal order function (Kesner, 1995).

Eslinger and Grattan (1995) also found that the serial position effect was disrupted as a result of frontal lobe lesions creating disturbances in temporal ordering. In their study
groups with focal acquired lesions of either frontal or nonfrontal cortices were compared with respect to verbal list learning. Subjects performed similarly on first trial learning however, significant primary and recency effects were not maintained by frontal lobe lesion subjects across trials whilst non frontal lobe lesion subjects demonstrated the expected ‘U’ shaped curve consistently. Dorsolateral frontal lobe lesion subjects were also deficient in regards to subjective organisation. The researchers concluded that ‘serial position effects are qualitatively different after frontal lobe lesions, being transitory and prone to alteration by the cumulative effects of disturbed temporal-spatial processing across learning trials’ (p. 729).

As mentioned in the Introduction (see 1.5.1) Dimitrov et al (1999) reported that patients with frontal lobe lesions exhibited diminished performance on tests of recognition, cued recall and free recall with the latter being disrupted the greatest and recognition being disrupted the least.

Results reported in the literature are not consistent however and the above contrasts those obtained by Shimamura, Janowsky and Squire (1990) when they used the RAVLT to ascertain the difference in performance between patients with unilateral frontal lobe lesions, bilateral lesions and normal subjects who were matched on age and education. Results demonstrated that whilst the frontal lobe lesion group recalled 13% less words on the recall trial of the RAVLT than the bilateral lesion group, the difference was not statistically significant. Nor was there any difference between the recognition scores of the groups. However, it was found that frontal lobe lesions resulted in a deficient performance on reproducing the sequential order of the fifteen words suggesting that damage to this area of the brain contributes to a deficit in memorizing temporal order.
Similarly Crockett, Hadjistavropoulos and Hurwitz (1992) found there was no significant difference in the primacy and recency effects as demonstrated by the RAVLT between subjects with lesions located posteriorally to the central sulcus, with anterior situated lesions and a psychiatric control group (see Section 1.5.1).
3.1 JUSTIFICATION AND PURPOSE OF STUDY 3.

As indicated in the general introduction (see Section 1.5.1 and 1.5.2), the literature surrounding the serial position effect in relation to location of damage to the brain is conflicting and a study by Dimitrov et al (1999) found that patients with damage to the frontal lobes demonstrated a reduced performance on tests of recognition, cued recall and free recall. In that experiment, tasks consisting of a free recall paradigm were the most severely affected.

These results did not support those obtained in an earlier study by Shimamura et al (1990) who found that there were no differences between four patients with unilateral frontal lesions, 2 patients with bilateral lesions and normal subjects on recall performance using a condensed version of the RAVLT. However, results did demonstrate that that patients with frontal lobe lesions were unable to reproduce the sequential order of the fifteen words used in the RAVLT thereby suggesting a deficit in memorizing temporal order.

Therefore, the purpose of the third study is to contribute to current research by comparing patterns of performance as demonstrated by the serial position utilising the RAVLT in groups of subjects who have experienced trauma to different areas of the brain. In addition, the third study will compare and contrast patterns of performance in groups who have sustained trauma to different areas of the brain to normal control groups. It should be kept in mind that none of the participants were suffering from any form of neurodegenerative disorder.
Hypotheses

As the previous two studies have not examined the serial position effect in subjects with lesions to a specific area of the brain, that is the goal of the third and final study. Relationships to be explored in the final study are;

1) Comparison of performance relative to the serial position in subjects with Frontal and Posterior lesions to the brain.

2) Comparison of the Frontal lesion groups pattern of performance with that of a normal control group.

3) Comparison of the Posterior lesion groups pattern of performance with that of a normal control group.

4) Examination of the serial position effect in subjects with diffuse damage to the brain.
3.2 METHOD: STUDY 3.

3.2.1 SUBJECTS:

3.2.1.1 FRONTAL LESIONS GROUP:

As with the preceding studies, data for this study was also accessed via the NU database. Subjects were only included in the Frontal Lesions Group (FL) when supporting evidence for frontal lobe damage in the way of MRI scans and neurological examination clearly indicated the involvement of the frontal lobes. Subjects with incomplete data or who were left handed, were excluded from the study. After eliminating these subjects, 30 subjects were contacted for permission to include results for the RAVLT in the study and 21 consent forms were returned giving permission. A full description of the NU database was given in Section 1.8.

3.2.1.2 POSTERIOR LESIONS GROUP:

As with the FL group, subjects were only included in the Posterior Lesions Group (PG) on the basis of supporting MRI scans and neurological examination which clearly indicated that the posterior section of the brain had sustained some form of damage. Subjects with incomplete data, or who were left handed, were eliminated from the study. After screening of the data, 35 subjects were contacted for permission to include results for the RAVLT in the study and 25 consent forms were returned giving permission. In order to maintain the same size groups, only data from the first 21 consent forms giving permission to access the database were used.

3.2.1.3 DIFFUSE DAMAGE Group:

There were a small number of subjects identified in the database with diffuse damage to the brain. Whilst this group had insufficient numbers to include in the main analysis, it was decided to keep the group in the study to observe what impact diffuse
damage would have upon performance as evidenced by the serial position on the RAVLT. Six of the 8 subjects contacted gave their permission to access their results for the RAVLT from the database.

3.2.1.4 NORMAL CONTROL GROUP:

As indicated previously, the normative data for the RAVLT was made available through Dr Graeme Senior. In establishing the Normal Control Groups (N/C 1 and N/C 2) subjects were selected from the main database of the RAVLT normative data to match as closely as possible subjects in the FL and PL groups.

3.3 SUBJECT DEMOGRAPHICS:

Demographic data for all groups in demonstrated in Table 3.
Table 3: Demographic characteristics of the FL, N/C FL, PL, N/C PL and DIFF groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>FL</th>
<th>N/C FL</th>
<th>PL</th>
<th>N/C PL</th>
<th>DIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>GENDER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>19</td>
<td>14</td>
<td>16</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>AGE (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>34.62</td>
<td>36.28</td>
<td>37.57</td>
<td>37.14</td>
<td>46.16</td>
</tr>
<tr>
<td>SD</td>
<td>12.23</td>
<td>15.13</td>
<td>13.86</td>
<td>12.59</td>
<td>18.97</td>
</tr>
<tr>
<td>Range</td>
<td>18-60</td>
<td>18-75</td>
<td>24-75</td>
<td>24-65</td>
<td>24-64</td>
</tr>
<tr>
<td>EDUCATION (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>10.24</td>
<td>10.76</td>
<td>11.09</td>
<td>11.86</td>
<td>11.67</td>
</tr>
<tr>
<td>SD</td>
<td>1.26</td>
<td>1.99</td>
<td>1.97</td>
<td>2.00</td>
<td>.81</td>
</tr>
<tr>
<td>Range</td>
<td>8-12</td>
<td>5-16</td>
<td>8-16</td>
<td>10-17</td>
<td>10-12</td>
</tr>
</tbody>
</table>

Note: FL = Frontal Lesions; PL = Posterior Lesions; DIFF = Diffuse Damage to the Brain; N/C FL = Normal Control for Frontal Lesion Group; N/C PL = Normal Control for Posterior Lesion Group.

3.4 MATERIALS

As with the preceding studies, the RAVLT was utilised for this study. A full description of the RAVLT is presented in Section 1.5 and the RAVLT is presented in Appendix A.
3.5 PROCEDURE

The procedure for Study 3 was identical to the procedure for Study 1 and is outlined in Section 1.11.

3.5 RESULTS: STUDY 3.

Preliminary analysis indicated that there were no significant differences between the FL and PL groups with regard to age \((F (1, 40) = .5354; p > .05)\), education \((F (1, 40) = 2.8149; p > .05)\), or gender \(\chi^2 (1, N = 42) = 1.54, p = > .05\). The DIFF group was not included in the main analysis as a result of the sample size being inadequate.

To analyze whether there were differences in primacy and recency effects insofar as the FL and PL groups were concerned, MANOVA with one between – subjects factor (the two groups) and one within – subjects factor (the five serial positions) was employed. Results indicated a significant groups by trial interaction \((F (4, 160) = 3.31; p < .001)\) and follow up ANOVAS indicated that the PL group recalled significantly more words on serial position 3 than the FL group \((F (1, 40) = 4.74; p < .05)\).

In examining primacy and recency effects within the two groups, Paired samples t tests indicated that the number of words recalled on serial position 1 compared to serial position 5 was not significantly different for the FL group \((t (20) = 1.24; p > .05)\). However, this result was significant for the PL group \((t (20) = 3.21; p < .01)\) with that group recalling significantly more words on serial position 1 than serial position 5 thereby demonstrating a greater primacy than recency effect. Figure 3 provides an analysis of the primacy and recency effects for the FL and PL groups and Table 3.1 demonstrates the means obtained across the serial positions for both groups.
Figure 3. Primacy and Recency effects between the FL and PL groups.
Table 3.1. Means and standard deviations across the serial positions for the FL and PL groups.

<table>
<thead>
<tr>
<th></th>
<th>FL</th>
<th>PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP 1</td>
<td>14.54 (3.55)</td>
<td>15.24 (2.68)</td>
</tr>
<tr>
<td>SP 2</td>
<td>10.16 (3.96)</td>
<td>10.86 (4.45)</td>
</tr>
<tr>
<td>SP 3</td>
<td>8.89 (3.53)</td>
<td>11.49 (4.18)</td>
</tr>
<tr>
<td>SP 4</td>
<td>13.84 (3.41)</td>
<td>11.75 (4.14)</td>
</tr>
<tr>
<td>SP 5</td>
<td>13.33 (2.23)</td>
<td>12.32 (3.50)</td>
</tr>
</tbody>
</table>

Note: FL = Frontal Lesion Group; PL = Posterior Lesion Group.

As indicated previously, there was a small group of subjects classified as having diffuse damage to the brain. Whilst the numbers in the group were not sufficient to include in the main analysis, Figure 3.1 demonstrates the pattern of performance relative to the serial position for this group.
Figure 3.1. Primacy and Recency effects for the DIFF group.

In order to compare the pattern of performance relative to the serial positions, the FL group was compared to a normal control group. Insofar as the FL and N/C 1 groups were concerned, no significant differences were seen to exist between the groups with regards to education \(F(1, 40) = 1.0324; p > .05\), age \(F(1, 32) = .1541; p > .05\) or gender \(\chi^2(1, N = 42) = 3.535, p = > .05\).

MANOVA results indicated a main effect for group \(F(1, 40) = 8.75; p < .01\) and a significant groups by trial interaction \(F(4, 160) = 3.50; p < .01\). Follow up ANOVA
indicated that significant differences between the groups on serial position 2 and serial position 5 were accounted for by the N/C group recalling more words on those positions than the FL group. Results for serial position 1 approached significance with the N/C group recalling more words than the FL group. Table 3.2 demonstrates the ANOVA results across all five serial positions and Figure 3.2 demonstrates visually the primacy and recency effects of the two groups.

Table 3.2. ANOVA results for the FL and N/C FL Groups (Means (SD)).

<table>
<thead>
<tr>
<th></th>
<th>FL</th>
<th>N/C FL</th>
<th>ANOVA RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>SP. 1</td>
<td>14.54 (3.55)</td>
<td>16.64 (3.36)</td>
<td>$F (1, 40) = 3.85; p = .0565$</td>
</tr>
<tr>
<td>SP. 2</td>
<td>10.16 (3.96)</td>
<td>13.90 (3.78)</td>
<td>$F (1, 40) = 9.80; p = .0032$</td>
</tr>
<tr>
<td>SP. 3</td>
<td>8.89 (3.53)</td>
<td>10.86 (3.98)</td>
<td>$F (1, 40) = 2.86; p = .0983$</td>
</tr>
<tr>
<td>SP. 4</td>
<td>13.84 (3.41)</td>
<td>12.82 (3.36)</td>
<td>$F (1, 40) = .9464; p = .3365$</td>
</tr>
<tr>
<td>SP. 5</td>
<td>13.33 (2.23)</td>
<td>15.94 (2.58)</td>
<td>$F (1, 40) = 12.22; p = .0012$</td>
</tr>
</tbody>
</table>

Note: FL = Frontal Lesions; N/C FL= Normal Control.
Figure 3.2. Primacy and recency effects between the FL and N/C FL groups.

As with the FL and N/C FL groups, the PL group was also compared to a normal control group (N/C PL). No significant differences were seen to exist between the PL and N/C PL groups with regards to education ($F(1, 40) = 1.5394; p > .05$), age ($F(1, 32) = .0110; p > .05$) or gender $\chi^2(1, N = 42) = 2.592, p = .05$).
MANOVA results indicated no main effect for group \((F(1, 40) = 1.48; \ p > .05)\) but a significant groups by trial interaction \((F(4, 160) = 2.78; \ p < .05)\). Follow up ANOVA indicated that the groups differed significantly only on serial position 5 with the N/C PL group recalling more words than the PL group. Table 3.3 demonstrates the ANOVA results across all five serial positions and Figure 3.3 demonstrates visually the primacy and recency effects of the two groups.

Table 3.3. ANOVA results for the PL and N/C PL Groups (Means (SD)).

<table>
<thead>
<tr>
<th></th>
<th>PL</th>
<th>N/C PL</th>
<th>ANOVA RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>SP. 1</td>
<td>15.24 (2.68)</td>
<td>15.30 (4.04)</td>
<td>(F(1, 40) = .0036; \ p = .9522)</td>
</tr>
<tr>
<td>SP. 2</td>
<td>10.86 (4.45)</td>
<td>12.70 (4.96)</td>
<td>(F(1, 40) = 1.603; \ p = .2127)</td>
</tr>
<tr>
<td>SP. 3</td>
<td>11.49 (4.18)</td>
<td>10.67 (4.38)</td>
<td>(F(1, 40) = 3902; \ p = .5357)</td>
</tr>
<tr>
<td>SP. 4</td>
<td>11.75 (4.14)</td>
<td>13.46 (4.38)</td>
<td>(F(1, 40) = 1.695; \ p = .2004)</td>
</tr>
<tr>
<td>SP. 5</td>
<td>12.32 (3.50)</td>
<td>15.43 (4.33)</td>
<td>(F(1, 40) = 6.549; \ p = .0144)</td>
</tr>
</tbody>
</table>

Note: PL = Posterior Lesions; N/C PL = Normal Control Posterior Lesions.
Figure 3.3. Primacy and recency effects between the PL and N/C PL groups.
3.7 DISCUSSION: STUDY 3

The three major aims in relation to the third study of this research were to;
1) compare patterns of performance relative to the serial position in subjects with Frontal and Posterior lesions; 2) compare the pattern of performance relative to the serial position in subjects with Frontal Lesions and that of a normal non-neurologically compromised group; 3) compare the pattern of performance relative to the serial position in subjects with Posterior Lesions and that of a normal non-neurologically compromised group and 4) explore patterns of performance relative to the serial position in a small group of subjects with diffuse damage to the brain.

3.7.1 Comparisons of FL and PL Groups:

Results demonstrated that when comparing the pattern of performance of the FL and PL groups on the serial position, the PL group recalled significantly more words on serial position 3 than the FL group thereby demonstrating a greater primacy effect. In examining the difference relative to number of words recalled within the groups, results demonstrated that whilst there was no significant difference in the number of words recalled on serial position 1 compared to serial position 5 for the FL group, this was not the case for the PL group who recalled significantly more words on serial position 1 as compared to serial position 5 and thus, demonstrated a greater primacy effect and a reduced recency effect.

Although the difference in recall between serial position 1 and 5 was not significant for the FL group, the overall pattern of response appears to be consistent with previous research which suggests that frontal lobe lesions results in deficits in being able to effectively organise information in order to facilitate recall, particularly on tasks relating to free recall (Dimitrov et al, 1999; Wheeler, Stuss, & Tulving, 1995). In comparing
the pattern of recall for the PL group, it can be seen that although this group demonstrated a significantly greater primacy effect than the FL group on serial position 1 by recalling more words on that position, their subsequent performance across the remaining positions reduces on serial position 2 and shows minimal improvement across the serial positions. It is possible that this indicates that the PL group were attempting to implement strategies which resulted in the slight improvement demonstrated in Figure 3. It should be kept in mind however that the result of the PL group in demonstrating a greater primacy effect as compared to the recency effect contrasts current literature which suggests that organically impaired subjects demonstrate a greater recency effect as compared to the primacy effect (Crockett et al, 1992; Wiggins & Brandt, 1988).

For example, a study by Crockett et al (1992) compared performance on the RAVLT with regard to the serial position between patients with posterior and anterior damage to the brain, and a psychiatric group with no neurological damage. Results demonstrated no significant differences between the groups relative to primacy and recency effects leading to the conclusion that the ‘findings limit the use of primacy and recency for the differentiation of memory deficits due to organic and nonorganic causes’ (p. 97). However, it should be kept in mind that the study by Crockett et al (1992) analysed and compared performance on the RAVLT across the five learning trials and how often each word on the list was recalled. It is suggested that this is more an analysis of the order of word recall and a demonstration of the learning curve rather than an analysis of the serial position. In addition, the above study used a mixed groups of subjects in that 15 of the subjects had sustained closed head injuries, 3 subjects were diagnosed with Huntington’s Disease, 1 subject had Alzheimer’s Disease, 1 subject had a frontal lobe infarct, 1 subjects had suffered a basal ganglia infarct and 4 subjects had severe amnesia
due to unknown causes. It is quite possible that if the subjects had been selected to form separate groups (i.e., one group of closed head injuries; one group of Alzheimer’s Disease) different results would have emerged. As demonstrated in the two previous studies of the current research, subjects with traumatic brain injury, Alzheimer’s Disease, Huntington’s Disease, dementia and depression demonstrate quite different serial position effects. As mentioned previously, Crockett et al (1992) analyzed results from the RAVLT differently as compared to the current research and as such, it is difficult to compare the above results to those obtained in the current study.

Results for the current study are comparable to those obtained in a single case study by (Markowitsch, Kalbe, Kessler, von Stockhausen, Ghaemi, Heiss, 1999). These researchers utilised several different language tests in order to study the impact of the removal of a left hemispheric tumor on memory and cognitions. Results demonstrated that the subject suffered short term memory deficits which were exhibited in a ‘strong primacy effect in the absence of a recency effect’ (p. 784).

Overall, results for the current study suggest that damage to the posterior lobes of the brain impacts upon performance in that subjects display a greater primacy effect when compared to a recency effect and that whilst little change occurs over the remaining four positions, the pattern of response appears to suggest some attempt at organisation of material (see Figure 3).

The pattern of performance for the FL group demonstrates a shape more typical of the ‘U’ shaped curve but performance is inconsistent over the positions suggesting an inability to effectively encode information to facilitate recall (Dimitrov et al, 1999; Wheeler et al, 1995). As with the PL group, results for the FL group also appear to contrast current literature which suggests that organically impaired subjects tend to
demonstrate a greater recency effect as compared to the primacy effect (Wiggins & Brandt, 1988).

**Comparisons of FL and NC - FL Groups:**

In attempting to ascertain the impact of damage to the frontal lobes of the brain, the FL group was compared to a NC – FL group. In comparing the pattern of performance relative to the serial position between the FL and a NC – FL groups, the NC – FL group recalled significantly more words on serial position 2 and serial position 5 thereby demonstrating a greater recency and primacy effect than the FL group. In addition, the NC-FL group demonstrated the ‘U’ shaped curve typical of serial position effects whilst the FL groups performance resembled the ‘U’ shape to an extent, performance significantly deteriorates from position 4 to 5. This suggests that in comparison to the NC – FL group, the FL group was unable to strategically organize material to facilitate consequent recall (Gershberg & Shimamura, 1995).

Current results also support those obtained by Dimitrov et al (1999) when in that study comparisons were made between groups with frontal lobe lesions and frontal lobe dementia. Results demonstrated that the frontal lobe dementia patients were moderately impaired on tasks relating to free recall but that the frontal lobe lesion group were severely impaired on tasks relating to free recall. These results led Dimitrov et al (1999) to conclude that ‘these findings indicate that both left frontal and temporal lobe damage can impair associative learning and that this impairment is more strikingly seen with free rather than cued recall’ (p. 213).
3.7.2 Comparisons of PL and N/C - PL Groups:

As with the previous analysis, performance of the PL group was also compared with a NC – PL group in order to ascertain the impact of damage to the posterior lobes of the brain relative to the serial position.

Results indicated that the PL and NC – PL groups differed only in relation to serial position 5 with the NC – PL group recalling significantly more words on that position and thus, demonstrating a greater recency effect than the PL group. However, whilst the overall pattern of performance in the PL group as compared to the NC – PL group indicated that the groups differed significantly on only serial position 5, the NC – PL group recalled progressively more words on each serial position with a mean of 10 words being recalled on the 3rd serial position and 15 words being recalled on serial position 5. Contrasting with this, the PL groups performance altered minimally over the serial positions with a mean of 11 words being recalled on serial position 3 and only 12 words being recalled on serial position 5. Examination of Figure 3.3 demonstrates the difference in pattern of response between the two groups and what appears to be a plateau effect in the PL group which could be suggestive of attempts at organisation of material. The non-significant difference between the PL and NC-PL groups on serial position 1 suggests that whilst lesions to the posterior region of the brain do not appear to impact upon the ability to effectively encode information, the significant reduction in words recalled in serial position 2 is suggestive of an inability to access information once it is encoded (Eslinger & Gratton, 1994). The PL group demonstrate a slow improvement across the serial positions however, performance deviated significantly from the N/C PL group on the recency position which may be indicative of a slowed processing of information.
3.7.4 **Diffuse damage to the brain and the serial position:**

As indicated previously, there was a small group of subjects identified as having sustained diffuse damage to the brain. Whilst this group was not compared to the FL and PL groups, and was not included in the main study, Figure 3.1 indicates that this group recalled a mean of 12.78 words on serial position 1 and a mean of 11.34 words on serial position 5 demonstrating a greater primacy and a reduced recency effect. However, the groups overall performance demonstrates minimal learning over positions with no improvement on serial position 1 to 2, and serial positions 3 to 4. This pattern of performance may indicate an inability to organise information in order to facilitate recall (Gershberg & Shimamura, 1995).

It should be kept in mind however, that this group was relatively small (N = 6) and results were not statistically analysed or compared to either the FL or PL groups and it is possible that if the sample had been larger, a different pattern of performance may have emerged.

In conclusion, results across the FL, PL and DIFF groups does not support literature which suggests organically impaired subjects would be expected to demonstrate a greater recency effect as compared to the primacy effect (see Wiggins & Brandt, 1988). In fact, results for the current study demonstrate an opposite effect in that the 3 groups tested demonstrated a greater primacy effect as compared to the recency effect.

In comparing the pattern of response in the PL and FL groups, the PL group recalled significantly more words on serial position 2 than the FL group thereby demonstrating a greater primacy effect. In addition, the PL group recalled significantly more words in the primacy position as compared to the recency position. This effect was
not apparent for the FL group. When the number of words recalled in the primacy and recency position were compared for the group, no significant differences emerged.
3.8 GENERAL DISCUSSION:

STUDY 1:

Initial results for Study 1 indicated that the LIT – TBI groups recalled significantly more words on serial position 2 as compared to the NONLIT-TBI group thereby demonstrating a greater primacy effect. Contrasting with this, the NONLIT- TBI group recalled significantly more words on serial position 4 than the LIT-TBI group thereby demonstrating a greater recency effect. These results conflict with those of Bernard (1991) who found that the ‘U’ shaped curve demonstrated by the primacy and recency effect was distorted by subjects who deliberately performed poorly on the RAVLT. The distortion was attributed to the ‘malingering’ TBI group ‘suppressing’ words from the first third of the list thereby demonstrating a reduced primacy effect. As indicated previously, the results from the Bernard (1991) study were based on subjects ‘pretending’ to have sustained a traumatic brain injury and who were seeking compensation as a result. It should be kept in mind that results from the Bernard (1991) study conflict with those obtained in a later study (Bernard, 1993) when simulated samples were again used as a measure of performance on the RAVLT. In that study there were no differences found between the litigating and nonlitigating traumatic brain injured subjects who had been instructed to perform poorly. Although Bernard (1993) cautions that the results obtained were from simulated research and may not generalise to a clinical population, the findings from the current study indicate that persons who have sustained a genuine head injury and who are litigating will perform differently on the RAVLT when compared to results obtained from subjects used in simulated research. As Reitan and Wolfson (1997) point out, ‘such an approach should prompt the reader to consider where we would be in our
understanding of the effects of brain damage if our methods of assessment had been based on people merely pretending to be brain damaged (p. 70).

In an attempt to identify factors which may have impacted upon performance in the litigating and nonlitigating groups, time for loss of consciousness was examined. Results indicated that once this factor had been controlled for, the differences between the groups became non-existent. This is an important clinical finding insofar as simulated research is concerned simply because it is not possible to 'fake' having been rendered unconscious as a result of head trauma. In this respect, simulated research which focuses on subjects 'pretending' to have received a head injury as a result of an accident becomes redundant and the results obtained by such meaningless. Whilst the results for the current study would need to be replicated, in the present study it seems as though time of loss of consciousness accounts for the variation of performance between litigating and non-litigating groups rather than litigating status.

In addition to the impact of loss of consciousness on the serial position effect, this study also examined the impact of depression in a sample who were not neurologically compromised and comparisons were made to a traumatic brain injured group and a normal group. Results demonstrated that there were no differences between the TBI and PSY – DEP groups on any serial position indicating that the impact of depression upon neuropsychological performance is similar to that incurred with a traumatic brain injury. Research supports the view that depression following a traumatic brain injury is not uncommon and that approximately 60% of patients developed depressive symptomology within 6 months of having experienced brain trauma and a further 34% of patients who were not acutely depressed were so several years following the traumatic brain injury (Robinson et al 1985; Robinson et al, 1987). Insofar as litigation is concerned, the
results of the current study have not made the clinicians role any easier in that it could be problematic trying to ascertain what is impacting upon neuropsychological performance – the brain trauma or the depression. To this end, it is suggested that future research could be conducted longitudinally and assess groups of subjects who have received a diagnosed of depression from a psychiatrist versus traumatic brain injured individuals in order to compare changes in depressive symptomology over time. It would not be unexpected that a group who had been diagnosed with depression but who were not neurologically compromised would improve with the passage of time however, the depressive symptomology of the traumatic brain injured group may be somewhat persistent as individuals come to terms with what may be the physical and/or cognitive deficits arising as a result of the injury.

In the current study it was not possible to ascertain the psychological state of the subjects simply because no inventories which could indicate levels of depressive symptomology were administered at the time of assessment and thus, this information was not available in the database. It is possible that subjects in the TBI group in the current study were depressed and that this contributed to the lack of difference between the TBI and PSY-DEP groups performance relative to the serial position effect.

**STUDY 2:**

The second study of the current research examined the serial position effect in groups suffering from differing types of dementia. Results were consistent with the literature in that organically impaired subjects appear to exhibit a greater recency effect than a primacy effect (Wiggins & Brandt, 1988). In the current study the AD group demonstrated a greater recency effect than a primacy effect which appears to suggest that a storage
disorder which is manifested by way of rapid forgetting emerges in the pattern of performance on the RAVLT (see Dimitrov et al, 1999; Tierney et al, 1994).

Overall, whilst the results for the current study supported those obtained by Tierney et al (1994) who also utilised the RAVLT to examine aspects of learning and memory and the serial position effect, several differences were noted. For example, subjects with AD in the Tierney et al (1994) study were classified as having either severe or moderate AD and the difference between the number of words recalled in the recency position as compared to the primacy position was statistically significant with more words being recalled in the recency position. This was not the case with the present study where, whilst there was a difference between the number of words recalled in the recency position as compared to the primacy position with more words being recalled in the recency position, the difference was not significant.

In comparing the demographic information of the Tierney et al (1994) study with the current study, it seems that subjects in the current study were not only younger than those in the Tierney et al (1994) study but were also in the early stages of the disease. This suggests that the ability to effectively encode and retrieve information deteriorates as the disease progresses which is consistent with current research. With this in mind, it is suggested that the RAVLT appears to be able to discriminate between the various stages of AD by demonstrating progressively poor performance on the primacy position as the disease becomes more severe.

There were also significant differences between the AD and DEM groups with the DEM group recalling significantly more words on serial position 1 and thus demonstrating a greater primacy effect than the AD group. This result suggests that the retrieval deficits evidenced by neurodegenerative processes are more severe in AD than in dementia.
Despite differences between the groups relative to the primacy position, both groups demonstrated a similar pattern of response which suggests that the inability to effectively access previously learned information is similar for both types of dementia.

The pattern of performance for both the AD and DEM groups contrasted with those of the HD groups performance insofar as primacy and recency effects were concerned. Whilst results for the three groups were not statistically compared, visual examination of Figure 2.2 demonstrates what appears to be a significant difference between the three groups on the primacy position.

Research concerning early memory deficits in HD patients is somewhat conflicting and de Boo et al (1999) found that memory problems were not impaired in presymptomatic individuals with HD. It that study no differences were found between subjects classified as having an increased risk of HD (> 95%) and those with a decreased risk (< 5%) of the disease on tasks relating to verbal and visual memory, word fluency and procedural learning. Results for the current study appear to contrast with those of the de Boo et al (1999) study with subjects demonstrating a poor performance on the primacy position. It should be kept in mind however that all subjects in the current study had received a definite diagnosis of the disease via genetic testing and it may be that the difference in performance between subjects who have an increased risk of the disease and those who have a definite diagnosis is related to the progression of the disease which is possibly manifested in poor performance on memory tasks. In addition, none of the subjects in the present study were symptomatic and all were referred for neuropsychological testing in order to establish a baseline of future cognitive decline. Thus, whilst memory deficits may not be demonstrated in those of increased risk of the disease, there appears to be a definite impact on memory once the disease has been confirmed.
It is interesting to note that the small group of subjects with HD who participated in the current study demonstrated results which indicated that 64% of the sample were outliers on serial position 1 with the mean number of words recalled on that position amounting to only 4. This result is consistent with previous research which suggests that memory is the initial faculty to be affected as a result of HD, especially verbal learning tasks which utilize a recall paradigm (see Butters, Albert, & Sax, 1979; Butters, 1984).

In conclusion, results for the current study are supportive of research which suggests that organically impaired subjects demonstrate a greater recency effect when compared to the primacy effect (Wiggins & Brandt, 1988) regardless of what type of neurodegenerative disorder is.

**STUDY 3:***

The third study investigated the pattern of performance relative to damage to different areas of the brain. Groups of FL and PL subjects were compared and results from a small group of subjects with diffuse damage to the brain were examined. Results for this study indicated differences between the FL and PL groups with the PL group demonstrating a significantly different primacy effect as compared to the FL group. Both groups demonstrated a primacy effect but a reduced recency effect with performance for the PL group improving marginally across the serial positions. It is possible that this represents an attempt to organise material in order to facilitate recall. The pattern of performance for the FL group was more like the ‘U’ shaped curve typically demonstrated in normal control group performance however, the deterioration from serial position 4 to serial position 5 suggests that this group experiences difficulties in maintaining the learning curve in that there is a decay of the words from short term memory.
In comparing both the PL and FL groups to a normal control group, the FL group was significantly different to the NC – FL group on serial position 1 and 5 indicating that damage to the frontal regions of the brain impact upon recall performance in both the primacy and recency positions. When comparing the PL groups to the NC – PL group, the PL group was significantly different to the NC – PL group in relation to serial position 5 thereby demonstrating a greater recency effect.
3.8.1 SUMMARY:

The aim of the current research was to explore patterns of performance on the RAVLT as demonstrated by the serial position in groups of subjects who were neurologically compromised in different ways. Patterns of performance were explored between subjects with traumatic brain damage who were and who were not litigating; subjects with damage to different areas of the brain; subjects who were depressed and subjects who were experiencing a neurodegenerative process.

In examining the serial position effects across all experimental groups, interesting patterns of performance emerged. For example, the litigating, nonlitigating, depressed, traumatic brain injured, frontal and posterior lesions and diffuse damage groups all demonstrated a greater primacy effect as compared to the recency effect by recalling more words on that position. This contrasts with the performance of the Alzheimer’s Disease, Huntington’s Disease and dementia groups where more words were recalled in the recency position as compared to the primacy position. It should be kept in mind that no subjects in the frontal, posterior and diffuse lesion groups were suffering from a neurodegenerative disorder.

These results suggest that the pattern of performance on the RAVLT relative to traumatic brain injury of any description is demonstrated by a greater primacy effect and thus, contrasting the pattern of performance when a neurodegenerative disorder is occurring which is demonstrated by a greater recency effect.
3.9 LIMITATIONS OF THE CURRENT RESEARCH:

In reviewing the literature, a criticism was the size of samples often utilised for research purposes. This is seen to be a problem with the current research in that groups across the three studies conducted consisted of less than 30 subjects. Insofar as the HD and DIFF groups were concerned, sample sizes were so small as to be excluded from the main analysis. However, subjects participating in the current study are what clinicians would typically see present for a neuropsychological assessment following traumatic brain injury of most types and where there is the question of a neurodegenerative disorder occurring.

A limitation of the first study was that location of damage was not considered. Whilst there is a need to conduct research relating to the performance of litigating and non-litigating TBI samples on neuropsychological tests, this variable is worthy of consideration. It is possible that different patterns of performance relative to the serial position would be elicited dependent upon location of damage as evidenced by the third study, and not just litigation status or time of loss of consciousness. It would not be unreasonable to assume that with cases of acquired TBI the location of damage to the brain will vary greatly and thus, possibly impact upon performance insofar as primacy and recency effects are concerned. In addition, it was not possible to control for depression insofar as the TBI subjects were concerned and this may have impacted upon results in that there was no difference demonstrated with regards to primacy and recency effects when this group was compared to a nonneurologically compromised depressed group. This is an important point from the perspective of litigation in that claims for compensation for injuries sustained could be compromised by the impact of depression upon neuropsychological performance.
As far as the third study is concerned, both the PL and FL groups were categorised dependent upon damage to the overall area of the brain thus, subjects with damage to any area of the frontal or posterior regions of the brain were grouped accordingly. However, research suggests that different patterns of response will be demonstrated dependent upon what area of the brain is damaged (e.g., unilateral, unilateral right, unilateral left (see Dimitrov et al., 1999) and it is possible that grouping subjects in such a general manner impacted upon the results demonstrated. It is also possible that damage caused by differing trauma also impacts upon performance for example, haematoma, infarcts and craniotomy (see Kopelman & Stanhope, 1998).

An additional problem seen to exist with the third study was that of the normal control groups which were used as comparison groups to both the frontal and posterior lesion groups pattern of performance on the RAVLT. Although this problem was not considered to be detrimental to the overall results obtained for the third study, it should be acknowledged. Figure 3.4 demonstrates the pattern of performance for both the normal control frontal lesion group compared to the normal control posterior lesion group.

Statistically, the between groups analysis was not significant nor was there any significant interaction. In examining the graph the two groups appear to be performing in a similar way. Again, whilst there appears to be a slight interaction between serial position 4 & 5, this interaction was not significant indicating that the differences between means at these two positions was not large enough for a significant result. There is a significant difference between the groups which appears to stem from the drop in both groups from serial position 1 to 3 and then back to serial position 5. However, as both groups trend the same way and their means are practically equivalent at each serial position, this then suggests that the two control groups appear to be equivalent. This also means that the experimental
groups are being compared to the same baseline conditions with minor variations as one would expect. The graph demonstrates clearly that the groups do not present enough evidence to be judged statistically different.

Figure 3.4. Primacy and Recency Effects on the RAVLT between the normal control frontal lesion and normal control posterior lesion group.

An additional problem which should be considered in relation to the results obtained in all three studies of the current research, and in particular the first study, is that of responder bias. It is possible that those subjects who responded positively to the request to access their neuropsychological results from the existing database were somehow different to those who did not respond. This problem is not unique to research yet nonetheless, should be acknowledged. In respect of the first study, it should be kept in mind that the aim of the study was to examine differences in performance between those who were litigating and those who were not. Insofar as litigants were concerned, it is
possible that only those participants who put forth a genuine effort during their
neuropsychological assessment responded to the request to access existing results.
However, this by no means detracts from the results obtained in the study and in fact,
would only serve to strengthen the results obtained by including results from those who did
indeed expend a true effort.

3.9.1 The Rey Auditory Verbal Learning Test.

Several problems were identified in the current literature as it relates to the analysis
of the RAVLT. Numerous studies have utilised the RAVLT in order to study patterns of
performance relative to the 'serial position' in different populations however, the appears
to be just as many ways in which to analyze results obtained from the measure.

Such analyses will involve totaling the number of words recalled for each trial and
comparing results from trial 1 to trial 5 resulting in what is referred to as a primacy and
recency effect. An alternative way to analyze the results obtained is by recording the order
of word recall and then examining the serial position effect. Yet another way is to record
the number of words recalled for each trial and expressing the result in percentages.

The overall impact of analysing results obtained in so many different ways is that it
is difficult to compare results across studies. In effect, when the serial position effect is
analysed by recording the number of words recalled after each trial, comparisons to
research that examines the serial position as a result of pooling across the trials such as the
current research does becomes problematic. This does not mean to imply that the serial
position cannot be examined and explored by way of analysing results trial by trial
however, it seems that to analyze results in such a way is more an examination of serial
position effects as it relates to the learning curve.
Similarly, it also seems that to analyze results by recording the order of word recall is more an exploration of temporal order effect. Certainly, until there is an agreement amongst researchers as to what constitutes the serial position as far as the RAVLT is concerned comparisons to existing research will remain problematic. An additional problem seen to exist with the RAVLT relates to what exactly is the measure measuring? For example, do subjects who are highly imaginative perform better on the RAVLT as a result of word association? Do subjects who utilize memory strategies such as mnemonics perform better than those who do not? If this is the case, then results obtained do not necessarily reflect permanent deficits with memory but more poor memory strategies. Results could also have been influenced by factors typically associated with retrospective research such as selective deposit, selective survival and spurious relationships in the dataset. Future research may consider the above when implementing the RAVLT in order to study memory and learning processes.

3.10 FUTURE RESEARCH:

Study 1 differed from the majority of research relating to patterns of performance relative to the serial position as demonstrated by performance on the RAVLT in that only genuine TBI subjects participated as compared to the majority of current research which utilizes simulated samples. Results for Study 1 clearly indicated that time of loss of consciousness impacts upon performance regardless of litigation status. Results also demonstrated that depression has a similar impact upon performance on the RAVLT to that of traumatic brain injury and it is suggested that future research be conducted longitudinally in order to study the differing effects of depression vs. traumatic brain injury over time. For example, at what point along the continuum would significant differences emerge insofar as depressive symptomology is concerned between the TBI and depressed
group. This will serve to give some indication of the impact of TBI combined with depression upon neuropsychological tests and how long depression is manifested for.

Future research needs to be conducted across differing samples of traumatic brain injured subjects, such as those who are litigating and not litigating, subjects who have sustained damage to differing areas of the brain, subjects who are suffering from various types of dementia and subjects who are depressed in order to evaluate the findings from the current research.

As indicated previously, samples in the current study were relatively small and the serial position as demonstrated by pooling the trials of the RAVLT has received little attention in the literature. With the above factors in mind, this study could be said to be an initial exploratory procedure to investigate the relationship between various types of TBI and serial position effects and would need to be replicated.
APPENDICES

Appendix A

Rey Auditory Verbal Learning Test

DRUM     DRUM     DRUM     DRUM     DRUM
CURTAIN  CURTAIN  CURTAIN  CURTAIN  CURTAIN
BELL     BELL     BELL     BELL     BELL
COFFEE   COFFEE   COFFEE   COFFEE   COFFEE
SCHOOL   SCHOOL   SCHOOL   SCHOOL   SCHOOL
PARENT   PARENT   PARENT   PARENT   PARENT
MOON     MOON     MOON     MOON     MOON
GARDEN   GARDEN   GARDEN   GARDEN   GARDEN
HAT      HAT      HAT      HAT      HAT
FARMER   FARMER   FARMER   FARMER   FARMER
NOSE     NOSE     NOSE     NOSE     NOSE
TURKEY   TURKEY   TURKEY   TURKEY   TURKEY
COLOR    COLOR    COLOR    COLOR    COLOR
HOUSE    HOUSE    HOUSE    HOUSE    HOUSE
RIVER    RIVER    RIVER    RIVER    RIVER
Appendix B

The Neurosciences Unit

The Neurosciences Unit is a state wide service that provides diagnostic support to tertiary hospitals, secondary level public hospitals and community based facilities. It is a government funded department whose primary role is to provide neuropsychological assessments for the Western Australian public. Referrals for patients to attend the NU come from a variety of sources and include neurologists both in private practice and from major teaching hospitals, psychologists, psychiatrists, medical practitioners, solicitors and other government agencies. The patient pool is varied and includes those suffering from difficulties arising from epilepsy, dementia, tumours, cerebrovascular disease and a variety of accidents including motor vehicle, work related injuries and falls. Once the client has been referred to the NU, qualified psychologists registered with the Psychologists Board of Western Australia, administer a battery of neuropsychological tests in order to assess brain functioning which includes intelligence, memory, language functioning, frontal lobe functioning, motor and sensory functioning and general cerebral efficiency. During the year 1999/00 the NU provided 18,058 'occasions of service' and over 1700 clients have been referred to the Unit over a period of at least 10 years.
Appendix C.

Instructions for Administration of the Rey Auditory Verbal Learning Test.

I am going to read a list of words. Listen carefully, for when I stop, you are to say back as many as you can remember. It doesn’t matter in what order you repeat them. Just try to remember as many as you can.

The examiner reads the words on the first list at a rate of one per second and writes down the client’s responses in the order in which they are recalled. The examiner should take care to record the words recalled by the client in the exact order in which they are recalled. Information on repeated words and queried responses is recorded. When no further words can be remembered, the examiner administers the second trial:

Now I’m going to read the same list again, and once again when I stop, I want you to tell me as many words as you can remember, including words you said the first time. It doesn’t matter in what order you say them, just say as many words as you can remember, whether or not you said them before.

The examiner repeats the preceding instruction for the third, fourth, and fifth trials. After the fifth trial with the first list, the examiner presents the second list:

Now I’m going to read a second list of words. This time, again, you are to say back as many words of this second list as you can remember. Again, the order in which you say the words does not matter. Just try to remember as many as you can.

After completion of the second, distracter list, the examiner administers the last recall trial but does NOT read the words form the first list again:

Now tell me the all the words you remember from the first list.

If a delayed recall trial is to be used, the examiner fills the delay period with other tasks that do not involve similar word recall tasks, such as vocabulary tests. After the completion of the 30-minute delay, the examiner administers the following instructions:

A short while ago, I read a list of words to you several times, and you were trying to learn these words. Tell me the words from this list again.
### Appendix D

**Rey Auditory Verbal Protocol (Neurosciences Unit)**

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<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>List B</th>
<th>B</th>
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Note: Bold lines indicate each Serial Position.
Appendix E

Consent Forms
Patterns of Performance: The Rey Auditory Verbal Learning Test

Request to use data collected from confidential database:

Dear Mr./Mrs.

My name is Marie Hardman and I am currently completing a Doctorate in Psychology at Murdoch University under the supervision of Professor Michael Innes and Associate Professor Laurence Hartley. I am currently investigating if people diagnosed with Alzheimer’s Disease, Huntington’s Disease and Dementia perform differently to each other on commonly used neuropsychological tests. As you know because of your referral for neuropsychological assessment, memory is often affected with these types of disorders.

There are several reasons why this research is being conducted; if we are able to study how memory is affected as a result of various disorders, then it is possible that we may be able to find ways in which to help you remember things which happen on a daily basis such as conversations, shopping lists, where you put the car keys etc. Additionally, new treatments are becoming available so correct diagnosis will help people diagnosed with differing types of dementia get the best possible treatment. Insofar as memory is concerned, there are many ways in which memory functions are assessed and one of these ways is to study how word lists are remembered.

My request to yourself is to seek permission to obtain the results from a measure which you completed during your assessment at the Neurosciences Unit. At the time of your assessment you indicated on the Information Sheet which you completed that you would be willing to be contacted in order to participate in specific research. The test I would like to use in the current research is one where a list of words was read out aloud to you and you were then requested to repeat as many words as you could remember. This test is known as the Rey Auditory Verbal Learning Test and it is your results from this test that I am requesting permission to use in my study.

Please remember, you do not have to engage in any further testing and I do not need to see you personally. The results from your assessment which I would need to include in my study is the results from the word list you completed. I would also need to note some existing file information including parameters such as your age, gender and diagnosis. Future treatment will NOT be compromised if you do not wish to participate in this study.

Please also remember, you can withdraw your consent for this study at any time. All information given during your assessment is confidential and no names or other information that might identify you will be used in any publication arising from this research. Once your results have been entered into a database for this research, a coding system is used and it is not possible to identify from whom the information came from.

If you have any questions about this study please feel free to contact either myself, Marie Hardman, on 9360 6000 or my supervisor's Professor Mike Innes on 9360 6670 or, Associate Professor Laurence Hartley on 9360 2398. My supervisors and I are happy to discuss with you any concern you may have on how this study has been conducted, or alternatively you can contact Murdoch University’s Human Research Ethics Committee on 9360 6677.

I have read the information above. Any questions I have asked have been answered to my satisfaction. I agree to take part in this activity. However, I know that I may change my mind and stop my participation at any time without prejudice to my future medical treatment. I understand that all information provided is treated as confidential and will not be release by the investigator unless required to do so by law. I also understand that once my results have been coded into the new database it will not be possible to identify myself. I agree that research data gathered for this study may be published provided my name, or other information which might identify me is not used.

Thankyou for your time and your help.

Participant/Representative: Marie Hardman (Investigator)  Professor M. Innes (Supervisor)

(Supervisor): Associate Prof. L. Hartley
Appendix F

Mean Number of Words Recalled for each Group Across the Five Trials of the RAVLT

<table>
<thead>
<tr>
<th></th>
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<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
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<td>5.64 (1.40)</td>
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<td>TBI-NONLIT</td>
<td>5.32 (1.80)</td>
<td>8.14 (2.28)</td>
<td>9.68 (2.50)</td>
<td>10.50 (3.02)</td>
<td>11.23 (3.21)</td>
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REFERENCES


