TACKLING MILD HEAD INJURY IN RUGBY:

A COMPARISON OF

THE COGNITIVE PROFILES OF PROFESSIONAL

RUGBY AND CRICKET PLAYERS.

Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Arts in Clinical Psychology.

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ABSTRACT

The aim of this study was to investigate the effect of cumulative mild head injury on the cognitive functioning of professional rugby players. A comprehensive battery of neuropsychological tests was administered to 26 professional rugby players and to a comparison group of 21 professional cricket players. The group test results of the rugby, cricket, rugby forwards and rugby backline players were each compared with established normative data. Generally, the comparison of the rugby and cricket mean scores relative to the normative data did not reveal significant differences on tests known to be sensitive to the effects of mild head injury. However, the comparison of variability for each of the rugby and cricket playing groups relative to variability for the normative data, revealed a pattern of increased variability among the rugby players. This implies a bimodal distribution in which a significant number of rugby players were performing poorly across these tests whereas a significant proportion were not. This variability effect was accounted for by further mean score comparisons which revealed that, as a group, it was the forward players whose performances were disproportionately poor on tests sensitive to the effects of mild head injury. The implications of these results are developed theoretically within the context of brain reserve capacity theory and suggestions for future research are provided.

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CHAPTER ONE: LITERATURE REVIEW

1.1 INTRODUCTION AND CLASSIFICATION OF TERMS

This section aims at situating mild head injury within the spectrum of head trauma, and includes definitions of the relevant terms as well as discussions on the incidence, the pathophysiology, and the typical symptoms associated with mild head injury.

1.1.1. Major Types of Head Trauma

Traumatic head injury is usually classified into two major types, open or penetrating head injury and closed head injury. Penetrating head injury typically involves perforation or fracture of the skull and damage to the brain tissue along the path of the penetrating object (Levin, Benton & Grossman, 1982). This type of injury typically results in a circumscribed focal lesion accompanied by relatively circumscribed, predictable cognitive losses (Lezak, 1995) and the severity of the injury is primarily determined by the depth of penetration and the loss of brain tissue involved (Levin et al., 1982).

Closed head injury is far more common in civilian practise (Lishman, 1987). This type of injury involves blunt trauma to the head, resulting either from impact by a moving object while the head is stationary or moving slowly (acceleration), or by the head and body being brought to an abrupt stop by a stationary or slower moving object (deceleration) (Levin et al., 1982). Focal lesions may occur at the point of impact (coup) and in an area opposite the blow (contre coup) which is caused by the brain rebounding off the opposite side of the skull, and these lesions account for the localizable changes that accompany closed head injury (Lezak, 1995). Diffuse damage in closed head injury arises from rotational shear stresses within the brain (Lishman, 1987). Evidence suggests that this diffuse cerebral damage, arising at the moment of impact, is the primary mechanism of brain damage in closed head injury and that the severity of this damage is a more important prognostic indicator than the presence of focal lesions in closed head injury (Adams, Mitchell, Graham & Doyle, 1977; Levin et al., 1982). The spectrum of closed head injury severity, depending on the amount of diffuse damage incurred, ranges from mild to moderate to severe (Levin et al., 1982). The focus of this research is on mild closed head injury, hereafter referred to as mild head injury.

1.1.2 Classification of Mild Head Injury

The classification of head injury severity is problematic and, although the problem possibly involves the whole injury spectrum, it is particularly salient in the mild to moderate range (Satz et al., 1997). The term mild head injury is broadly understood to refer to head injuries in which loss of consciousness and/or post-traumatic amnesia (PTA) is relatively brief and in which there is an absence of any structural pathology of the skull (Binder, 1986). However, criteria used in defining mild head injury have varied considerably in the literature (Binder, 1986; Evans, 1992; Levin, Eisenberg & Benton, 1989) and no acceptable definition has achieved widespread usage. Criterea are usually based on alterations in consciousness (the Glasgow Coma Scale), changes in orientation and memory (length of post-traumatic amnesia) and duration of unconsciousness (Satz et al., 1997). These measures can be problematic when applied to mild head injury, for example measures such as the Glasgow Coma Scale are effective in evaluating depth of coma in severe head injury but are not designed to quantify mild disturbances of consciousness or post-traumatic amnesia (PTA) associated with mild head injury (Levin et al., 1989). Similarly, estimates of post-traumatic amnesia are usually based on self-reported brief, transient symptoms and are often unreliable (Satz et al., 1997).

The variability of defining criteria has been a major problem in research into mild head injury (Binder, 1986; Satz et al., 1997; Williams, Levin & Eisenberg, 1990). Evans (1992) stresses that strict criteria for defining mild head injury are essential to ensure the exclusion of confounding variables in such studies. He recommends that a duration of loss of consciousness of 30 minutes or less without further neurological complications are reasonable defining criteria to adopt for research into mild head injury. Consequently, these criterea are adopted for the empirical aspect of this research.

1.1.3 Incidence of Mild Head Injury

The incidence of mild head injury is high, accounting for between 66% and 75% percent of hospital admissions for head trauma and it results in an estimated 325 000 new cases in the United States each year (Kraus & Nourajah, 1989). This figure is however likely to be much higher because, as Jennett (1995) notes, approximately five cases of mild head injury are treated on an outpatient basis for every case that is admitted to hospital. Moreover, the number of patients who are rendered unconscious briefly and who do not seek any medical attention is unknown (Rimmel, Giordani, Barth, Boll & Jane, 1981). Increasing attention has been given to the neuropsychological and psychosocial sequelae of mild head injuries. Reasons include the fact that mild head injury occurs more frequently compared to moderate or severe head injury and although mild, often results in persisting symptoms which inhibit social and vocational readjustment (McLean, Tenken, Dikmen & Wyler, 1983).

1.1.4 Pathophysiology of Mild Head Injury.

Research supports the idea of a continuity of organic brain damage in closed head injury, from mild to severe, resulting from mechanically induced diffuse axonal injury (Ommaya & Gennareli, 1974; Adams et al., 1977; Satz et al., 1997). This diffuse axonal injury resulting from shear strain (Holbourn, 1943) is the primary mechanism proposed to account for damage and subsequent behaviourial dysfunction in mild head injury (Anderson, 1996; Evans, 1992; Gualterri, 1995). Both linear and rotational acceleration of the brain usually co-exist or follow on one another in closed head injury (Levin et al., 1982; Richardson, 1990). This causes swirling movements of the brain within the skull and the resulting linear and rotational strain tears and damages nerve fibres throughout the brain (Lishman, 1987), with the loss of consciousness often associated with mild head injury pointing to significant involvement of the brain stem centres (Lishman, 1987; Ommaya & Gennarelli, 1974; Walsh, 1987). Such diffuse axonal injury occurs in situations where the head is free to move and can occur without any direct impact to the brain such as in whiplash injuries which also involve rapid acceleration and deceleration of the brain (Holbourn, 1943; Gualtierri, 1995). The neuronal damage is accompanied by small hemorrhages from ruptured blood vessels scattered throughout the cerebral white matter and lower brain structures. Pang (1989) cited in Lezak (1995) comments:

> "The tremendous clinical significance of these microscopic lesions is easily understood if one realises that myriad microscopic shearing injuries occur simultaneously within a rapidly rotating brain, resulting in myriad axonal and neuronal disruptions within the deep white matter of both cerebral hemispheres, which in essence disconnect the cortex from subcortical structures in widespread regions of the brain" (p 178).

The presence of diffuse axonal injury in mild head injury has been supported by research involving postmortem examinations (Alexander, 1995). Oppenheimer (1968) demonstrated pathologic changes in the form of microscopic lesions of the cerebral white matter in patients who had died from complications following mild head injury, concluding that permanent damage in the form of microscopic lesions accompanies even trivial head injury. In a more recent study by Blumbergs et al. (1994), the researchers examined five patients between the ages of 59 and 89 years old who sustained mild concussion and who died of unrelated reasons 2 - 99 days post head injury. Staining of the amyloid precursor protein, a marker of rapid axonal transport, revealed multi-focal axonal damage in all five patients.

1.1.5 Mild Head Injury and the "Post-Concussive Syndrome"

Following mild head injury a significant number of patients have complained of a variety of subjective somatic, cognitive, emotional, motor and sensory disabilities (Benton, 1989). Constituting what is termed the "Post Concussive Syndrome", these symptoms typically include increased anxiety, irritability, emotional lability, depression, sleep disturbances, dizziness, attention and concentration difficulties and memory problems (Benton, 1989; Binder, 1986; Evans, 1992; Lishman, 1988; Szymaski & Linn, 1992). Because of the discrepancy between these subjective complaints often experienced by patients following mild head injury and the absence of convincing organic pathology, the post-concussive syndrome was initially believed to be primarily psychological in origin (Benton, 1989; Bohen & Jolles, 1992). Previously, psychometric tests used have often not been sensitive enough to pick up objective evidence for some post-concussive symptoms (Gronwall & Wrightson, 1975). However, in the past two decades neuropsychological investigation using more appropriate and sensitive testing has shown that a significant percentage of patients display measurable deficits in attention and concentration, information processing and memory function that do have a neurological basis (Barth et al., 1983; Bohen & Jolles, 1992). These findings have been supported by the advent of more sophisticated neurological testing such as the Magnetic Resonance Imaging (MRI) scan which provides evidence for the presence of organic brain damage following mild head injury (Eisenberg & Levin, 1989).

1.1.6 Section Summary

In summary, the term mild head injury broadly refers to head injury in which loss of consciousness and/or posttraumatic amnesia is relatively short and there is no structural pathology of the skull. The incidence of mild head injury is high. Mild head injury is primarily associated with diffuse type cerebral damage which gives rise to a varied but typical pattern of symptomology.

1.2 REVIEW OF RESEARCH INTO THE COGNITIVE SEQUELAE OF MILD HEAD INJURY

This section reviews research into the cognitive sequelae associated with mild head injury in general, and introduces the more controversial area of persisting cognitive symptomology associated with mild head injury.

1.2.1 Cognitive sequelae of Mild Head Injury

The cognitive sequelae of mild head injury have received much attention since an extensive study by Rimmel et al. (1981) alerted health professionals to the high morbidity associated with mild head injury (Bohnen & Jolles, 1992). Their investigation revealed problems with attention, concentration, memory and/or judgment at three months post head injury in nearly all of the 69 patients assessed. Subsequent research has indicated that cognitive functions typically compromised in mild closed head injury are: rate of information processing (for example, Gronwall, 1989; McLean et al., 1983; Leininger, Grammling, Farrell, Kreutzer & Peck, 1990); memory (for example, Barth et al., 1983; Levin et al., 1987; Ruff et al., 1989); attention (for example, Bohnen, Jolles & Twinstra 1992; Gentillini et al., 1985; Parasuman, Mutter & Molloy 1991).

Not all research, however, supports the presence of cognitive impairment following mild head injury and in a recent comprehensive review on mild head injury in children by Satz et al. (1997) the authors challenge the general trend of positive research findings regarding the neuropsychological and psychosocial sequelae of mild head injuries. Their results reveal 13 adverse, 18 null and 9 indeterminate findings with respect to mild head injury in children, with studies of stronger methodological merit more generally associated with null outcomes. The authors note that an inherent bias on the part of journals to publish studies which reject the null hypothesis, favours research which shows support for cognitive impairment following mild head injury. However, they do caution against applying their findings to adults in that the phenomenology of head injury in children differs in several respects compared with adults and efforts to make direct comparisons on the effects of mild head injury in children and adults are thus inherently problematic.

1.2.2 Persisting Symptomology Following Mild Head Injury

Although there is substantial evidence that mild head injury in adults does result in cognitive deficit (Binder, 1986), much controversy exists over the duration of this deficit (Binder, 1986; Klonoff & Lamb, 1998). Some researchers have found a rapid resolving of cognitive deficit one to three months following mild head injury (for example, Dikmen et al., 1986;

Gentillini et al., 1985; Levin et al., 1987; McLean et al., 1983). A methodological weakness of these studies is the lack of baseline premorbid data which prevents the researchers from stating unequivocally that patients have in fact returned to their previous level of functioning. Both McLean et al. (1983) and Dikmen et al. (1986) noted that, although there was no statistically significant difference between subjects and controls at one month post injury, there was a general trend for the subjects to perform more poorly across the tests than the uninjured controls. Other researchers have found significant deficit at three months post injury (for example, Barth et al., 1983; Rimmel et al., 1981), however, these studies are weakened by their failure to include matched control groups. Other more carefully controlled studies provide evidence that some patients do suffer residual cognitive deficit. A study by Leininger et al. (1990) involved assessing patients with subjective post-concussive symptomology and comparing their test performance with matched uninjured controls. The researchers found evidence for deficits in information processing, verbal learning and reasoning at 22 months post injury. These findings are supported by Bohnen et al. (1992), who tested symptomatic patients at six months post injury and found deficits in selective and divided attention relative to an asymptomatic control group. These results suggest that, although the majority of patients may recover functionally from single uncomplicated mild head injury, a small but significant number do experience persisting cognitive deficit, at least up to 22 months post head injury.

The etiology of persisting symptomology following single mild head injury is a source of ongoing controversy (Dikmen et al., 1989; Raskin, Mateer and Tweeten, 1998). Factors that appear to contribute toward the selective vulnerability to persisting measurable cognitive deficit include premorbid personality, age, socioeconomic status and previous head injury

(Binder, 1986; Gualtierri, 1995). There is often a lack of correspondence between severity of injury and persistence of symptoms, an observation that tends to support a psychogenic etiology (Dikmen et al., 1989; Lishman, 1968). There is also literature emerging indicating that secondary gain such as the financial incentives of litigation may contribute to reported persisting cognitive deficit (Alexander, 1995; Lishman, 1988; Raskin et al., 1998; Youngjohn, Burrows & Erdal, 1994).

In a recent study by Klonoff & Lamb (1998), 9 patients with a history of mild head injury and with complaints of persisting symptoms were assessed on neuropsychological tests. The authors found significant deficits on testing. However, they suggest that atypical response styles to the tests and evidence of psychiatric disability and/or malingering indicate that psychogenic factors were primarily behind the low test scores. The generalizability of these results is compromised by the small sample size. In one of the few studies to date that thoroughly investigates the relative influence of emotional factors on cognitive status, Raskin et al. (1998) tested 148 patients with prolonged symptomology following mild head injury on a comprehensive range of personality and neuropsychological tests. The mean time elapsed since the injury was 21 months. The authors found a pattern of significant deficit in complex attention, working memory and verbal learning, particularly on time dependant tasks. Although the authors acknowledge that emotional factors can complicate neuropsychological assessment, they found no direct correlation between personality and emotional factors and test performance, suggesting that persistent cognitive deficit does have an organic basis. Lishman (1987), argues for a mixed organic and psychogenic etiology in which, as symptoms persist, numerous factors come to play a part.

1.2.3 Section Summary

In summary, the body of research up to the present generally indicates that mild head injury results in measurable acute cognitive deficit and, that in most cases, deficit following single uncomplicated mild head injury resolves within three months. However, research indicates that a small but identifiable number of patients do exhibit residual cognitive deficit on neuropsychological testing, at least up to 22 months post head injury. The etiology of persisting symptomology remains controversial and evidence tends to point towards a mixed psychogenic and organic basis with factors such as premorbid personality, age, socioeconomic status, impending litigation and previous head injury playing a part.

1.3 CUMULATIVE MILD HEAD INJURY

This section reviews research into the cognitive sequelae of cumulative mild head injury and links the concept of the cumulative effect of repeated mild head injury to the threshold concept of the Satz (1993) theory of Brain Reserve Capacity.

1.3.1 Cognitive Sequelae of Cumulative Mild Head Injury

Apart from the substantial evidence for acute cognitive impairment following single mild head injury there is growing evidence that the risk of permanent residual cognitive deficit increases consequent on cumulative mild head injury (Dikmen et al., 1989). Gronwall and Wrightson (1975) tested twenty young adults on the PASAT after they had suffered a second concussion. The subjects showed greater impairment of information processing capacity when compared to a group of controls tested after only a single concussion, they also took longer to recover to normal levels of functioning. The researchers concluded that, although full functional recovery is the norm for young patients, central nervous system (CNS) damage possibly due to neuronal fallout, is in fact irreversible. This residual CNS damage leaves the patient more vulnerable to the effects of further concussive head injury. Consistent with these findings, further research by Gronwall (1989) involving a series of studies using the PASAT found that mild head injury results in reduced information processing ability. In the young adult group recovery after four to six weeks was full, however, recovery among older patients and those with previous head injury took longer.

The residual effect of permanent CNS damage is also apparent among patients who have made a full functional recovery but remain vulnerable to secondary CNS stressors (Evans, 1992). Ewing, McCarthy, Gronwall & Wrightson (1980) conducted a study comparing the performance, under mildly hypoxic conditions, of a group of university students who had suffered a mild head injury between one and three years previously and had made "full recoveries" with a matched control group of students who had never had a head injury. They found that the group with previous head injury performed significantly poorer on a memory and on a vigilance task than the controls, in addition they found that there was no evidence to indicate that the vulnerability to secondary CNS stressors decreases over time. Thus the indication is that, although patients may have appeared to have made a full recovery, structural damage is permanent and any subsequent concussion only adds to neuronal loss.

1.3.2 Brain Reserve Capacity Theory

An important theoretical framework in understanding the cumulative effects of mild head injury is the theory of brain reserve capacity (BRC), formulated by Satz (1993). In terms of this theory, brain reserve capacity, corresponding to the amount of functional brain tissue, represents physiological brain advantages or disadvantages, and the two psychosocial factors that represent indirect measures of BRC are general intelligence and educational level. Further, in terms of Satz's theory, the greater the BRC, the less likelihood there is of an individual exhibiting symptoms of neurological impairment as a higher BRC is likely to act as a protective factor, decreasing the risk of functional impairment. This will be reflected in higher premorbid scores and higher levels of functioning, even in the presence of brain damage. The less the BRC the more vulnerable an individual will be to showing symptoms of neurological impairment as the threshold (the critical amount of brain tissue at which normal functioning can be sustained) will be lower. In terms of this theory any reduction in BRC due to neurological pathology is likely to increase an individual's vulnerability to functional impairment. Furthermore, recent research on Alzheimer's Dementia is commensurate with indications from BRC theory in that the evidence suggests that previous head trauma significantly increases the risk for Alzheimer's Dementia (Mortimer et al., 1991; Mortimer, 1994; Rasmusson, Brandt, Martin and Folstein, 1994) and arguably this occurs as a consequence of lowered brain reserve capacity.

Jordan (1997), postulates that different levels of BRC between individuals are reflected in group performance on neuropsychological testing as inter-individual variability, (ie. the extent to which individual raw scores vary about the mean). Variability reflects a differential fall off due to differential threshold levels such that some fall off markedly while others have greater BRC to call upon and are protected up to a point. Jordan (1997) makes the point that brain damaged groups are initially typically associated with increased variability reflecting the scattered distribution of scores. However, she postulates that as the majority of a group begin to exhibit signs of functional symptomology, reduced scores for all members of the group will narrow the distribution of the scores and will be reflected in reduced variability of cognitive test scores. Jordan demonstrates her argument using data for ageing effects across the adult life course, conceptualizing ageing as a form of increasing brain impairment. Hence her thesis has relevance for encroaching levels of brain impairment with etiology other than ageing, such as cumulative mild head injury.

1.3.3 Section Summary

In summary, research shows cumulative mild head injury to be associated with permanent residual neuropsychological deficit. Although individuals may appear to have made a full functional recovery, neuronal change is permanent, and, in terms of BRC theory, any neuronal changes that lower the threshold (for example previous head injury) are likely to increase the individuals vulnerability to functional impairment. In neuropsychological testing, differing brain reserve capacity thresholds within a brain damaged group will be reflected initially in increased inter-individual variability, but when the brain damage is more progressed, affecting all members of the group, there will be a decrease in inter-individual variability.

1.4 MILD HEAD INJURY AND CONTACT SPORT

Substantial effort has been made in most sports to minimise the potential for significant or severe head injury, however this has not been the case with most sports related mild head injury which until recently has not been seen as a major problem (Barth et al., 1989). Players of contact sport are at particular risk for cumulative mild head injury, however the incidence and outcome of mild head injury sustained in contact sports has not been sufficiently investigated (Barth et al., 1989; Hinton-Bayre, Geffen & McFarland; Levin et al., 1989; Shuttleworth-Jordan, Balarin & Putchert, 1993) and participants are often unaware of the risks involved. This section focuses on research into the cognitive sequelae of contact sport including boxing, soccer and finally rugby, the focus of this research.

1.4.1 Boxing

Although players of all contact sport are at risk for cumulative mild head injury, in some sports such as boxing, blows to the head are an intended part of the game (Drew & Templar, 1992). Research into the neuropsychological consequences of professional boxing, albeit not limited to mild head injury, has found evidence of cognitive deficit (Haglund & Eriksson, 1993) and poor performances have been demonstrated on tests measuring attention, concentration, immediate and delayed memory, new learning, sequencing abilities and speed of information processing (Heilbronner, Henry and Carson-Brewer, 1991).

A relationship between the incidence of abnormalities and number of fights has also being established supporting the evidence of cognitive dysfunction consequent on cumulative head injury (Barth et al., 1989; Butler, Forsyth, Beverly & Adams, 1993). Ross, Casson, Siegel & Cole (1981) studied 15 active and former professional boxers on a battery including the Trail Making Test, the Digit Symbol test, the Weschler Memory Scale and the Bender Gestalt test. Results were compared with established normative data for the general population. Ninety percent of the subjects performed poorly on the memory tests and fifty percent on the non-memory tests. The researchers also found a significant correlation between poor test performance and number of fights as well as a correlation between poor test performance and increasing age. Consistent with these findings is a study by Drew, Templar, Schuyler, Newell & Cannon (1986). They tested 19 young, active, professional boxers with a mean of 13.7 bouts on a comprehensive neuropsychological test battery which included the Halstead-Reitan Neuropsychological Battery, the Quick Neurological Screening Test and the Randt Memory Test. The researchers found a strong correlation between number of professional bouts and number of professional boxing losses and draws. They conclude that:

> "appreciable brain damage and associated neuropsychological deficits in todays active professional boxers may be the rule rather than the exception" (p 525).

Research into the effects of head injury in amateur boxing (again not limited to mild head injury) is more equivocal. Some researchers (for example, Brooks, Kupshik, Wilson, Galbraith & Ward, 1987; Butler et al., 1993) have found no evidence for significant cognitive deficit among amateur boxers, nor any correlation between number of fights and cognitive performance. Methodological weaknesses of these studies include a voluntary sampling procedure (the authors acknowledge that those boxers aware of cognitive difficulties may refuse to take part in the study) as well as the lack of carefully matched control groups. In the study by Butler et. al., (1993), the subjects had a mean age of only 16.7 years, thus making it difficult to extrapolate the results to amateur boxing at a more experienced and elite level. Other research into the effects of amateur boxing have found deficits in the areas of information processing (for example, McLatchie et. al., 1987) as well as in verbal memory and verbal new learning (for example, Heilbronner et. al., 1991). The deficits in new learning were found to be primarily due to difficulties with verbal retrieval which as Lezak (1995) notes are a common consequence of mild head injury and are often misinterpreted as primary memory or verbal learning disorders.

One study that has isolated the effects of mild head injury in boxing is a neurological study by Casson, Sham, Campbell, Tarlau & DiDomenico (1982). In this study ten professional boxers were assessed following mild head injury - all had experienced duration of loss of consciousness including post-traumatic amnesia of less than two minutes. One boxer had an abnormal neurological examination, two boxers had abnormal electroencephalograms (EEG's) and five boxers showed abnormal computed tomography (CT) scans with mild to moderate cerebral atrophy. As none of the boxers had been knocked unconscious more than twice the authors concluded that the neurological damage evidenced was not due to the number of knockouts but was the result of multiple sub-concussive blows to the head.

1.4.2 Soccer

Soccer is generally assumed to be a non-contact sport, however minor head injuries sustained in collisions with other players are possibly under-diagnosed (Dailey & Barsan, 1992). Moreover, soccer involves frequent 'heading' of the ball which would further expose players to multiple sub-concussive knocks to the head (Spear, 1995; Tysvaer, Storli and Bachen, 1989). Abreau, Templar, Schuyler & Hutchison (1990) compared the performance of 31 soccer players with 31 controls (tennis players) on a battery that included the Ravens Progressive Matrices, Symbol Digit Modalities, Perceptual Speed and PASAT tests. Although they found no significant difference between the two groups on test performance, there was a negative correlation between number of games played and performance on the PASAT. This suggests compromised information processing abilities consequent on cumulative mild head injury. However the small numbers involved in the test and the lack of premorbid data allowed the authors to only put forward tentative support for cognitive deterioration among soccer players. A neurological study by Tysvaer et al. (1989) provides stronger evidence for the presence of cognitive deficit among soccer players. They conducted neurological and EEG examinations on 37 former football players (aged 34-64 yrs) of the Norwegian national team, with the aim of investigating the incidence of head injuries due to 'heading' the ball. An increased incidence of EEG abnormalities was recorded among the players compared with 37 non-football playing, non-injured controls of similar age. The researchers concluded that the high incidence of EEG changes in the football players was probably the result of the cumulative effect of repeated head traumas.

1.4.3 Rugby

As the focus of this research is rugby, the sport will be dealt with in more depth and this section includes a discussion on the epidemiology of mild head injury in rugby as well as a review of research into the neuropsychological sequelae associated with the sport.

1.4.3.1 Epidemiology of Mild Head Injury in Rugby.

Mild head injury in rugby results from stresses and impacts to the head and neck during scrumming, tackling and collisions (Shuttleworth-Jordan et al., 1993) and the incidence of mild head injury among rugby players is high (De Villiers, 1987; Nathan, Goedecke & Noakes, 1983; Roux, Goedecke, van Zyl & Noakes, 1987). Nathan et al., (1983), reported that concussive head injuries, together with muscle injuries were the most common type of injury at school level rugby while Roux et al., (1987) put the incidence of concussion at school level as high as 20%.

Research in the USA among college Football players (a comparable contact sport to rugby in terms of injury risk) have come up with a similar incidence of head injuries. Barth et al.,

(1989) puts the incidence of head injury at 10%. Of those injured 42% had a previous head injury and half of these had a history of repeated head injury. Gerberich, Priest, Boen, Straub and Maxwell (1983) reported a 20% incidence of concussion among high school football players and noted that players with a prior history of head injury had four times the risk of further head injury. Albright, Mcauley, Martin, Crowley and Foster (1985) conducted a study of 342 college football players at a single institution over a period of five years and of the players, 29% suffered head and neck injuries, most being mild in severity. The researcher also noted that, following a single head injury, the probability of subsequent head injury escalated to 42% and that 24% of the players experienced recurrent head injury within a single season.

In addition to concussive head injury, sub-concussive head injuries involving relatively subtle changes in consciousness can be difficult to detect in that they are not specifically looked for and the criterea are often not rigid enough to extract relevant information (De Villiers, 1987). Anderson (1995) comments that, despite the risks of sustaining mild head injury in rugby, symptoms are often inadequately evaluated by medical professionals or played down by athletes wishing to return to the game and players remain at risk for cumulative mild head injury. De Villiers (1987) stresses that the incidence of mild, including sub-concussive, injury should be a source of concern for both rugby administrators and trainers.

1.4.3.2 Research into the Cognitive Sequelae of Mild Head Injury in American Football and Rugby

Although epidemiological studies confirm that the nature of the game puts rugby players at risk for cumulative mild head injury, few studies have been conducted into the cognitive sequelae of repeated mild head injury in rugby. Barth et al. (1989) conducted a four year prospective study involving 2350 American college football players. All players were assessed at pre-season, players who then sustained a mild head injury during this period were tested on a neuropsychological battery that included the PASAT, the Digit Symbol and the Trail Making Test, within 24 hours, 5 days and 10 days post injury. Test practice effects were controlled for using a group of college students as well as a group of mildly injured orthopaedic patients. The researchers found that players with reported single mild head injury showed impaired attention and concentration and impaired information processing abilities at 24 hours post trauma. There was a pattern of rapid recovery up to 10 days when a direct comparison of raw scores between injured players and control students revealed no significant differences between the groups.

Maddock's and Saling (1991), conducted a study on concussive injury among Australian Rules Footballers which involved using baseline premorbid data and a matched control group. The battery included the Digit Symbol Substitution Test, the PASAT, and the Four Choice Reaction Time Test. The baseline measures were obtained in a sample of 130 players, 10 players who were subsequently concussed were tested at 5 days post-injury. Impaired information processing (Digit Symbol Substitution Test) and slowed measures of decision time and reaction time (Four Choice Reaction Time Test) were noted. In another Australian study Hinton-Bayre et al. (1997), conducted a study which involved determining test sensitivity to cognitive impairment immediately following concussive head injury. They tested 10 professional league rugby players on a battery consisting of the Symbol Digit Modalities Test, the Digit Symbol Substitution test and the Speed of Comprehension Test. All players were tested within 24 to 48 hours of sustaining a mild head injury. In comparison with baseline premorbid data, the researchers found that speed of information processing (Digit Symbol and Symbol Digit Modalities Test) and speed of comprehension (Speed of Comprehension Test) were impaired in the post-acute phase of mild head injury.

Methodological strengths of the above studies include the use of premorbid data and the repeated testing of matched control groups to control for practice effects. The studies, however also share certain methodological weaknesses. A limitation of these studies was that they all tended to focus on the acute or sub-acute phase of single reported mild head injury which did not allow for the effective monitoring of a recovery curve or of residual symptoms. The studies also all focused on single reported mild head injury and failed to take into account previous mild or sub-concussive head injury (injuries of this kind were reported by 67% of the subjects in the study by Barth et al., 1989). Hinton-Bayre et al. (1997), acknowledge this weakness and suggest that, when the majority of players have had a previous head injury, it is arguable that a study cannot be interpreted as examining the effects of a single head injury. A further limitation are the fairly limited test batteries employed by these researchers which does not allow for testing across the entire range of cognitive functions that would typically be compromised in closed head injury.

In South Africa there has been one previous study into the effects of mild head injury in rugby. Shuttleworth-Jordan et al. (1993) conducted a study involving 60 university rugby players. The test battery included tests of hand-motor dexterity (Denckla Finger Tapping and Purdue Pegboard), short-term verbal memory (Digits Span Forwards), verbal new learning (Digits Supraspan Test) and working memory (Trail Making parts A & B and Digits Span Backwards). Pre-season testing enabled the researchers to establish baseline premorbid data for the subjects. The investigation involved two levels of analysis: (i) an analysis of pre- and post-season differences between non-concussed players (ie. players who did not sustain a concussion that season) and matched controls, and (ii) an analysis of test differences between rugby players with a reported mild head injury sustained during the season and matched controls at pre-season, five days, one month, two months and three months post season.

The pre-season comparison of non-concussed players and matched controls indicated the presence in the rugby playing group of a pattern of impairment typically associated with diffuse brain damage, including deficits in working memory, verbal new learning ability and hand motor dexterity. Since the authors particularly attempted to identify the presence of permanent brain damage effects following mild head injury, players with more than one reported concussion in the previous three years were excluded from the study. The authors argue that these results were thus likely to be an estimate of permanent deficits in a rugby playing group. The rugby playing group also showed less capacity than the controls for practice effects between pre- and post-season testing, also consistent with diffuse brain injury. It was argued that this phenomenon was likely to be the result of concussions sustained in previous rugby seasons, of unreported concussion during the season they were assessed, or of a combination of both. Further analysis revealed greater impairment among the forward players when compared to the backline players. The authors suggest that this was due to the nature of play in the scrum that is likely to expose these players in particular to the risk of cumulative mild head injury.

Further, with respect to this (1993) study, five of the 60 rugby players reported sustaining a mild head injury during the season. The prospective analysis of this concussed group, relative to controls, showed the presence of significant impairment to attention, verbal new learning, working memory and hand motor dexterity at three days post injury. Substantial recovery was indicated at one month, with further recovery indicated at two months, however at three months the concussed group was still not exhibiting a practice effect to the same degree as the controls on Digits Backward, Digit Difference, Digit Supraspan and Finger Tapping, suggesting that recovery was not yet complete. The pattern of deficit in working memory, verbal new learning ability and hand motor dexterity among the concussed group was highly comparable to the pattern of deficit recorded among the non-concussed group.

The above study shares certain methodological strengths with previous studies in the area such as the use of baseline premorbid data and the repeat testing of control groups to control for practice effects. In addition, by examining the recovery curve up to 3 months as well as by examining the effects of previous concussive or unreported sub-concussive head injury this study was able to overcome some of the limitations of previous studies. However, the number of concussed players available to assess was relatively small, and the test battery used, although chosen on the basis of tests sensitive to the presence of diffuse damage, remained fairly limited.

1.5.3 Section Summary

In summary, research (albeit not limited to mild head injury) supports the presence of cognitive deficit among boxers. In addition the relationship established by some researchers between the number of bouts and degree of impairment supports the concept of cognitive dysfunction consequent on cumulative mild head injury. Research on mild head injury in soccer indicates the presence of cognitive deficit among players, hypothetically due to the cumulative cerebral insult due to repeatedly "heading" the ball. Epidemiological research points to a high incidence of mild concussive head injury in the sport of rugby. Albeit limited to a few studies, research into the cognitive effects of mild head injury in rugby and American football has consistently identified patterns of deficit among players that are typically associated with diffuse brain damage. A recent South African study on rugby suggests that such deficits are likely to be permanent.

1.6 AIMS OF THIS RESEARCH

As noted above, studying the effect of a single mild head injury in a sport where by far the majority of players have experienced previous head injury is problematic (Hinton-Bayre et al., 1997). Moreover, the study by Shuttleworth-Jordan et al. (1993) highlights the dangers of unreported concussive and subconcussive, as well as prior head injury over the years, among the rugby playing population. In line with Shuttleworth-Jordan et al., (1993), the present study aimed to move away from focusing on the effects of single mild head injury and to conduct a study focusing on the cognitive sequelae of the likely history of cumulative mild concussive and sub-concussive head injury among professional rugby players. Also, as noted above, the test batteries used in previous research in this field have been rather limited. This project aimed to include in the test battery a wider range of tests than have been used in all previous research, covering a comprehensive spectrum of key cognitive modalities typically compromised in closed head injury. These modalities, as defined by Lezak (1995), included attention and concentration, memory/new learning, language fluency, visuoperceptual tracking and fine hand motor dexterity. Importantly, unlike in any previous study in this area, tests which typically do <u>not</u> show deficits associated with head injury were also included in the battery, to provide a measure of premorbid intelligence. The test results of the professional rugby playing participants were compared with established normative data. A matched non-contact sport sample of professional cricket players was also tested and their results compared with established normative data, thus providing additional level of comparative analysis. The comparison of the test performance, relative to the normative data, between the rugby forwards and the rugby back line players was also analysed. The rationale for this was that, because of the more physical nature of play in scrums and loose scrums, the forwards are likely to be at greater risk than backline players for multiple sub-concussive injury. It was hypothesised that:

1) Rugby players, compared to cricket players, would be more likely to show impairment relative to the norms on tests sensitive to the effects of mild diffuse head injury.

2) Rugby forward players, compared to rugby backline players, would be more likely to show impairment relative to the norms on tests sensitive to the effects of mild diffuse head injury.

3) Variability would increase, relative to the norms, with rugby players as commonly occurs in brain damaged groups.

CHAPTER TWO: METHODOLOGY

2.1. PARTICIPANTS

This study forms part of a larger and ongoing study into the effects of mild closed head injury in rugby being conducted by Rhodes University and the South African Rugby Football Union (SARFU) in collaboration with the South African Sports Science Institute in Cape Town. The participants for this study were drawn from professional rugby players and the sample included all designated professional rugby players selected to undergo a series of physical and psychological tests at the South African Sports Science Institute. The rationale for using professional rugby players is that the long duration of their playing careers, and the highly competitive nature of play at such an elite level, would be likely in particular to expose them to cumulative mild head injury.

A matched comparison group of professional non-contact sport players comprising professional cricket players was also assessed. This sample also included all designated professional cricket players selected to undergo physical and psychological tests at the Sports Science Institute. It was considered that non-contact sport players at the professional level would closely compare with the professional rugby players in terms of important demographic data such as premorbid level of functioning and level of education (arguably any individual capable of playing sport at a national level is likely to be particularly high functioning based on Lezak's (1995) assumption of transituational consistency of performance across functions). Factors such as premorbid level of functioning and level of education are known to effect performance on cognitive tests (Lezak, 1995) and a close match with respect to these variables would thus help minimise confounding variables in the analysis of the data. A comparison of mean years of education and mean pro-rated IQ scores between the rugby and cricket playing groups revealed no significant differences ($p = 0,24$ & $p = 0,57$ respectively). Similarly a comparison of mean years of education and mean pro-rated IQ scores between the rugby forward and backline groups also revealed no significant differences ($p = 0,17$ & $p = 0,33$ respectively).

In order to control for other variables that can negatively influence cognitive performance it was decided to exclude any players with a reported history of substance abuse, players with any neurological disorder known to detrimentally influence cognitive functioning, as well as players with any reported previous head injury of greater severity than mild. As noted in the introduction to this study, the classification of mild head injury is controversial. Broadly it is understood to refer to head injury in which loss of consciousness is relatively brief and there is no accompanying structural pathology of the skull. Specifically, for the purposes of this study, mild head injury is defined as per Evans's (1992) recommendation that a duration of loss of consciousness of 30 minutes or less without further neurological complication are reasonable defining criteria for mild head injury.

Nearly all the rugby and cricket players included in this study reported at least one mild head injury at some point in their history. Previous mild head injury was not used as an exclusion criterea for the cricket group as the high incidence of such injury would have effectively excluded them as a comparison group. However, the focus of this study was to explore the effects of underlying cumulative head injury anticipated among the rugby players and not isolated mild head injury in an individual's history. None of the rugby or cricket players interviewed reported a head injury of greater severity than mild, nor did any player meet any of the other exclusionary criteria. The final sample included 26 rugby players and 21 cricket players. For demographic data of participants, see following table.

Table 1. Demographic Data of Participants

Group	No. of Subjects	Age	Years of Education	Estimated Premorbid IQ
Rugby	26	27.5	14.2	119.2
Cricket	21	27.1	13.7	121.1
Forward	15	27.2	13.9	117.2
Backline	11	27.8	14.6	121.9

2.2 PROCEDURE

Testing of the rugby players took place at the Sports Science Institute between the 2nd and the 5th of February 1997 during their pre-season medical and psychological evaluation. The cricket players were tested between 14th and 16th of April 1997 during their post-season medical and psychological evaluation. Under ideally matched conditions it would have been preferable to also test the cricket players during their pre-season evaluation, as with the rugby players, in order to eliminate possible differences in factors such as levels of fatigue and motivation between pre- and post-season. However, access to professional players is difficult to obtain and the researchers were restricted to assessment times determined by the sports organisations. As was the case in this situation, the cricketers lost their season and fatigue and lack of motivation was apparent among the team members, possibly compromising their test performances. While testing under these conditions might have obscured the extent of fall off of the rugby relative to the cricket players, it minimises the possibility of inflating differences in test performance between the rugby and cricket players, hence providing a more stringent test with respect to finding deficit among the rugby players.

The core research team consisted of a research co-ordinator and three researchers. Time constraints allowed for only three days to assess the group of rugby players and two days to assess the cricket players. As a result of this, one research assistant was employed to assist in assessing the rugby players and three research assistants were employed to assist in assessing the cricket players. All researchers and research assistants were psychology graduates trained and experienced in the administration of the psychometric tests. The researchers met with the research assistants before the testing to school them in the interview technique as well as in the administration of the test protocols. Standardised written instructions from the original test manual and/or Lezak (1995) were attached to the test material in order further to ensure uniform administration of the tests by the different testers. In order to ensure a valid assessment it is important to maximise the participant's performance and this includes testing individuals in an environment free from distractions (Lezak 1995). The participants were all tested individually in private, quiet offices and two hours were set aside for each participant. Although most players were fully bilingual, players were given the option on verbal tests of being tested in Afrikaans if they felt this would better reflect their capability. Anxiety is known to have a negative influence on cognitive test performance (Lezak 1995). In order to help alleviate any anxiety subjects may have been experiencing, the nature and purpose of the procedure was explained to each participant and the opportunity was given to ask questions, before the actual assessment began. The participant was then required to sign a written consent form (see appendix I).

2.3. QUESTIONNAIRES

The assessment included the administration of demographic questionnaires designed to provide information on educational and occupational history, sport playing history, previous head injuries as well as other exclusion type criteria such as substance abuse (see appendix II). A symptom checklist to assess the frequency of any residual post-concussive symptomology suffered by the individual players was also administered. However, as this checklist did not form part of the data base for this particular aspect of the study it is not included in the appendix.

2.4. NEUROPSYCHOLOGICAL TEST BATTERY

Neuropsychological testing is the most sensitive instrument available for detecting the presence of subtle neurological abnormalities (Casson et al., 1982; McLatchie et al., 1987), however it is essential that measures chosen for research into mild head injury be sensitive to the presence of the kind of cognitive deficit known to occur in mild head injury (Bohnen & Jolles, 1992). The neuropsychological test battery employed was designed to include tests particularly sensitive to the effects of diffuse damage associated with mild head injury as well as to test current functioning across a comprehensive spectrum of key cognitive modalities, typically compromised in closed head injury, including: attention and concentration, memory/new learning, language fluency, visuoperceptual tracking and fine hand motor dexterity. The battery included the following tests, administered in the following order: South African Wechsler Adult Intelligence Scale (SAWAIS) Digit Symbol Substitution Test; Digit Symbol Substitution Test Incidental Recall; Trail Making Test parts A & B; Words-in-One-Minute Unstructured Verbal Fluency Test; "S" Words Fluency Test; Sequential Finger Tapping Test; SAWAIS Digit Symbol Substitution Test Delayed Recall; Wechsler Memory

Scale (WMS) Memory for Designs subtest; SAWAIS Picture Completion Subtest; SAWAIS Comprehension Subtest; WMS Memory for Designs Delayed Recall; WMS Paired Associate Learning subtest; SAWAIS Digit Span Subtest; Digit Supraspan; Sequential Finger Tapping -repeat trial; WMS Paired Associate Learning Delayed Recall. These are tests in regular use in neuropsychological assessment (Lezak, 1995; Spreen & Straus, 1991). A full test battery is included in appendix III.

2.4.1 Tests of General Intellectual Functioning

As noted in Chapter one of this report, many studies on mild head injury have failed to take into account the premorbid level of cognitive functioning of the subjects involved. Estimates of levels of premorbid cognitive functioning is important in research of this kind because: 1) It helps to estimate more accurately any level of deficit among individual players. 2) It is also an important variable in the ability to adjust to cognitive deficit following brain injury, and research has found a consistent relationship between premorbid ability and the level of impairment suffered (Lezak, 1995).

In order to enable the researchers to estimate a premorbid level of intellectual functioning, tests of general intellectual functioning drawn from the SAWAIS were administered. Lezak (1995) condones the use of a single raised subtest score in isolation as an adequate estimate of premorbid IQ (best performance method), but suggests that the use of a cluster is more preferable. Two subtests were administered (Comprehension and Picture Completion) and, in all instances of normal scores (8,5+), a pro-rated IQ was then calculated. This method was employed for all participants except for participant no. 22 (see appendix IV) where a defective score of 6,5 on Picture Completion was recorded which contradicted his performance across other tests as well as his relatively high educational level of 22 years, years of education being a variable which usually correlates well with IQ. Hence, for this participant the score obtained on Comprehension only was used to estimate the premorbid IQ. A full list of estimated pre-morbid IQ's as well as educational levels of the participants is included in appendix IV. As noted earlier, based on these individual calculations, there was no significant difference for estimated IQ between the rugby and cricket players or between the rugby backline and forward players.

Comprehension

This test consists of 10 questions of common sense judgement and practical reasoning. Instructions were taken from the SAWAIS Manual (1969). Participants were instructed that there were no fixed answers to the questions and to say what they thought in each case. Brief answers requiring amplification were questioned further. Comprehension is a test of verbal reasoning, a function that holds up well in the presence of diffuse damage and, in cases of diffuse damage, it is likely to be one of the best indicators of premorbid ability (Lezak, 1995).

Picture Completion

This test consists of 15 drawings, each of which has a key part missing. Instructions were taken from the SAWAIS Manual (1969), the cards were presented in numerical order and the participant was asked to name the missing part. The time limit is 20 seconds per picture. Picture completion is primarily a test of visual reasoning but involves both visuoperceptual and verbal abilities. It tends to be relatively unaffected in the presence of diffuse damage and is also a very good indicator of premorbid ability (Lezak, 1995).

2.4.2 Tests of Verbal Memory

Digit Span

The version from the SAWAIS manual (1969) was used. As a test of verbal memory, the digits forwards and digits backwards were reported and analysed as separate tests as they involve different mental processes and are effected differently by brain damage (Lezak, 1995).

Digits Forwards

Although Digits Forwards does test immediate verbal memory it is primarily a test of efficiency of attention or "freedom from distraction" (Lezak, 1995). Because it is not as sensitive as digits backwards to the effects of diffuse damage, it would be expected to maintain relative to the backwards span in the presence of diffuse damage. The participants were asked to repeat, in the correct order, a sequence of numbers after the researcher had finished reading them. Each trial consisted of a pair of sequences consisting of the same amount of numbers. If a participant was able to repeat one sequence of a trial, the researcher continued with the next trial which consisted of an extra number. The test was discontinued after two sequences of a trial were failed. The score is the longest sequence of numbers correctly repeated.

Digits Supraspan

Digits Supraspan is a test of verbal new learning ability and as an extended version of the Digits Forwards Test, it is more sensitive to memory function (Shuttleworth-Jordan, 1992). The method of McFie (1975) was used, after a participant failed two consecutive sequences of the same length, the researcher repeated the last failed sequence until the participant recalled it correctly. The score is the number of trials the subject takes to learn the sequence correctly.

Digits Supraspan Sustained Learning

This test requires the participant to repeat the supraspan twice consecutively as this more sensitively taps the number of trials taken for real learning to take place (Shuttleworth-Jordan, 1992). As no established normative data exist for this test, it was excluded from the final data analysis for this particular study.

Digits Backwards

This test involves storing data while manipulating it mentally and it taps working memory function (Lezak, 1995). It is particularly sensitive to diffuse damage as might be expected in closed head injury. The instructions differ from digits forwards in that the participant is instructed to repeat in the reverse order, the sequence of numbers which the researcher reads out.

WMS Paired Associate Learning

The version used was taken from Form 1 of the WMS manual (Weschler, 1945). The test consists of a series of 10 paired words, divided into 5 easy pairs and 5 hard pairs. The easy pairs consist of words normally associated with one another, the hard pairs consist of words not normally associated with one another and are therefore more difficult to learn. The researcher read out the sequence of pairs, then read out only the first word in each pair and the participant was instructed to recall the associated word. The test consists of three presentations. For Afrikaans participants, an Afrikaans translation (Burbach, 1987) was used. The participant's ability to remember the easy pairs relies primarily on old associate learning whereas the hard pairs rely more on new learning ability (Lezak, 1995), the hard pairs are thus much more susceptible to the effects of brain damage. Reporting the tests as a single score loses this distinction and for this reason the easy and hard pairs were reported and analysed separately.

WMS Paired Associate Learning Delayed Recall

Where appropriate, 20 minute delayed versions of the memory tests were administered, delayed memory being typically more sensitive to the effects of diffuse brain damage (Lezak, 1995). In the delayed version of this test only the first word of the pairs is read out and the subject is instructed to try and recall the associated word as per the list read earlier. Stuss et al. (1985) found that slight, but fairly consistent, lower scores on the delayed version of the WMS version distinguished patients who had apparently recovered from mild head injury from normal control subjects.

2.4.3 Tests of Visual Memory

Digit Symbol Incidental Recall

The short form method of the incidental recall test (Shuttleworth-Jordan & Bode, 1995) was used. This is a test which taps recent memory function and has been shown to be sensitive to the effects of diffuse brain pathology. The procedure involved noting which square the participant filled in on the Digit Symbol test at 90 seconds but allowing the subject to continue to the end of the second last row. The subject was then given a sheet marked with the numbers and was instructed to fill in as many of the matching symbols as could be recalled.

Digit Symbol Delayed Recall

A delayed recall version of the incidental recall test (Lezak, 1995) was administered. The participants were asked to fill in as many matching symbols as they could after a 20 minute delay. As no established normative data exist for this test, it was excluded from the final data analysis for this particular study.

WMS Visual Reproduction of Designs

The Form 1 version from the WMS manual (Weschler, 1945) was used. This test is sensitive to the effects of head trauma (Lezak, 1995) and Stuss et al. (1985) have shown it to significantly differentiate a group of patients with mild head trauma from uninjured controls. The test consists of three cards. Card I and II consisting of one design each and Card III of two designs. The participants were shown each card separately for 10 seconds and then instructed to draw the design from memory.

WMS Visual Reproduction of Designs Delayed Recall

A delayed version of the test was administered, where the participants were asked to draw the designs after 20 minutes without being shown the designs again.

2.4.4 Tests of Verbal Fluency

Words-In-One-Minute (Terman & Merrin 1973)

This is an unstructured test of verbal fluency. Instructions for this test were derived from a description of the test by Lezak (1995). The participants were instructed by the researcher to say as many words as they could think of as fast as they could. They were cautioned against using proper nouns, using the same words while changing only the suffix, as well as not to count or to construct sentences. The instructions were repeated until they were clearly understood. The participants were stopped after one minute.

S-Words-In-One-Minute

Instructions were as per the above test except that the participants were instructed to use only words beginning with an S.

2.4.5 Tests of Visuoperceptual Tracking

SAWAIS Digit Symbol

The SAWAIS version consists of three rows consisting of 67 digits and a key consisting of 9 symbols. Instructions were as per the SAWAIS Manual (1969). The participants were instructed to draw symbols in the spaces beneath the digits according to the key at the top of the page. The examiner first demonstrated the procedure by completing a sample section consisting of 8 blocks. The participants weres then asked to draw in the symbols associated with the digit in the order presented, without leaving any out and to work as quickly as possible. Any participant that paused to correct an error was told to move on to the next symbol. The number of blocks the subject completed in 90 seconds was noted. The digit symbol test is a test of complex visuoperceptual tracking. It is a test which is consistently sensitive to brain damage and it's score is likely to be depressed even when damage is minimal (Lezak, 1995; Russell, 1984). It is particularly useful in picking up the diffuse damage that would be expected in closed head injury such as would be sustained by players of contact sport.

Trail Making Test (Reitan, 1956)

The Trail Making Test is another test that is particularly sensitive to the effects of brain injury (Lezak, 1995). It consists of two parts, A and B.

Part A - The test consists of a series of numbers within circles on a sheet of paper. Participants were instructed to join the numbers in the correct sequence without lifting their pencils from the page. The participants first completed a mini practice trial before proceeding onto the test. If the subjects made a mistake, it was immediately pointed out to them and they were required to correct it immediately. The score is the time taken to complete the trial.

Part B - The test is similar in format and administration to trail A, except that the participants are required to join alternating numbers and letters in the correct sequence. Part B involves complex visuoperceptual tracking, the ability to shift a response set and it also taps working memory function, as a result scores on part B are likely to be more markedly lowered than those on Part A in the presence of diffuse brain damage.

2.4.6 Tests of Hand-Motor Dexterity

Finger Tapping Test (Denckla, 1973)

The participants were instructed to place both elbows on the table (the researcher demonstrated what was required) and to touch each finger to the thumb, starting with the index finger, as fast as they could. The score is the time a participant takes to do five sets of the above. As it is a timed test, bilateral slowing on this test would indicate diffuse brain damage. Two trials of this test were administered in order to elicit the participants best performance.

2.5 DATA PROCESSING

To ensure maximum uniformity in marking, the test protocols were marked by the three researchers only and not by any of the four research assistants. The individual researchers met to ensure a uniform standard of marking was applied to all tests. The data was then broken up for analysis to form the following three separate research projects:

1) A direct comparison of group scores of the rugby versus the cricket players across all tests administered.

2) A comparison of the cognitive profiles of the rugby versus the cricket players with available normative data.

3) A comparison of the proportion of cognitive deficit present in the rugby versus the cricket playing groups in each functional modality, as well as a comparison of the frequency of cognitive deficit and post-concussive symptomology.

The focus of the present project was the second level of analysis: A comparison of the cognitive profiles of the rugby vs the cricket players with available normative data. There is an existing published normative data base for all of the tests included in the data analysis for this particular study. In the case of each test, the most appropriate normative data available were used. Normative data were taken from Shuttleworth-Jordan (1995) for all the tests with the exception of the "S" Words Fluency Test where norms were taken from Yeudal (1986). The normative data for the majority of the tests (Shuttleworth-Jordan, 1995) were acquired by assessing 18-25 year old male university students, a group that closely matches both the rugby playing and cricket playing groups in terms of important variables such as age, as well as a relatively high level of education and intellectual functioning.

The purpose of this study was to conduct a comparison of the rugby players results with the appropriate normative data and to run a similar comparative analysis of the cricket players results with the normative data. Since the direct comparison of raw scores between the rugby and cricket players formed the basis of another study, the present study constituted an alternative way of analysing the data, providing a further way of comparing the rugby and cricket player's cognitive functioning. An additional comparison within the rugby playing group ie. a comparison of the forwards and backline players with the normative data was also carried out. It was hypothesised that the forwards, because of the nature of play in scrums and loose scrums, ran a greater risk of sustaining repeated concussive and sub-concussive head injury than the backline players. In addition, as both the cricket and rugby groups were found to be high functioning, this research aimed to provide information on whether existing normative data, albeit derived from an elitist university population, are adequate when applied to such exceptional groups.

2.5.1 STATISTICAL PROCEDURE

For each test the means and standard deviations were calculated, for each of the rugby, cricket, rugby forward and rugby backline groups. The means of the rugby and cricket players and the means of the rugby forward and backline players were then each compared with the means of the normative data using independent two sample t-tests. In order to compare variability the standard deviations of each group were compared with the normative standard deviations by means of a test of the homogeneity of paired variances. Both the statistical test procedures assume normality of distribution of variables. Comparative neuropsychological testing is based on the assumption that tests of intellectual function assume a normal distribution (Lezak, 1983). Raw scores for three of the tests used in the present study (Digit Symbol Substitution; Digit Symbol Incidental Recall and the Trail Making test) were subjected to the Kolmogorov-Smirnov procedure in Jordan's (1997) research, with results indicating that the assumption of normality of distribution for those neuropsychological tests was valid. Thus, as in Jordan's research, it was considered legitimate to assume normality of distribution for the standard tests of intellectual function used in the present research.

CHAPTER THREE: RESULTS

3.1 INTRODUCTION

The comparative data between the participants and the available norms, including mean scores, standard deviations, t-statistics, F-statistics and significant differences (p values) will be presented separately for cricket, rugby, rugby forward and rugby backline groups.

3.2 COMPARISON OF CRICKET PLAYERS RESULTS WITH NORMATIVE DATA

3.2.1 Comparison of Means.

In comparison with the normative data, the cricket players showed significantly poorer performance on tests of Words-in-One-Minute ($p < 0,01$), Visual Reproduction Immediate Recall ($p < 0,01$), and on Finger Tapping preferred hand - 1st trial ($p < 0,05$). The cricket players showed a significantly better performance on Paired Associates (easy and hard pairs) Delayed Recall ($p < 0,01$). See Table 2 (p.42).

3.2.2 Comparison of Variability.

In comparison with the normative data, the cricket players showed significantly increased variability on the tests of Digits Forwards ($p < 0,05$), Digits Supraspan ($p < 0,05$) and WMS Paired Associates (easy pairs) Immediate Recall ($p < 0,01$). The cricket players showed significantly decreased variability, in comparison with the normative data on Words-in-One Minute ($p < 0,01$), Paired Associates (easy and hard pairs) Delayed Recall, Visual Reproduction Delayed Recall ($p < 0,05$), and on the Trail Making Test part B ($p < 0,05$). The cricket players also revealed significantly decreased variability, in comparison with the normative data across all trials of the Finger Tapping test. See Table 2 (p.42).

Table 2: Cricket Players versus Norms: Comparison of Means (t-statistic) and Standard Deviations (F-statistic) for Neuropsychological test performance

Test	Norms n	Norms Mean	Norms SD	Results n	Results Mean	Results SD	t-Statistic	F-Statistic
Digits Forward	61	7.67	1.00	21	7.33	1.35	1.22	0.55 *
Digits Backward	61	6.19	1.26	21	5.95	1.50	0.72	0.71
Digit Supraspan	57	2.37	1.59	21	2.76	2.21	-0.86	0.52 *
WMS Pairs (easy) - Immed	63	8.69	0.45	21	8.50	0.82	1.34	0.30 **
WMS Pairs (hard) - Immed	63	8.57	2.91	21	8.36	3.13	0.28	0.86
WMS Pairs (easy) - Delay	54	3.65	2.90	21	5.95	0.21	-3.62 **	173.76 **
WMS Pairs (hard) - Delay	54	2.30	2.70	21	3.42	0.81	-2.93 **	4.40 **
Visual Reproduction - Immed	60	12.39	1.54	21	11.29	1.65	2.77 **	0.87
Visual Reproduction - Delay	58	11.54	2.04	21	10.95	1.43	1.22	2.04 *
Digit Symbol Substitution	30	53.28	9.46	21	50.44	6.90	1.19	1.88
Digit Symbol Incidental Recall	28	7.32	1.68	21	6.86	1.71	0.94	0.97
Trail Making A	49	26.13	8.57	21	25.76	6.14	0.18	1.95
Trail Making B	48	54.89	17.39	21	53.95	11.00	0.23	2.50 *
Words-in-One-Minute	49	51.65	14.21	21	39.48	7.14	3.72 **	3.96 **
S-Words-in-One-Minute	73	16.94	5.05	21	17.10	5.10	-0.13	0.98
Finger Tapping 1 preferred	57	5.32	1.22	21	5.86	0.77	-1.89 *	2.51 *
Finger Tapping 1 non.preferred	57	5.48	1.12	21	5.75	0.68	-1.04	2.79 **
Finger Tapping 2 preferred	57	5.32	1.22	21	5.25	0.58	0.25	4.42 **
Finger Tapping 2 non.preferred	57	5.48	1.12	21	5.20	0.60	1.09	3.48 **

Significant Difference (* p < 0,05; ** p < 0,01)

Table 3: Rugby Players versus Norms: Comparison of Means (t-statistic) and Standard Deviations (F-statistic) for Neuropsychological test performance

Test	Norms n	Norms Mean	Norms SD	Results n	Results Mean	Results SD	t-Statistic	F-Statistic
Digits Forward	61	7.67	1.00	26	7.42	0.99	1.07	1.02
Digits Backward	61	6.19	1.26	26	6.15	1.38	0.13	0.83
Digit Supraspan	57	2.37	1.59	26	2.30	1.32	1.45	0.17
WMS Pairs (easy) - Immed	63	8.69	0.45	26	8.81	0.43	-1.16	1.10
WMS Pairs (hard) - Immed	63	8.57	2.91	26	8.08	2.80	0.73	1.07
WMS Pairs (easy) - Delay	54	3.65	2.90	26	5.92	0.27	-3.97 **	115.36 **
WMS Pairs (hard) - Delay	54	2.30	2.70	26	3.26	1.07	-2.69 **	2.48 **
Visual Reproduction - Immed	60	12.39	1.54	26	11.96	1.40	1.22	1.21
Visual Reproduction - Delay	58	11.54	2.04	26	11.30	1.89	0.49	1.17
Digit Symbol Substitution	30	53.28	9.46	26	52.60	9.06	0.27	1.09
Digit Symbol Incidental Recall	28	7.32	1.68	26	6.73	2.35	1.07	0.51 *
Trail Making A	49	26.13	8.57	26	27.66	9.12	-0.72	0.88
Trail Making B	48	54.89	17.39	26	58.03	18.60	-0.86	0.87
Words-in-One-Minute	49	51.65	14.21	26	38.92	7.78	4.23 **	3.34 **
S-Words-in-One-Minute	73	16.94	5.05	26	17.50	4.58	-0.50	1.22
Finger Tapping 1 preferred	57	5.32	1.22	26	5.14	0.95	0.67	1.65
Finger Tapping 1 non.preferred	57	5.48	1.12	26	4.90	0.85	2.31 *	1.74
Finger Tapping 2 preferred	57	5.32	1.22	26	4.73	0.71	2.29 *	2.95 **
Finger Tapping 2 non.preferred	57	5.48	1.12	26	4.70	0.85	3.16 **	1.74

Significant Difference (* p < 0,05; ** p < 0,01)

3.3 COMPARISON OF RUGBY PLAYERS RESULTS WITH NORMATIVE DATA

3.3.1 Comparison of Means.

In comparison with normative data, the rugby players showed a significantly poorer performance on the test of Words-in-One-Minute ($p<0,01$). The rugby players showed significantly better performances, in comparison with the normative data, on Paired Associates (easy and hard pairs) Delayed Recall, on Finger Tapping preferred hand - 2nd trial ($p<0,05$) as well as on Finger Tapping non-preferred Hand - 1st trial ($p<0,05$) and 2nd trial ($p<0,01$). See Table 3 (p.42).

3.3.2 Comparison of Variability

In comparison with the normative data, the rugby players showed significantly increased variability on the test of Digit Symbol Incidental Recall ($p<0,05$). The rugby players recorded significantly decreased variability, in comparison with the normative data, on Words-in-One-Minute ($p<0,01$), on Paired Associates (easy and hard pairs) Delayed Recall ($p<0,01$) and on Finger Tapping preferred hand - 2nd trial ($p<0,01$). See Table 3 (p.42).

3.4 COMPARISON OF BACKLINE PLAYERS RESULTS WITH NORMATIVE DATA

3.4.1 Comparison of Means.

In comparison with the normative data, the backline players recorded a significantly poorer performance on the test of Words-in-One-Minute ($p<0,05$). The backline players recorded significantly better performances, in comparison with the normative data, on the tests of Paired Associates (easy pairs) Delayed Recall ($p<0,01$), Digits Backwards ($p<0,05$), Digit

Symbol Substitution ($p<0,05$) as well as on Finger Tapping, preferred hand -2nd trial ($p<0,05$) and Finger Tapping, non-preferred hand - both trials ($p<0,01$). See Table 4 (p.45).

3.4.2 Comparison of Variability

In comparison with the normative data, the backline players, recorded significantly decreased variability, on the tests of Paired Associates (easy pairs) Immediate and Delayed Recall ($p<0,01$), on Words-in-One-Minute ($p<0,01$) and on Finger Tapping preferred hand - 2nd trail ($p<0,05$). See Table 4 (p.45).

3.5 COMPARISON OF FORWARD PLAYERS RESULTS WITH NORMATIVE DATA

3.5.1 Comparison of Means

In comparison with the normative data, the forward players recorded a significantly poorer performance ($p<0,05$) on the tests of Digits Backwards, Digit Symbol Substitution, Digit Symbol Incidental Recall and part A of the Trail Making test. The forward players recorded a highly significantly poorer performance ($p<0,01$), in comparison with the normative data, on part B of the Trail Making test, and on Words-in-One-Minute. The forward players recorded significantly better performances on Paired Associates (easy pairs) Delayed Recall ($p<0,01$) and Paired Associates (hard Pairs) Delayed Recall ($p<0,01$). See Table 5 (p.46).

3.5.2 Comparison of Variability

In comparison with the normative data, the forward players recorded significantly decreased variability, on the test of Words-in-One-Minute ($p<0,01$), on Paired Associates

Table 4: Backline Players versus Norms: Comparison of Means (t-statistic) and Standard Deviations (F-statistic) for Neuropsychological test performance

Test	Norms n	Norms Mean	Norms SD	Results n	Results Mean	Results SD	t-Statistic	F-Statistic
Digits Forward	61	7.67	1.00	11	7.45	0.93	0.68	1.16
Digits Backward	61	6.19	1.26	11	7.09	1.04	-2.23 *	1.47
Digit Supraspan	57	2.37	1.59	11	2.36	1.56	0.02	1.03
WMS Pairs (easy) - Immed	63	8.69	0.45	11	8.91	0.20	-1.59	5.06 **
WMS Pairs (hard) - Immed	63	8.57	2.91	11	8.36	2.80	0.22	1.07
WMS Pairs (easy) - Delay	54	3.65	2.90	11	5.90	0.30	-2.57 **	93.44 **
WMS Pairs (hard) - Delay	54	2.30	2.70	11	3.18	1.07	-1.65	2.48
Visual Reproduction - Immed	60	12.39	1.54	11	12.27	1.49	1.52	1.34
Visual Reproduction - Delay	58	11.54	2.04	11	11.00	2.14	0.80	0.91
Digit Symbol Substitution	30	53.28	9.46	11	58.91	6.56	-1.81 *	2.08
Digit Symbol Incidental Recall	28	7.32	1.68	11	7.72	2.10	-0.64	0.64
Trail Making A	49	26.13	8.57	11	23.54	7.50	0.92	1.31
Trail Making B	48	54.89	17.39	11	46.66	14.19	1.46	1.50
Words-in-One-Minute	49	51.65	14.21	11	41.55	5.92	2.30 *	5.76 **
S-Words-in-One-Minute	73	16.94	5.05	11	18.64	4.15	-1.06	1.48
Finger Tapping 1 preferred	57	5.32	1.22	11	4.79	1.12	1.34	1.19
Finger Tapping 1 non.preferred	57	5.48	1.12	11	4.41	0.84	3.01 **	1.82
Finger Tapping 2 preferred	57	5.32	1.22	11	4.45	0.72	2.28 *	2.87 *
Finger Tapping 2 non.preferred	57	5.48	1.12	11	4.30	0.87	3.27 **	1.66

Significant Difference (* p < 0,05; ** p < 0,01)

Table 5: Forwards versus Norms: Comparison of Means (t-statistic) and Standard Deviations (F-statistic) for Neuropsychological test performance

Test	Norms n	Norms Mean	Norms SD	Results n	Results Mean	Results SD	t-Statistic	F-Statistic
Digits Forward	61	7.67	1.00	15	7.40	1.05	0.93	0.91
Digits Backward	61	6.19	1.26	15	5.40	1.19	2.00 *	1.12
Digit Supraspan	57	2.37	1.59	15	2.67	1.62	0.23	1.88
WMS Pairs (easy) - Immed	63	8.69	0.45	15	8.73	0.53	-0.30	0.72
WMS Pairs (hard) - Immed	63	8.57	2.91	15	7.87	2.88	0.84	1.02
WMS Pairs (easy) - Delay	54	3.65	2.90	15	5.93	0.25	-3.03 **	124.41 **
WMS Pairs (hard) - Delay	54	2.30	2.70	15	3.33	1.11	-2.23 *	2.30 *
Visual Reproduction - Immed	60	12.39	1.54	15	11.73	1.33	0.24	1.07
Visual Reproduction - Delay	58	11.54	2.04	15	11.53	1.73	0.02	1.39
Digit Symbol Substitution	30	53.28	9.46	15	47.97	7.86	1.87 *	1.45
Digit Symbol Incidental Recall	28	7.32	1.68	15	6.00	2.30	2.15 *	0.53
Trail Making A	49	26.13	8.57	15	30.69	9.24	-1.77 *	0.86
Trail Making B	48	54.89	17.39	15	67.42	16.69	-2.46 **	1.09
Words-in-One-Minute	49	51.65	14.21	15	37.00	8.58	3.78 **	2.74 **
S-Words-in-One-Minute	73	16.94	5.05	15	16.67	4.84	0.19	1.09
Finger Tapping 1 preferred	57	5.32	1.22	15	5.40	0.74	-0.27	2.72 *
Finger Tapping 1 non.preferred	57	5.48	1.12	15	5.30	0.65	0.59	2.97 *
Finger Tapping 2 preferred	57	5.32	1.22	15	4.94	0.65	1.16	3.52 **
Finger Tapping 2 non.preferred	57	5.48	1.12	15	4.99	0.73	3.27	1.66 *

Significant Difference (* p < 0,05; ** p < 0,01) (easy Pairs) Delayed Recall ($p<0,01$) and Paired Associates (hard pairs) Delayed Recall ($p<0,01$), as well as on both trials of Finger Tapping preferred hand ($p<0,05$ & $p<0,01$), and on both trials of Finger Tapping non-preferred hand ($p<0,05$). See Table 5 (p. 45)

CHAPTER FOUR: DISCUSSION

4.1 INTRODUCTION

The present research was concerned with investigating the effect on cognitive performance of cumulative concussive and sub-concussive head injury among professional rugby players. It was hypothesised that rugby players would show greater impairment relative to the norms than cricket players and that rugby forward players would show greater impairment relative to the norms than rugby backline players. These hypotheses were posed on the basis that rugby players are likely to have more exposure to multiple concussive and sub-concussive head injury than cricket players, and that rugby forward players, because of the nature of play in scrums and loose scrums, are likely to have more exposure to such injuries than backline players. It was also hypothesised that variability would increase relative to the norms among the rugby players as commonly occurs in brain damaged groups. Generally, the outcome of this research indicated that neither the cricket nor rugby playing groups show a pattern of significant difference, relative to the norms, on tests known to be sensitive to the effects of mild head injury. However, an interpretation of variability does suggest differences between the two groups relative to the norms, as does the comparison of the backline and forward players results relative to the norms. These results and their implications will be discussed in more detail below. The comparison of rugby and cricket players relative to the norms will be discussed in paragraph 4.2, and the comparison of forward and backline players relative to the norms will be discussed in paragraph 4.3. The implications of these research findings will then be discussed and conclusions drawn.

4.2 CRICKET VS RUGBY PLAYERS IN COMPARISON WITH NORMATIVE DATA (SIGNIFICANT RESULTS)

With regard to mean scores, the only instances of significant difference relative to the norms were recorded on four tests (Words-in-One-Minute, Paired Associates (easy and hard pairs) Delayed Recall, Finger Tapping and Visual Reproduction Immediate Recall). A difference from the norms was evident for both the rugby and cricket playing groups on Words-in-One-Minute, Paired Associates and Finger Tapping while the cricket group only recorded a significant difference on Visual Reproduction Immediate Recall. In terms of variability, significant differences among the cricketers, in comparison with normative data, were recorded on tests of: Digits Forwards; Digits Supraspan; Paired Associates (easy pairs) Immediate Recall; Paired Associates (easy and hard pairs) Delayed Recall; Visual Reproduction Delayed Recall, Trail Making part B; Words-in-One-Minute; Finger Tapping. In terms of variability, the rugby players recorded significant differences in comparison with the normative data on: Digit Symbol Incidental Recall; Words-in-One-Minute; Paired Associates (easy and hard pairs) Delayed Recall; one trial of Finger Tapping preferred hand. Tests on which significant differences were recorded will be discussed separately, with differences in mean scores addressed first followed by differences in variability.

4.2.1 Words-in-One-Minute

Lower performances relative to the norms in both the rugby and cricket playing groups were recorded on the Words-in-One-Minute test at a highly significant 1% level. Although word finding difficulties can be a consequence of mild closed head injury (Lezak, 1995) it is unlikely, in the case of mild head injury, that highly significant verbal fluency problems would manifest in the absence of more classic diffuse symptomology such as working memory difficulties and slowed information processing abilities. These impairments would manifest primarily in lowered scores on the Digits Backwards, the Digits Symbol Substitution and the Trail Making tests. However, the scores on these latter tests do not differ significantly from the norm for either the rugby or cricket playing groups. This suggests that the poor performance for both groups on the Words-in-One-Minute test is not as a result of head injury and is possibly linked to the administration of the test itself. Retrospectively it emerged that the written instructions for the rugby research protocols for this test differed from the original protocol employed in the normative research. The instructions for the normative research were taken from Hemp's (1989) description of the test used in her head injury research on children and included examples of everyday words to be read to the testee prior to the test, whereas instructions used in the rugby research were derived from Lezak's (1983) description of the test and did not include the examples of everyday words to be read to the testee prior to the test. It appears that this had a differential effect on the results obtained between these two different administration procedures in that the word examples in the Hemp protocol were likely to have had a facilitating effect on the production of words. The important point, however, is that there was no marked difference between the cricket and rugby team's performance on this test.

4.2.2 Paired Associates Delayed Recall

Better performance relative to the norms in both the rugby and cricket playing groups were recorded on Paired Associates (easy and hard pairs) Delayed Recall at the highly significant 1% level. A highly significant improvement on the delayed recall trials in the absence of any significant improvement on the more easy immediate trials, as was the case with both the rugby and cricket playing groups, is unusual. As with the Words-in-One Minute test, the highly significant global differences among both the rugby and cricket playing groups relative to the norms appear to be the result of differential administrative procedures between the normative research and the present research. Delayed recall trials are susceptible to interference effects (Lezak, 1995) and the order of presentation of tests in the present research was not modeled on the order of presentation for the normative data (a different battery was employed). It appears that differing interference effects had a differential effect on the results obtained on this test between the normative and the present research. Again, as with the Words-in-One Minute test, the important point is that there was no marked difference between the cricket and rugby teams' performance on this test.

4.2.3 Finger Tapping Tests

The other cognitive modality in which both the rugby and cricket players displayed significant mean differences relative to the norms was for hand-motor dexterity. The cricket players recorded a poor performance relative to the norms on Finger Tapping preferred hand (1st trial) but over the 4 trials no clear pattern of deficit in hand-motor dexterity emerged. The rugby players on the other hand displayed a pattern of significantly better hand-motor dexterity than the norms. A similar pattern of superior performance among rugby players on the Finger Tapping test was noted in the research by Shuttleworth-Jordan et. al. (1993), who argued that the nature of play in rugby, through manipulating and handling the ball, requires the development of superior hand-motor dexterity among rugby players. Handling of the ball at an elite playing level would require highly developed skills and these present results provide support for the hypothesis of Shuttleworth-Jordan et. al. that superior hand motor dexterity among rugby players is related to the nature of the game.

An analysis of the variability on the Finger Tapping test shows a pattern of significantly decreased variability, for the cricket players, relative to the normative data. This pattern was not observed for the rugby players who showed decreased variability on only one of the

Finger Tapping tests. This implies that, relative to each other, the rugby players are showing overall greater variability than the cricketers on this test. This implies in turn that, whilst as a group the rugby players are performing better than the cricketers on the Finger Tapping tests, their more variable level of response suggests that a proportion of the rugby playing group have dropped off relative to the rest of the rugby group in terms of hand-motor dexterity.

4.2.4 Visual Reproduction Immediate Recall

The cricket players recorded a significantly poorer performance relative to the norms on the immediate recall trial of Visual Reproduction. This test has been shown to be sensitive to the effects of mild head injury (Stuss et al., 1985), with the delayed version being more sensitive. However, the cricketers' performance on the delayed recall trial did not differ significantly from the norms as would be expected, based on their significantly poor performance on the immediate recall trial. Such a result could conceivably occur in the presence of slowed information processing resulting in an improvement on the delayed task and/or profound attention and concentration problems, in either case as a consequence of compromised cerebral function. However, it is likely rather that this result reflects inattentiveness due to the poor motivation and fatigue that was evident among the cricket group on testing (see methodology p.27), rather than profound attention and concentration problems following compromised cerebral functioning.

4.2.5 Visual Reproduction Delayed Recall

Whereas no significant differences in mean scores were recorded on the delayed recall trial of Visual Reproduction, the cricket players recorded significantly reduced variability relative to the norms on the delayed trial of this test. As with the variability results on the Finger

Tapping test, this implies that, relative to the cricketers, the rugby players are showing greater variability on this test, and this in turn implies that a proportion of the rugby players' performances on this test are dropping off relative to the rest of the rugby group. Within a brain damaged group, increased variability may show up earlier than decreased performance on mean scores ie. variability tends to be more sensitive to the presence of cerebral impairment. This greater sensitivity of variability to the presence of cerebral impairment was demonstrated by Jordan (1997), in an analysis of variability trends, associated with normal ageing, on the Boston Word Naming Test. While significantly increased variability was recorded from age 50 onwards, a significant decline in mean scores for this test was only apparent from age 70 onwards. The delayed recall trial of Visual Reproduction is a test sensitive to the effects of mild head injury (Lezak, 1995) and this result appears to indicate early visual memory difficulties among a proportion of the rugby group.

4.2.6 Digit Symbol Incidental Recall

Whereas no significant differences in mean scores were recorded on this test, the rugby players recorded significantly increased variability relative to the norms on Digit Symbol Incidental Recall, implying that a significant proportion of the rugby players' performances on this test have fallen off relative to the rest of the rugby group.

4.2.7 Trail Making Test

No significant differences in terms of mean scores were recorded on this test, however, the cricket players showed a significantly decreased variability relative to the norms on part B of the Trail Making test, whereas no significant difference in variability was recorded for the rugby players. Again, this implies that, relative to the cricketers, the rugby players are showing greater variability on this test and this in turn implies that a proportion of the rugby players' performances on this test are dropping off relative to the rest of the rugby group. Trails B, is highly sensitive to the effects of diffuse damage associated with mild head injury (Lezak, 1995) and this result provides further support that a notable proportion of the rugby players are showing deficit as a result of diffuse brain damage. This is not showing up as a fall-off on the group mean score because of a number of intact superior performances across the tests.

4.2.8 Digits Forwards

Whereas no significant differences in terms of mean scores were recorded on the Digits Forwards test, variability increased significantly among the cricket players relative to the norms on this test. Digits Forwards is primarily a measure of attention and concentration (Lezak, 1995) and the increased variability recorded on this test among the cricketers indicates that a proportion of the group were dropping off relative to the others on this measure. Although impaired attention and concentration is a symptom associated with mild head injury (for example, Rimmel et. al., 1981), the test of Digits Forwards tends to hold well relative to Digits Backwards in the presence of diffuse brain damage (Lezak, 1995). As the cricketers showed no indication of poor performance on Digits Backwards, it is likely that the increased variability recorded by the cricketers on Digits Forwards (as with Visual Reproduction Immediate Recall) is a reflection of the poor motivation and fatigue that was evident among the group on testing.

4.2.9 Digits Supraspan

Whereas no differences in terms of mean scores were recorded on Digits Supraspan, again variability increased significantly for the cricket players on this test. This indicates that a proportion of the cricket group are dropping off relative to the others on this test. This result is commensurate with the poor performance of a proportion of the cricketers noted on the Digits Forwards test. The cricketers, as a group, were not performing optimally on the Digits Forwards test and therefore, this tends to invalidate their performance on the supraspan version of the test.

4.2.10 Paired Associates Immediate Recall

Whereas no differences in terms of mean scores were recorded on the immediate trial of Paired associates, variability increased significantly among the cricketers relative to the norms on the immediate trial of Paired Associates (easy pairs), whereas this was not the case for the rugby players. This again implies that the performances of some of the cricketers on this test were falling off relative to the rest of the group. The easy pairs represent old acquired knowledge that invariably tends to hold in the presence of brain damage (Lezak, 1995), hence impaired performance on this part of the test is <u>not</u> expected in the presence of a dementia. Consequently, this result adds substantial weight to the above argument (see paragraphs 4.2.4 and 4.2.8), that variable scores among the cricketers were due to poor motivation and fatigue. An analysis of the raw scores reveals that the increased variability on this test was a result of only two of the cricket players performing well below the norm of 8.69, at 6.0 and 6.5 respectively, and does not represent a tendency of the group as a whole, the rest of whom scored within the expected narrow 8 to 9 range.

4.2.11 Summary Cricket vs Rugby Players Relative to the Norms.

In summary, where anomolous differences between both the rugby and the cricket playing groups relative to the normative data were recorded, this was explained due to different administration procedures between the normative research and the present research on the particular tests involved. An analysis of the significant mean score differences between the rugby and cricket groups relative to the normative data, did not provide support for indications commensurate with the presence of diffuse brain damage in either group. However, an analysis of the variability implies increased variability for the rugby players compared with the cricketers on Visual Reproduction Delayed Recall, part B of the Trail Making test and on the Finger Tapping test, as well as significantly increased variability relative to the norms on Digit Symbol Incidental Recall. This particular cluster of tests are all known to be sensitive to cognitive deficit associated with mild head injury. The relative increased variability among the rugby players across this cluster of tests suggests that, although as a group the rugby players are showing no deficit in terms of mean scores relative to the norms, there are a notable proportion of the group of rugby players whose performances are dropping off relative to the other rugby players, possibly as a result of cognitive deficit due to cumulative mild head injury.

In contrast, the increased variability recorded by the cricketers in relation to the norms across a cluster of tests which do not typically fall following head injury, ie.: Digits Forwards; Digits Supraspan; Paired Associates (easy pairs) Immediate Recall; Visual Reproduction Immediate Recall (in the absence of a poor result on the delayed recall trial), on the other hand, confirms the presence of poor motivation and possible fatigue among the group, rather than providing support for the presence of brain damage.

4.3 RUGBY BACKLINE VS FORWARD PLAYERS IN COMPARISON WITH NORMATIVE DATA (SIGNIFICANT RESULTS)

With regard to mean scores, both the backline and forward groups recorded significant differences relative to the norms on the tests of Words-in-One-Minute, Paired Associates (easy pairs) Delayed Recall, Digits Backwards and on Digits Symbol Substitution. In addition the backline players recorded a significant difference, relative to the norms, on Finger Tapping preferred hand (2nd trial) and Finger Tapping non-preferred hand (both trials), while the forward players recorded significant differences relative to the norms on the tests of Paired Associates (hard pairs) Delayed Recall, Digit Symbol Incidental Recall and Trail Making. With regard to variability, both the backline and forward groups recorded significant differences relative to the norms on the tests of Words-in-One-Minute and on Paired Associates (easy pairs) Delayed Recall. In addition the backline players recorded a significant difference relative to the norms on Paired Associates (easy pairs) Immediate Recall and on one trial of Finger Tapping preferred hand, while the forward players recorded a significant difference relative to the norms on Paired Associates (hard pairs) Delayed Recall and across all trials of Finger Tapping. Tests on which significant differences were recorded will be discussed separately, with differences in mean scores addressed first followed by differences in variability.

4.3.1 Words-in-One-Minute.

In terms of mean scores, both the rugby backline and forward players recorded significantly poorer performances relative to the norms on the test of Words-in-One-Minute. As discussed in paragraph 4.2.1, this appears to be a result of differential administration procedures between the normative research and the present research rather than a reflection of deficit in verbal fluency per se, the important point being that there was no marked difference between the backline and forward players' performance on this test.

4.3.2 Paired Associates Delayed Recall

With regard to mean scores both the backline and forward players recorded highly significant better performances relative to the norms on the delayed trial (easy pairs) of this test. The forward players also recorded significantly better performances on the delayed trial (hard pairs) of this test. As discussed in paragraph 4.2.2 the anomalous results on the delayed recall trial of the Paired Associates test also appear to be the result of differential administrative procedures, the important point being that there was no marked difference between the backline and forward players' performance on this test.

4.3.3 Digits Backwards

The rugby backline players recorded a significantly better performance relative to the norms on the test of Digits Backwards, whereas the forward players recorded a significantly poorer performance relative to the norms on this test. Digits Backwards is primarily a test of working memory (Lezak, 1995) and is relatively sensitive to the effects of diffuse brain damage. This discrepancy in performance between the backline and forward players relative to the norms, accentuates the degree to which performance of the forward players has dropped off on working memory function compared with the backline players.

4.3.4 Digit Symbol Substitution

The other test where this pattern of the rugby backline players performing significantly better relative to the norms while the forward players are performing significantly poorer relative to the norms is noted on the Digit Symbol Substitution test. This is a test which involves complex visuoperceptual tracking and is highly sensitive to the effects of diffuse damage (Lezak, 1995; Russell, 1984). Impaired performance on this test reflects impaired information processing abilities which are associated with diffuse damage consequent on mild closed head injury. This result is consistent with previous research into mild head injury in rugby: albeit limited to the sub-acute phase of single mild head injury, poor performance on the Digits Symbol test was recorded in the studies by Barth et al. (1989), Maddocks and Saling (1991) and by Hinton-Bayre et al. (1997).

4.3.5 Digit Symbol Incidental Recall

The forward players also recorded a significantly poorer performance relative to the norms on Digit Symbol Incidental Recall. As discussed in paragraph 4.2.6, the rugby group as a whole showed a significantly increased variability relative to the norms on this test, implying that a significant proportion of the players' performances on this test were dropping off relative to the rest of the group. The significantly poorer mean performance of the forwards relative to the norms, compared with the backline group, provides an explanation for increased variability recorded among the rugby group as a whole, and confirms specifically that it was the group of forward players whose performances were dropping off relative to the rest of the group. This is a test which has a particularly good discriminating ability (Shuttleworth-Jordan & Bode, 1995) for of the presence of cognitive deficit, and these results support the fact that the test is a good differentiator between brain damaged groups and normal groups.

4.3.6 Trail Making Test

The forward players recorded a significantly poorer performance at the 5% level, relative to the norms, on part A and a highly significantly poorer performance at the 1% level relative to the norms on part B of the test. Moreover, the backline players, although not at a significant level, are recording better performances relative to the norms on part B, further highlighting the degree to which the forward players have dropped off in comparison with backline players on this test. Trail Making is another test which is highly sensitive to the effects of diffuse brain damage (Lezak, 1995). Performance on part B, which tests complex visuoperceptual tracking, ability to shift a response set, as well as working memory, is likely to be more markedly lower than on part A (as was the case with the forward players) in the presence of diffuse brain damage. This result is consistent with the findings of Barth et al. (1989) who recorded impaired performances on the Trail Making test among rugby players, albeit, as mentioned above this was confined to the sub-acute phase of mild head injury.

The mean results of the rugby backline and forward players on the Trail Making test provide corroboration for the argument in paragraph 4.2.7 that a proportion of the rugby players have fallen off relative to the rest of the group as indicated by increased variability relative to the cricketers on part B of the Trail Making test for the rugby group as a whole. This further analysis has clearly revealed specifically, that the group of rugby players that have fallen off are the forward players, those most likely to be exposed to the risk of multiple concussive and sub-concussive head injury.

4.3.7 Finger Tapping Test

Whereas the forward players showed no significant difference in terms of mean performance relative to the norms, the backline players showed a pattern of highly significant better performance relative to the norms at the 1% level across three of the four Finger-Tapping tests. This discrepancy in hand-motor dexterity suggests that, relative to the backline players, the forwards are performing at a level below what would be expected of them.

The analysis of variability further supports the presence of deficit in hand-motor dexterity among the forward players, relative to the backline players. As discussed in the paragraph 4.2.3, although the rugby players as a group performed better than the cricketers on the Finger Tapping tests, the rugby players also recorded a higher variability on the tests than the cricketers, suggesting that a proportion of the rugby players performances on this test were dropping off relative to the rest of the group. The rugby backline players performed significantly better than the forwards on the Finger Tapping tests, yet the forwards showed significantly lower variability relative to the norms across all trials of these tests, whereas the backline players did not. The increased variability for the rugby group as a whole compared with the cricketers, in conjunction with reduced variability of the rugby forwards sub-group relative to the rugby backline sub-group can be explained in terms of a curvilinear pattern of inter-individual variability associated with brain damaged groups, conceptualized in a "Shuttle" model of variability (Jordan, 1997).

According to the above model, brain damaged groups typically exhibit an initial increased variability as a significant proportion of the group begin to exhibit functional symptomology and fall off on test performance relative to the group mean as a result of cognitive deficit, as is evidenced by the increased variability among the rugby group as a whole. Further, according to the 'Shuttle' model, after an initial increase, variability then tends to decrease as almost all of the group begin to exhibit functional symptomology, and scores thus fall closer to the group mean again on cognitive testing. Variability in test performance thus narrows and is reflected in decreased variability, as is evidenced in the significantly decreased variability among the forward playing group (see Figures 1 and 2). The decreased variability recorded by the forward players on this test again confirms that among the rugby playing group, it was specifically the group of forward players who were primarily and consistently exhibiting cognitive deficit commensurate with exposure to cumulative mild head injury. This confirms the hypothesis that this deficit is to be expected among forward players ie. those most likely (because of the nature of play in scrums and loose scrums) to be exposed to multiple concussive and sub-concussive head injury.

4.3.8 Paired Associates Immediate Recall

No difference in mean scores relative to the norms were recorded on this test, however there was significantly decreased variability for the backline players relative to the norms on this test. This implies that, in comparison with the backline group, the forward players are recording relative increased variability and this implies in turn that a proportion of the forward players' performances are dropping off relative to the rest of the forwards. Although not a typical indicator of diffuse brain damage, increased variability on this test for the forwards within the context of consistent indications that they are a cerebrally compromised group, suggests that among the forward group there are players who are beginning to exhibit cerebrally related attention difficulties even on this task.

4.3.9 Summary Backline vs Forward Players Relative to the Norms.

In summary, while the backline players as a group are not exhibiting symptoms of cognitive deficit, the forward players are showing deficit relative to the backline players in the modalities of working memory (Digits Backwards), visuoperceptual tracking (Digit Symbol Substitution, Trail Making) as well as with hand-motor dexterity (Finger Tapping). The analysis of variability between the rugby players and the normative data indicated that some of the rugby group were falling off relative to the rest of the group on the Trail Making test part B, on Digit Symbol Incidental recall and on the Finger Tapping tests. The fact that the forward players performed significantly poorly on each of these tests, relative to the norms, while the backline did not, confirms specifically that it was the group of forward players whose performances were dropping off relative to the rest of the group ie. those most likely to be exposed to the risk of cumulative mild head injury. Further, a comparison of the variability relative to the norms, on the Finger Tapping test (ie. the significantly increased variability among the rugby group as a whole and the significantly decreased variability among the forward players) provides corroborating evidence for the presence of deficits in hand-motor dexterity specifically among the forward players. This phenomenon can be explained in terms of the curvilinear pattern of variability commonly associated with brain damaged groups.

4.4 IMPLICATIONS OF THIS RESEARCH

4.4.1 Nature and permanency of deficit

It appears that the only other research to date that has addressed the permanent cumulative effects of mild head injury in rugby has been carried out by Shuttleworth-Jordan et al. (1993). The present results are consistent with these researcher's findings of deficit in working memory (Digits Backwards) and in hand-motor dexterity (Finger Tapping test) and lend support for the hypothesis that these deficits can be the result of unreported cumulative concussive and sub-concussive mild head injury. In addition, among the forward players, the present research identified deficit in the modality of visuoperceptual tracking. In that both visuoperceptual tasks tapped in the present study (Digit Symbol Substitution and Trail Making) also involve working memory, a possibility is that this working memory function is the more fundamental functional deficit which further stresses the consistency between the two studies. Taken together, the deficits recorded among the forward players across these modalities is highly consistent with the effects of diffuse cerebral damage associated with cumulative mild head injury.

The results of the present research also support previous findings (Barth et al., 1989; Maddocks & Saling, 1991; Hinton-Bayre et al., 1997) of cognitive deficit associated with mild head injury in rugby. However, these studies limited their focus to the acute and sub-acute phase of single mild head injury and thus, unlike the present research, they are unable to comment on the permanency of deficit. The present research, in that it assessed a pre-season group of players who would not have sustained a rugby related head injury for at least four months is in a better position to comment on chronic rather than acute sequelae. In terms permanent deficit, the present research supports findings of research into cumulative mild head injury in general (Gronwall & Wrightson, 1975; Gronwall, 1989), and is consistent with these researchers findings that cumulative mild head injury increases the risk of permanent residual cognitive deficit.

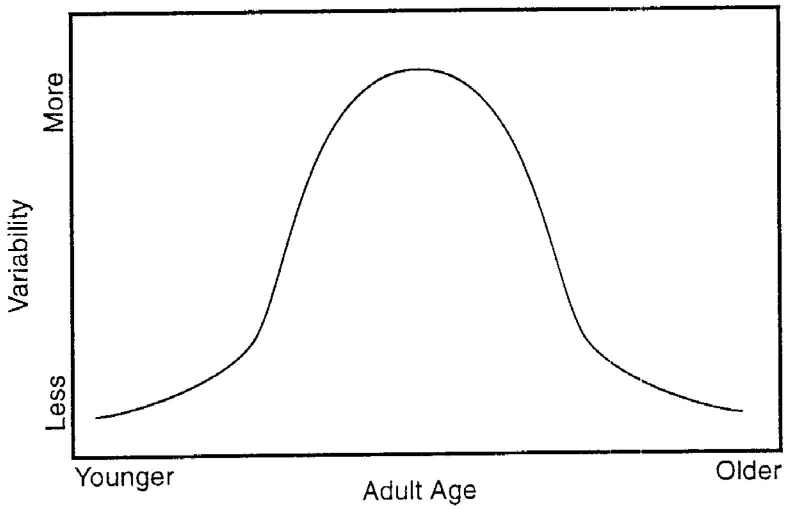
4.4.2 Positional variability of effects

The present results also corroborate the argument put forward by Shuttleworth-Jordan et al. (1993) that forward players, because they are at greater risk for more frequent exposure to concussive and sub-concussive head injuries than backline players, are more likely to show evidence of cognitive deficit. This argument can be developed further theoretically in terms of the brain reserve capacity threshold theory (Satz, 1993). As noted in the introduction to this study (paragraph 1.3.2), the two key variables which are considered to reflect BRC are general intelligence and level of education. As the rugby backline and forward players show no significant difference in terms of these two variables (see methodology, paragraph 2.1) they can be assumed to have been equivalently high functioning and to have had a similar premorbid BRC. However, anything that causes neuronal change and lowers BRC (in this case cumulative concussive and sub-concussive head injury) is likely to lower the critical threshold at which functional symptomology will manifest and thus increase vulnerability to cognitive deficit. The present results indicate that the forward players, because of more frequent exposure to mild head injury than the backline players, are reaching the critical threshold where they are no longer able to adjust to deficit. As a group, when confronted with tests that are known to be particularly sensitive to the effects of diffuse brain insult, they are manifesting functional symptomology indicative of diffuse cerebral damage typically associated with mild head injury.

Higher BRC arguably means higher functioning even with brain damage, thus, although structural damage is invariably associated with even mild head injury (for example, Blumbergs et al., 1994; Oppenheimer, 1968), individuals with relatively high BRC are likely to show a good capacity to adjust to this damage and to be relatively protected from exhibiting permanent residual symptomology. Although the backline players are not yet exhibiting symptoms of functional pathology despite relatively long rugby playing careers, they still remain at risk and any neuronal change lowering BRC such as further head injury will increase their vulnerability to exhibiting symptomology associated with cognitive deficit. It is also likely that any secondary stressors that temporarily lower their critical threshold, may elicit underlying symptomology. This possibility which was shown up in research by Ewing et al. (1980), where 'recovered' mild head injury patients were tested under mildly hypoxic conditions, revealing underlying residual symptomology (see introduction, paragraph 1.3.1). Although not confirmed by research, it is reasonable to extrapolate (see Jordan, 1997) that other secondary stressors for example, fatigue, may also temporarily lower critical threshold and elicit underlying symptomology. Of concern is that the process of normal ageing also has the effect of lowering BRC and thus increasing vulnerability to underlying symptomology. Further, head injury has been shown to be a risk factor in hastening the onset of dementia due to ageing (Mortimer et al., 1991; Mortimer, 1994). Hence, exposure to cumulative mild head injury earlier in adulthood, albeit it not showing signs of symptomology at present such as in the backline players, may yet ultimately lead in turn to clinical presentations such as earlier onset of dementia in later life.

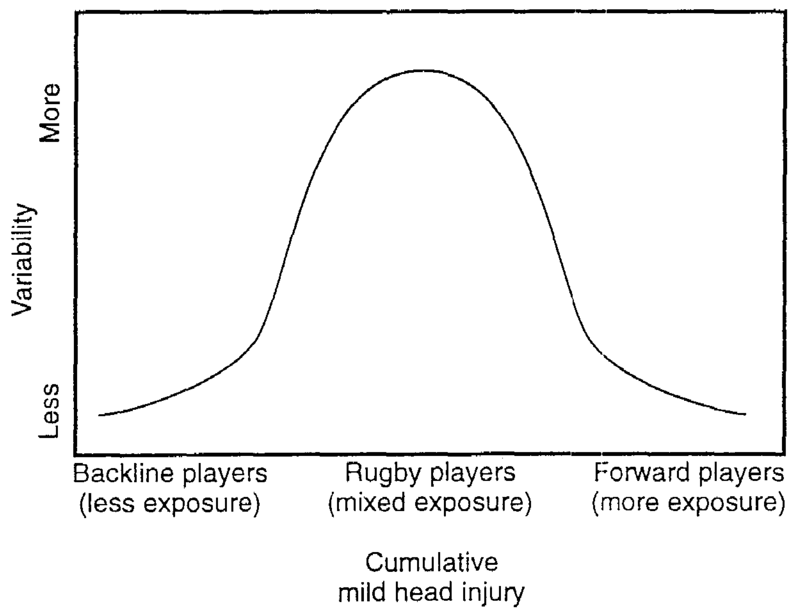
The investigation of variability effects in this research provides support for conceptualising the differences in backline and forward player symptom presentation in terms of the BRC threshold theory. As stated in paragraph 4.3.7 the patterns of inter-individual variability noted in this research are commensurate with the curvilinear pattern of inter-individual variability associated with brain damaged groups, a pattern conceptualised in a "Shuttle" model of variability by Jordan (1997). This model, in accordance with the Satz BRC threshold theory, represents variability as reflecting differing thresholds of symptom presentation within a group. Jordan (1997), conceptualised this model in terms of the effects of ageing on cognitive performance, with an initial increase in variability among older adult groups as a substantial proportion of the group begin to fall off relative to the rest of the group on test performance, and a subsequent decrease in variability in older old groups where arguably, almost all, if not all members have been negatively affected by age and individual test scores thus lie closer to the mean again (see Figure 1, p.66).

Figure 1: The Shuttle Model of Inter-Individual Variability: Schematic representation of patterns of inter-individual variability associated with normal ageing.



The patterns of variability noted in the present study indicate that the above model can also be utilised to explain differences in inter-individual variability associated with cumulative mild head injury in rugby. The proposed variation of the model is represented on page 68 (Figure 2). Here, increasing exposure to concussive and sub-concussive mild head injury, rather than ageing, is the key factor reflected in the variability of individual scores about the mean on test sensitive to the effects of diffuse brain damage. The top of the curve represents the initial increase in variability among the rugby group as a whole, implying a bimodal distribution in which a significant number of rugby players (the forward players due to more frequent exposure to mild head injury) are performing poorly across these tests whereas a significant proportion (the backline players) are not. Variability for backline players as a group (because of less frequent exposure to mild head injury) remains low as players have not yet reached the critical BRC threshold, and are still performing well on testing with scores falling close to the mean. However, variability for the forward players as a group is also low, but this is because the majority of the these players (due to more frequent exposure to mild head injury) are performing poorly across these tests and scores are falling close to the mean.

Figure 2: Shuttle Model of Inter-individual Variability: Schematic representation as adapted to represent patterns of inter-individual variability associated with the effects of cumulative mild head injury in rugby.



4.5 CONCLUSION

In conclusion, the conceptual clustering of the results indicate that a notable proportion of the rugby players' performances were falling off relative to the rest of the rugby group across tests sensitive to the cognitive sequelae of diffuse cerebral damage. Moreover, further analysis of the results revealed that it was specifically the group of forward players whose performances were dropping off on a cluster of tests sensitive to the effects of diffuse cerebral damage. Thus, the findings of the present research do indicate that rugby players run a risk of sustaining permanent cognitive deficit commensurate with diffuse cerebral damage as a result of being exposed to multiple concussive and sub-concussive blows to the head. These findings are consistent with previous research into cumulative mild head injury in rugby which has identified deficit in the modalities of working memory and hand-motor dexterity, in addition this research identified deficit specifically in visuoperceptual tracking tests involving working memory. The results of the present research also corroborated previous findings that the forward players (because of being at higher risk for cumulative mild head injury) are more susceptible to cognitive deficit than the backline players. This greater vulnerability of the forward players can be understood in terms of the Satz (1993) brain reserve capacity threshold theory. It is evident that the "Shuttle" model of variability (Jordan, 1997), derived from the BRC theory and conceptualised to explain differences in inter-individual variability in ageing, can be effectively utilised to illustrate differences in inter-individual variability as a result of exposure to cumulative mild head injury.

The results of the present research highlight the fact mild concussive head injury in contact sport needs to be taken seriously. Moreover, particularly in the context of compulsory participation in rugby at school level in South Africa, potential participants in the game should be made aware of the potential risks involved and be able to make an informed decision regarding their participation in the game.

4.6 EVALUATION OF THIS RESEARCH

The methodological strengths of this study include:

1) The study had access to norms, drawn from a population (university students) with a similar relatively high level of cognitive functioning to the participants in the research. It appears, in fact, that in certain instances (Digits Backwards, Digit Symbol Substitution and Finger Tapping), the backline players were performing at a higher level than the normative data. Thus, it is highly likely that a comparison using norms derived from a more general

population of average intellectual ability would have failed to pick up deficit in a high functioning group such as the present group of rugby players.

2) By employing two levels of comparison (normative data in addition to cricket players), the researcher was able to elicit more information than a single level of comparison would have revealed.

3) This study highlights the importance of interpreting variability differences as well as differences in mean scores. Patterns of deficit may show up earlier on variability and analysing mean scores on their own would have resulted in valuable data being overlooked. Further, the interpretation of variability differences provided valuable information regarding inter-group trends and also provided corroborating evidence for conclusions based on the interpretation of mean score differences.

4) The wide range of cognitive tests employed allowed for a clear pattern of deficit to emerge across key functional modalities typically associated with mild head injury. This allowed for clearer conclusions to be drawn concerning the presence of diffuse brain damage than would have been possible if based on only a few tests covering one or two cognitive modalities, as was the practice in previous research in this area.

5) By drawing participants from a well defined homogenous group of high functioning, physically fit sportsmen, the researcher was able to control for extraneous variables that can effect cognitive performance and vulnerability to long term effects of mild head injury. This can be a problem in research into mild head injury in general where participants, for

example, may have histories of alcohol abuse or widely differing pre-morbid levels of cognitive functioning.

The study also had the following methodological weaknesses:

1) Since the sample rugby group was of exceptionally high level professionals, it was possibly not representative of the rugby playing population as a whole and this lessens the generalizability of these results to rugby players in general. However, in terms of BRC theory, less high functioning players would be even more vulnerable to the effects of cumulative mild head injury sustained in rugby and thus, although not directly comparable, a player functioning at a lower level could be expected to suffer cognitive impairment earlier in his playing career.

2) Satz et al. (1997) stipulate 20 or more participants as adequate for research into mild head injury and from this point of view the sample size was adequate. However, in these terms the sample size was a bare minimum, and a larger sample size would provide a more robust data base.

3) As noted in the methodology, availability to cricketers was only at post-season whereas rugby players were tested at pre-season. Consequently, there was an apparent lack of motivation and fatigue among some of the cricketers resulting in a negative effect on their test performance, as was corroborated by their performances on Digits Forwards, and on the immediate recall trials of Paired Associates and Visual Reproduction. This factor may reduce the validity of comparisons made between the rugby and cricket players relative to the normative data. However, the cricketers below par performance provides a more stringent comparison relative to rugby players in that it reduces the chance of exaggerating

differences relative to the norms between the rugby and cricket playing groups. In other words, differences reflecting compromised functioning for rugby players may have in fact have come out more strongly if the cricketers were performing optimally.

4) Another factor that weakened the cricketers appropriateness as a comparison group was that most of them had a history of playing rugby, at least at school level and sometimes beyond, and so have also been exposed to the risk of rugby related mild head injury. It is envisaged that against a more pure comparison group (ie. one relatively free from exposure to possible mild head injury), the effects would come out more strongly. Such a group would be hockey players who have to choose between rugby and hockey as a winter sport, and thus will not have a history of playing rugby as cricketers often do.

5). Because of time limits, the estimated premorbid IQ was based on only two tests. A more substantial range of tests may have been preferable in estimating a premorbid level of functioning. However, the two tests used are good estimates of general level of intellectual functioning (Lezak, 1995). Moreover, by using tests that are relatively unaffected by prior head injury, the present study has distinct advantages over other studies that have tended to use pre-season testing on tests sensitive to the effects of mild head injury as baseline premorbid data.

4.7 RECOMMENDATIONS FOR FUTURE RESEARCH

1). A prospective study involving the assessment of younger top level rugby players (for example the under 19's) with follow up studies as the group gets older, would provide valuable data regarding vulnerability to cognitive deficit among rugby players. In terms of the present research it would be expected that the under 19's may not show, or at would at least show less, difference in performance on cognitive testing across tests sensitive to diffuse brain damage because their shorter playing careers have not exposed them to as much concussive and sub-concussive mild head injury. However as their playing careers progressed, a greater proportion of this group, particularly the forward players could be expected to begin to show signs of cognitive deficit. Such a study would provide valuable baseline data for future studies, as well as valuable information regarding the relationship between BRC theory and vulnerability to mild head injury in rugby. In addition such a study may identify players that are particularly at risk for cognitive deficit if they continue with their rugby playing careers.

2). The inclusion of a matched control group of non-contact sportsmen, preferably without a history of rugby playing (for example hockey players) would provide for a stronger comparison group than did the cricket players.

3). The assessment of less high functioning groups would help confirm whether reduced BRC results in greater vulnerability to mild head injury in rugby and also provide results which may be more immediately applicable to the average rugby player.

4). Finally, the inclusion of a stress test (for example testing under conditions of reduced oxygen levels) would be very valuable in eliciting evidence for underlying cognitive deficit among rugby players as well as for identifying players at risk for cognitive deficit.

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APPENDIX I

CONSENT FORMS

NEUROPSYCHOLOGICAL ASSESSMENT

CONSENT FORM

I hereby agree to undergo a neuropsychological assessment of my cognitive functioning on the following understanding:

1. This testing will provide the means to identify impairments in the areas of language fluency, attention and memory, visuoperceptual and fine hand motor skills, which may or may not be due to head injuries. The data from this testing will be used for group research and publication purposes in which the individual results will remain <u>totally confidential and anonymous</u>.

2. Specific findings for individuals will be made available in the form of a brief report to the sports physicians of the Sports Science Institute of South Africa, and will form part of a comprehensive report for the South African Rugby Football Union. These individual results will be released to the two above-mentioned bodies on the understanding that they are based on a <u>preliminary</u> research assessment, do not constitute a full clinical assessment, and hence in themselves should not be used to make substantive career decisions. It is understood, however, that the assessment may reveal important indicators of cognitive difficulties which would be in the best interests of an individual to follow up. Should such follow-up neuropsychological assessment be indicated this can be arranged on request. It would involve supplementary testing and personalized counselling about the risks involved in playing contact sport considering that individual's particular life circumstances.

Signed: Date:

NEUROPSYCHOLOGICAL ASSESSMENT

CONSENT FORM

I hereby agree to undergo a neuropsychological assessment of my cognitive functioning on the following understanding:

1. The assessments will take around 2 hours per person, and involve a series of questions and a variety of intellectual tests which are usually quite enjoyable for the testee.

2. The results will serve as a *normal control group* data base for research into mild head injury sustained in contact sports such as football and rugby.

3. The data from this research will be used exclusively for research and publication purposes in which individual results will remain confidential and anonymous.

4. However, if any cricketer would like feed-back on the outcome of their assessment, this can be arranged. Furthermore, on request individual results will be kept on confidential file at the Psychology Clinic in the event that they might be useful for subsequent professional purposes at some later date - for example, should any player suffer a head injury in a motor vehicle accident (MVA).

Signed: Date:

APPENDIX II

PRE-ASSESSMENT QUESTIONAIRE

RHODES UNIVERSITY PSYCHOLOGY DEPARTMENT

Pre-assessment Questionnaire

NAME:______________________________DATE OF BIRTH:__________

ADDRESS:____

PHONE:____________________HIGHEST QUALIFICATION:__________

FIRST LANGUAGE:__________________________________

- **GENERAL HISTORY**

Question 1

Did you ever fail a year at school? [] Yes [] No

If Yes, when?__________For what reason?__________________________

Question 2

What symbol did you achieve for your Senior Certificate (matric)?________________

If qualification lower than matric, please state average mark attained____________

Question 3

What was your final result at University?

Undergraduate:______________________________________

Postgraduate:______________________________________

Question 4

Have you had any other occupations aside from professional rugby? [] Yes [] No

If Yes, please specify______________________________________

____

Question 5

Have you ever been diagnosed with a learning disorder? [] Yes [] No

If **Yes**, what disorder was diagnosed?____

Question 6

Have you ever suffered from a neurological disorder? [] **Yes** [] **No**

If **Yes**, what disorder was diagnosed?____

Question 7

Have you ever been diagnosed with a psychiatric disorder? [] **Yes** [] **No**

If **Yes**, what disorder was diagnosed?____

Question 8

Are you currently taking any form of medication? [] **Yes** [] **No**

If **Yes**, please specify____

Question 9

Do you smoke? [] **Yes** [] **No**

If **Yes**, how much?____

Question 10

Do you consider yourself to be a normal drinker? (By 'normal' we mean drinking *less than* or *as much as* most other people). [] **Yes** [] **No**

Question 11

Have you ever felt that you should cut down on your drinking? [] **Yes** [] **No**

Question 12

What other forms of substances do you take?____

How often?____

Question 13

Have you ever sustained a head injury or concussion that was *not* related to sport (e.g. motor vehicle accident). *Note to examiner: DO NOT INCLUDE SPORTS-RELATED INJURIES HERE.*

[] Yes [] No

If yes, date/s? **Injury 1**________________**Injury 2**________________

Injury 1

- What caused the injury/concussion?________________

____

____

- Did you lose consciousness? [] Yes [] No

  If **Yes**, for how long?________________
- Did you lose your memory? [] Yes [] No

  If **Yes**, for how long?________________
- Were you hospitalised? [] Yes [] No

  If **Yes**, for how long?________________

Injury 2

- What caused the injury/concussion?________________

____

____

- Did you lose consciousness? [] Yes [] No

  If **Yes**, for how long?________________
- Did you lose your memory? [] Yes [] No

  If **Yes**, for how long?________________
- Were you hospitalised? [] Yes [] No

  If **Yes**, for how long?________________

- **SPORTS HISTORY**

Question 14

a) At what age did you first start playing rugby?____________________

b) What team/s did you play for in high school?____________________

c) What was the position you played most often?____________________

d) How long have you been playing provincial/national rugby?____________________

____

e) In which position do you play now?____________________

Question 15

a) Have you ever sustained a head injury or concussion during a game of rugby?

[] Yes [] No

If Yes, date/s? **Injury 1**____________________ **Injury 2**____________________

Injury 3________________ **Injury 4**________________ **Injury 5**________________

Injury 1

- What caused the injury/concussion?____________________

____

____

- Were you dazed or confused? [] Yes [] No

  If **Yes**, for how long?____________________

- Did you lose consciousness? [] Yes [] No

  If **Yes**, for how long?____________________

- Did you lose your memory? [] Yes [] No

  If **Yes**, for how long?____________________

- Were you hospitalised? [] Yes [] No

  If **Yes**, for how long?____________________

- Did you have any other symptoms or difficulties? [] Yes [] No

If Yes, please specify____

____

<u>Injury 2</u>

- What caused the injury/concussion?__________________________________

____

____

- Were you dazed or confused? [] Yes [] No

  If Yes, for how long?____

- Did you lose consciousness? [] Yes [] No

  If Yes, for how long?____

- Did you lose your memory? [] Yes [] No

  If Yes, for how long?____

- Were you hospitalised? [] Yes [] No

  If Yes, for how long?____

- Did you have any other symptoms or difficulties? [] Yes [] No

  If Yes, please specify____

____

<u>Injury 3</u>

- What caused the injury/concussion?__________________________________

____

____

- Were you dazed or confused? [] Yes [] No

  If Yes, for how long?____

- Did you lose consciousness? [] Yes [] No

  If Yes, for how long?____

- Did you lose your memory? [] Yes [] No

  If Yes, for how long?____

- Were you hospitalised? [] Yes [] No

  If Yes, for how long?____

- Did you have any other symptoms or difficulties? [] Yes [] No

  If Yes, please specify____

____

<u>Injury 4</u>

- What caused the injury/concussion?____

____

- Were you dazed or confused? [] Yes [] No

  If Yes, for how long?____

- Did you lose consciousness? [] Yes [] No

  If Yes, for how long?____

- Did you lose your memory? [] Yes [] No

  If Yes, for how long?____

- Were you hospitalised? [] Yes [] No

  If Yes, for how long?____

- Did you have any other symptoms or difficulties? [] Yes [] No

  If Yes, please specify____

____

<u>Injury 5</u>

- What caused the injury/concussion?____

____

____

- Were you dazed or confused? [] Yes [] No

  If Yes, for how long?____

- Did you lose consciousness? [] Yes [] No

  If Yes, for how long?____

- Did you lose your memory? [] Yes [] No

  If **Yes**, for how long?________________________________

- Were you hospitalised? [] Yes [] No

  If **Yes**, for how long?________________________________

- Did you have any other symptoms or difficulties? [] Yes [] No

  If **Yes**, please specify________________________________

____

b) What other injuries have you sustained while playing rugby?____________________

____

____

<u>Question 16</u>

a) What other sports do you/have you play/ed? **(QUERY BOXING)**____________________

____

b) Have you ever sustained a head injury or concussion while playing a sport *other than rugby*?

[] Yes **[] No**

If **Yes**, date/s? **Injury 1**______________**Injury 2**______________**Injury 3**______________

<u>Injury 1</u>

- What caused the injury/concussion?________________________________

  ____

  ____

- Were you dazed or confused? [] Yes [] No

  If **Yes**, for how long?________________________________

- Did you lose consciousness? [] Yes [] No

  If **Yes**, for how long?________________________________

- Did you lose your memory? [] Yes [] No

If Yes, for how long?______________________________

- Were you hospitalised? [] Yes [] No

  If Yes, for how long?______________________________

- Did you have any other symptoms or difficulties? [] Yes [] No

  If Yes, please specify______________________________

____

Injury 2

- What caused the injury/concussion?______________________________

____

____

- Were you dazed or confused? [] Yes [] No

  If Yes, for how long?______________________________

- Did you lose consciousness? [] Yes [] No

  If Yes, for how long?______________________________

- Did you lose your memory? [] Yes [] No

  If Yes, for how long?______________________________

- Were you hospitalised? [] Yes [] No

  If Yes, for how long?______________________________

- Did you have any other symptoms or difficulties? [] Yes [] No

  If Yes, please specify______________________________

____

Injury 3

- What caused the injury/concussion?______________________________

____

____

- Were you dazed or confused? [] Yes [] No

  If Yes, for how long?______________________________

- Did you lose consciousness? [] **Yes** [] **No**

  If **Yes**, for how long?____

- Did you lose your memory? [] **Yes** [] **No**

  If **Yes**, for how long?____

- Were you hospitalised? [] **Yes** [] **No**

  If **Yes**, for how long?____

- Did you have any other symptoms or difficulties? [] **Yes** [] **No**

  If **Yes**, please specify____

____

APPENDIX III

NEUROPSYCHOLOGICAL
TEST BATTERY

NEUROPSYCHOLOGICAL TESTING

ASSESSMENT SCHEDULE

Testee:________________________ **Date:**________________

Time **Test**

1. Consent form
2. Pre-assessment questionnaire
3. Symptom checklist
4. Digit Symbol *including* INCIDENTAL RECALL
5. Trail Making A and B
6. Words-in-a-Minute
7. "S" Words-in-a-Minute
8. Finger Tapping Test A
9. Digit Symbol DELAYED RECALL (20mins)
10. WMS - Designs - IMMEDIATE RECALL
11. Picture Completion
12. Comprehension
13. WMS - Designs - DELAYED RECALL (20mins)
14. WMS - Paired Associate Learning - IMMEDIATE RECALL
15. Digit Span
16. Digit Supraspan A and B
17. Finger Tapping Test B
18. WMS - Paired Associate Learning - DELAYED RECALL (20mins)

DIGIT SYMBOL SUBSTITUTION

Testee's Name:______________________________

Requirements: Test sheet
Pencil
Stop watch

TIMED

Time Limit: 90 seconds (1 minute 30 seconds)

Instructions: *Place the Digit Symbol sheet in front of the subject and indicate the key at the top.*

"Look at these little boxes or squares. You will notice that each has a number in the upper part and a sign or mark in the lower part. Every number has a different sign *(indicate)*. Now, down here *(point to the sample)* there are some more of the boxes, but this time they only have the numbers at the top and the spaces below are empty. You have to put into each of the spaces the mark that belongs (corresponds) to the number at the top. The first number is 2, so we have to put in this mark *(pointing to the key - examiner fill in the 2-sign)*. The next is a 1, so we put in this mark *(indicating the sign and filling it in)*.

The examiner then fills in the rest of the examples ***personally***, *asking the subject in each case to point out the appropriate symbol. Do not permit the subject to do the examples, as he must be shown the correct substitutions in the examples.*

When all the examples have been filled in, say:

"Now I want you to go on from here yourself and put into each space the sign that belongs to the number at the top. Take each in order as it comes and do not leave any out. Work as quickly as you can and see how many you can do in 1½ minutes.

If the subject begins erasing or correcting an incorrect solution tell him to leave it out and go on with the next.

IMPORTANT:

Make a note of how many the subject completes in 1½ minutes but allow him to finish up to the end of the second last horizontal line (or 42 blocks from the beginning of the test). If the subject has passed this point during the test then carry on with incidental recall.

X. SYFERS VERVANG DEUR SIMBOLE.
X. DIGIT SYMBOL SUBSTITUTION.

NAAM
NAME ....

Datum
Date ....

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9
–	И	⊐	L	U	O	Λ	X	=

VOORBEELD SAMPLE								TOETS BEGIN TEST BEGINS																
2	1	3	1	2	4	3	5	3	1	2	1	3	2	1	4	2	3	5	2	3	1	4	6	3
1	5	4	2	7	6	3	5	7	2	8	5	4	6	3	7	2	8	1	9	5	8	4	7	3
6	2	5	1	9	2	8	3	7	4	6	5	9	4	8	3	7	2	6	1	5	4	6	3	7

Aantal korrek 120" Number correct 90"	Aantal half korrek 120" Number half correct 90"	TOTAAL 120" TOTAL 90"

DIGIT SYMBOL SUBSTITUTION - INCIDENTAL RECALL

Testee's Name:______________________________

Requirements: Test sheet
Pencil

NOT TIMED

Instructions: *Place the Digit Symbol Incidental recall sheet in front of the subject.* "See how many of the symbols used in the previous test you are able to remember. There is no time limit and you can do them in any order you wish."

SCORE:

Number remembered correctly: ____________

X. SYFERS VERVANG DEUR SIMBOLE.
X. DIGIT SYMBOL SUBSTITUTION. – IMMEDIATE

NAAM
NAME .... Datum
Date ....

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9

TRAIL MAKING

Requirements: test sheets (4 pages)
pencil
Stop watch

TIMED

Instructions: **TRAIL A:**

SAMPLE - Draw a line to connect the circles consecutively from 1 to 8, without lifting your pencil, as fast as you can.

(Showing the subject the test sheet and pointing out the first 3 or 4 circles which must be joined give the following instruction)

Now draw a line to connect the circles consecutively from 1 to 25, without lifting your pencil, and do it as fast as you can.

Record time

TRAIL B:

SAMPLE - Draw a line to join the circles consecutively by alternating between 1 and A, as fast as you can.

(Showing the subject the test sheet and pointing out the first 3 or 4 circles which must be joined give the following instruction)

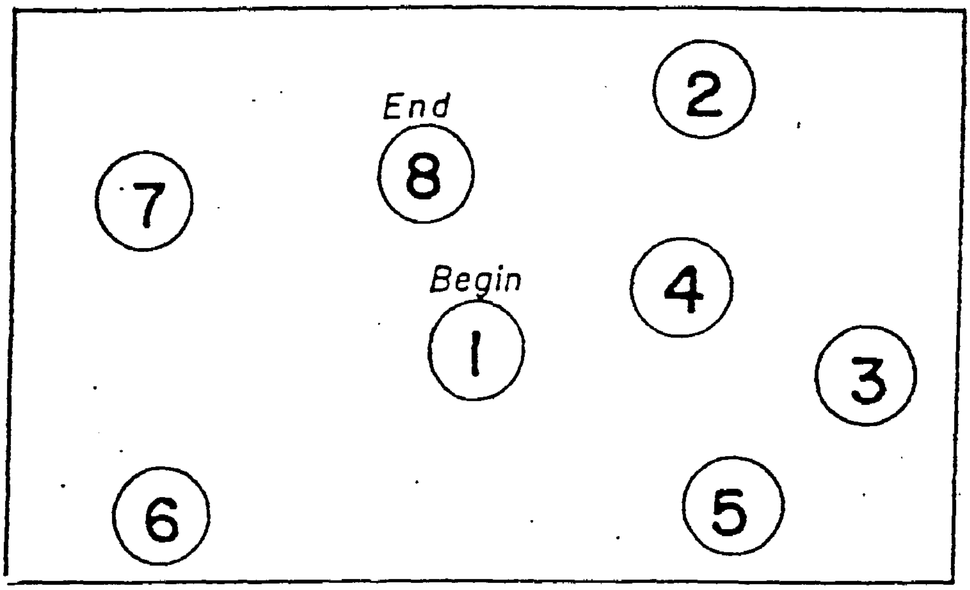
Draw a line to join the circles consecutively by alternating between 1 and A, as fast as you can.

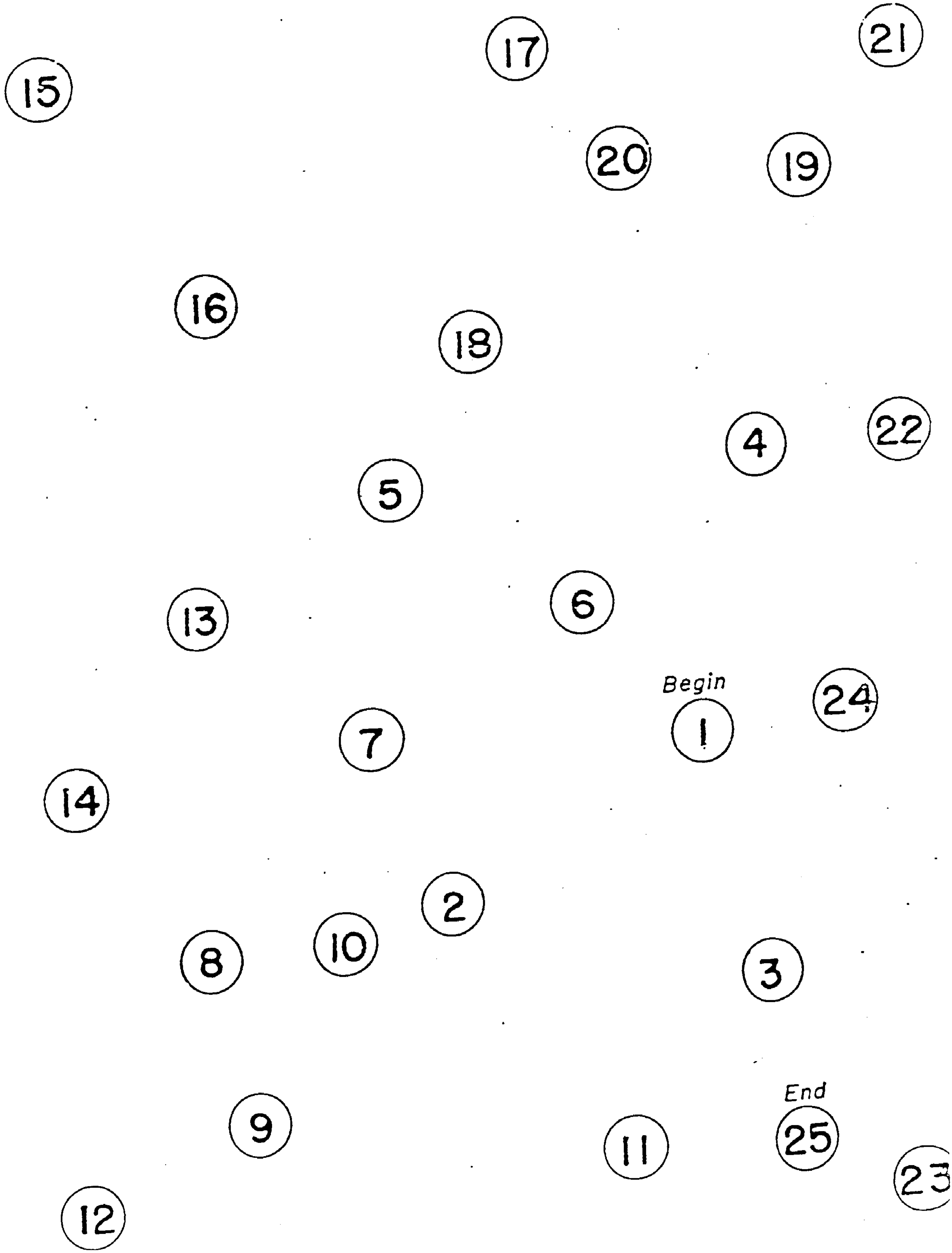
(Note: If subject makes mistake, **don't stop timing**; point out mistake and subject carries on).

TRAIL MAKING

Part A

SAMPLE



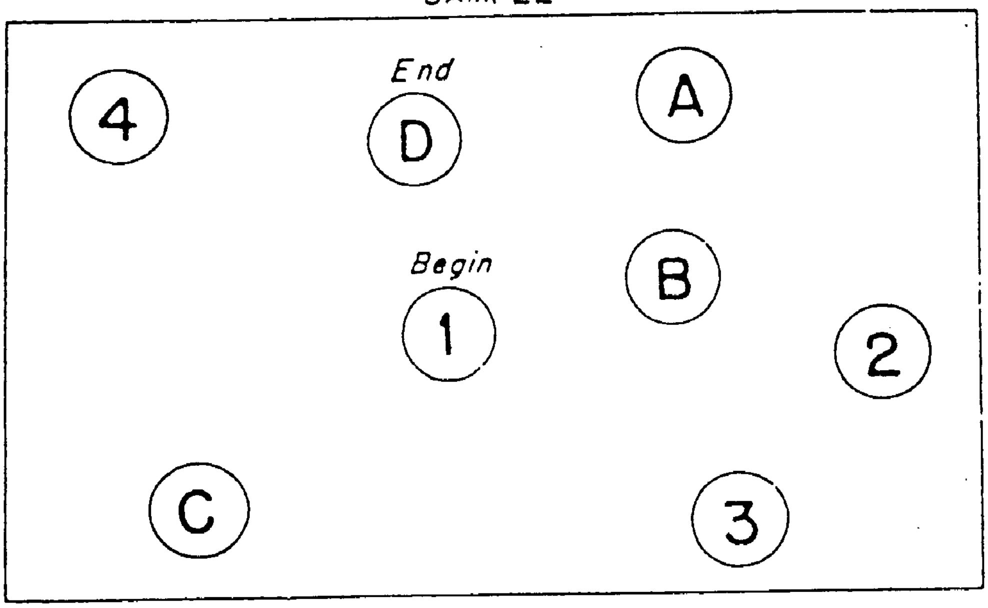


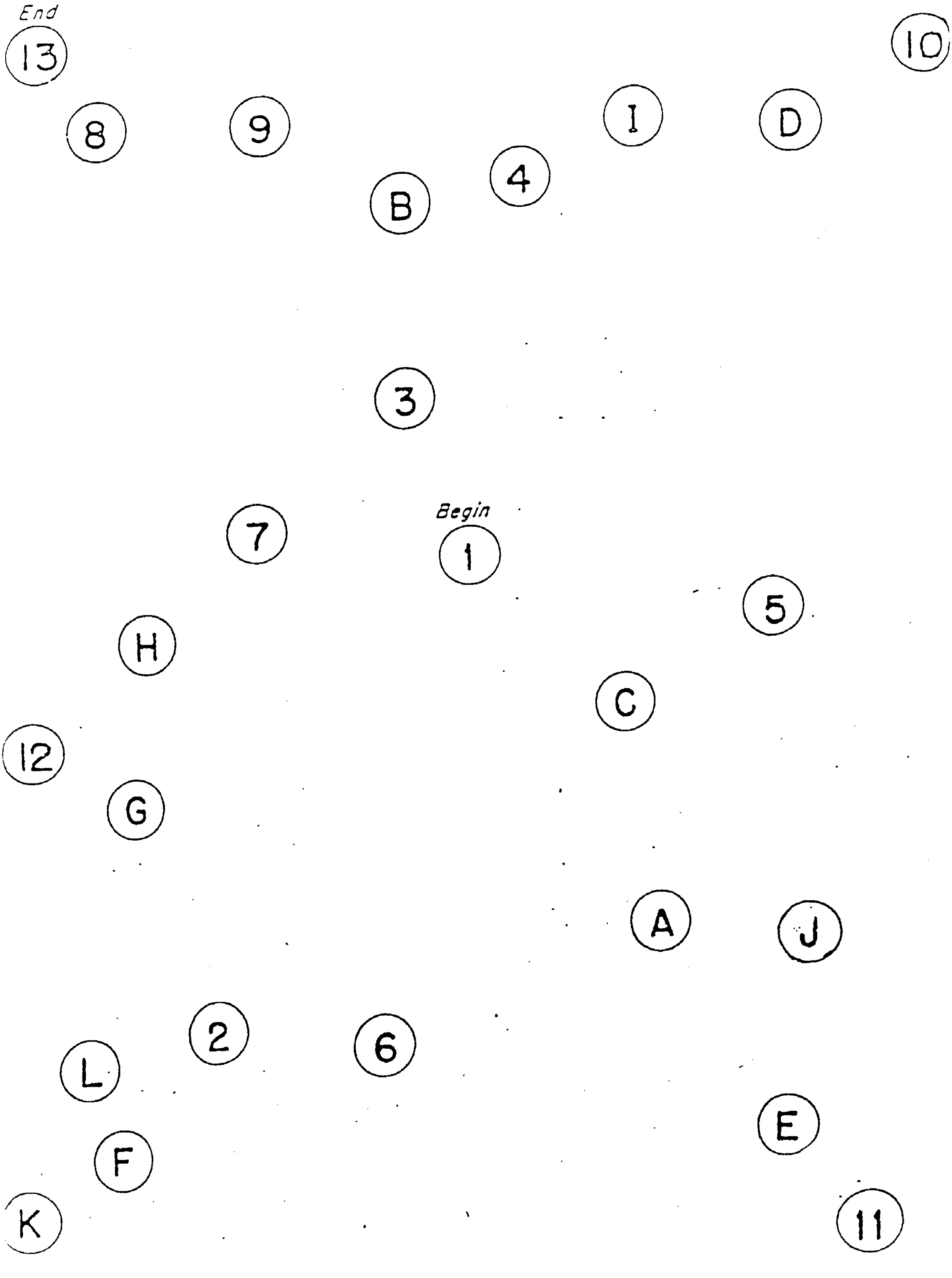
21
17
15
20
19
16
18
22
4
5
6
13
Begin
24
1
7
14
2
10
8
3
End
9
25
11
23
12

TRAIL MAKING

Part B

SAMPLE




End
13
10
8
9
I
D
4
B
3
Begin
7
1
5
H
C
12
G
A
J
2
6
L
E
F
K
11

WORDS-IN-A-MINUTE

Testee's name:

Instruction: "I would like you to say as many different words as you can think of. You must say the words as fast as you can and I will count them. You can say any words *except* proper nouns (like your name or the name of a city) and words with a different suffix (like sit and sitting). Counting or sentences are also not allowed. Do you understand? Just keep going, I will tell you to stop after one minute".

Instructions to be repeated if the subject does not understand what is required.

Score:

Notes or Observations:

"S" WORDS-IN-A-MINUTE

Testee's name:

Instruction: "Now I would like you to say as many words as you can think of that begin with the letter "S". You must say the words as fast as you can and I will count them. You can say any words *except* proper nouns (like your name or the name of a city) and words with a different suffix (like sit and sitting). Counting or sentences are also not allowed. Do you understand? Just keep going; I will tell you to stop after one minute".

Instruction to be repeated if the subject does not understand what is required.

Score:

Notes or Observations:

FINGER TAPPING TEST A

Testee's Name:______________________________

Requirements: stop watch

TIMED: **Time to perform 20 taps (5 sets of 4 taps) per hand**

Time Limit: No

Instruction: *It is important to determine which is the subject's preferred hand.* "Place both your elbows on the table *(examiner models what is required)* and touch each finger to your thumb in turn starting with your index finger *(examiner can again model what is required)*. Practice that. When I say go, I would like you to do this as fast as you can until I tell you to stop. Be sure to touch each finger and do not go backwards. Are you ready? Go..."

"I would like you to repeat this test using your other hand. Practice that. Are you ready? Go..."

SCORE:

Preferred hand: (RH / LH) __________seconds

Non-preferred hand: __________seconds

Notes or Observations:

DIGIT SYMBOL SUBSTITUTION - DELAYED RECALL

Testee's Name: ______________________________

Requirements: Test sheet
Pencil

NOT TIMED

Instructions: *Place the Digit Symbol Incidental recall sheet in front of the subject.* "I would like to see how many of the symbols used in the earlier test you are still able to remember. There is no time limit and you can do them in any order you wish."

SCORE:

Number remembered correctly: ____________

X. SYFERS VERVANG DEUR SIMBOLE.
X. DIGIT SYMBOL SUBSTITUTION. – DELAYED

NAAM
NAME ....

Datum
Date ....

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9

WMS : VISUAL REPRODUCTION - *IMMEDIATE RECALL*

Testee's Name:______________________________

Requirements: 3 cards
stop watch / count in head
pencil
1 piece A4 paper

TIMED viewing

Time Limit: 10" viewing per card

Instructions: *All drawings to be drawn on one piece of A4 paper.*
Cards 1 and 2: "I am going to show you a drawing. You will have just 10 seconds to look at it. Then, I shall take it away and let you draw it from memory. Don't begin to draw until I say "Go". Ready? *Expose card: 10 seconds.* Go."

Card 3: "Here is one that is a little harder. This card has 2 designs on it. I want you to look at them both carefully - again you will have only 10 seconds to look at the card, then I shall take it away and let you make both drawings; the one on the left side - here (*pointing to space in which subject is to make drawing*) and the right one - here (*pointing*). Ready? *Expose card: 10 seconds.* Go."

SCORE:

Card 1: ________________

Card 2: ________________

Card 3: ________________

Notes or Observations:

Test 7

PICTURE COMPLETION

Directions

The test consists of 15 drawings, each of which has a part missing. The cards are presented in numerical order and the subject has to name or indicate the missing part in each.

Say: "I am going to show you some pictures, in each of which there is something missing. Look at each picture carefully and tell me the most important thing missing. Now, look at this picture" (presenting No. 1). "What important part is missing?"

If the correct answer is given, proceed with the test, **saying** in each case: **"Now what is missing in this one?"**

If the subject fails to detect the omission in No. 1,

Say: "You see, the nose is missing".

If he fails the second also, he is again helped, thus:

"You see, the pig's tail is missing here"

From the third picture onwards no further help is given. The examiner simply presents each card, asking what is missing.

Sometimes the subject mentions an inessential missing part. The **first time** this occurs, the examiner **says:**

"Yes, but what is the most important thing missing?"

A correct answer given within the time limit will be scored as correct. If this comment is repeated for any of the remaining presentations, the subject will not score except in the case of No. 13 (Mirror). Here, if the subject says that the hand is missing, **say:**

"Yes, and what else?"

"Hand" alone, or "Powderpuff" alone does not score.

If the subject mentions more than one missing part, ask which is the most important and score accordingly.

The time limit is 20 seconds for each picture. If the correct answer is not given within this time, score as a failure and pass on to the next picture.

N.B.: All times and responses are to be recorded.

Present all 15 cards. Use the timer in such a way that the subject realises that he is being timed, but do not make any remark to this effect. If the subject quickly gives an incorrect answer, wait in silence until the end of the 20 seconds; a spontaneous correction made within this period may be credited.

Test 7

PICTURE COMPLETION

Scoring

1 point for each picture for which a correct response is given within the time limit. No half-marks.

Maximum Score: 15

PICTURE COMPLETION
VOLTOOIING VAN PRENTE

RESPONSE/ANTWOORD

1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

SCORE
TELLING ....

Test 2

GENERAL COMPREHENSION

Directions

Be sure that the subject is attending when you give the question. Young subjects and clinical patients sometimes find it difficult to remember the entire question from a single statement of it. It is therefore advisable to **repeat the question** if no response is obtained after 10 to 15 seconds, but **do not abbreviate or alter the wording.**

Say: "Now I am going to ask you some questions and I want you to tell me what you think in each case. There is no fixed answer. Just tell me what you think. Here is the first one ...."

Record the subject's responses verbatim. If the answer is very long-winded and he speaks rapidly, so that the whole of his statement cannot be noted, record the salient points, trying to preserve as much of the answer as possible.

It is sometimes necessary to encourage the subject. This may be done by means of such remarks as "Yes?". "Go ahead", etc. If a response is not clear, add "Please explain further" or "Can you explain to me a little more clearly?". Ask no questions which may indicate the type of answer required.

N.B.: Never pass on to the next question before making certain that the meaning of each answer is clear. Examiners are advised to keep the Guide to Marking before them while administering the test, particularly as specific answers requiring amplification are noted there.

e.g., Q.2 "Report it", "Report it to the manager".

Here the examiner must find out what object the subject has in mind and should grant full marks only if it is made clear that the management may be expected to take charge in order to prevent panic and see that the fire is dealt with.

It is important to **note down such explanations.** Do not merely state "Explained".

N.B.: If more than one answer is given, ask the subject which he considers most important and score on that basis.

Ask all the questions, except for subjects with very low intelligence.

Test 2

GENERAL COMPREHENSION

Scoring

In scoring this test 2, 1 or 0 marks are given, according to the generalisation and quality of the response. It is therefore re-emphasised that the examiner must **persevere in order to discover exactly what is meant where responses are not clear. This is particularly important in the case of simpler persons who express themselves badly,** or of those who answer obliquely, but who seem to have the correct principle in mind. Unless doubtful responses are investigated, difficulty will be experienced in allotting marks.

The accompanying guide to scoring gives the criteria for acceptable 2 and 1 scores, in addition to examples of which responses clearly fall into one or the other category and of those of a type which may leave the examiner in doubt as to where they fall.

Total Score: The sum of marks on the 10 questions

Maximum : 20

Test 2

GENERAL COMPREHENSION

Questions

1. What is the thing to do if you find an envelope in the street that is sealed and addressed and has a new stamp on it?
2. What should you do if, while sitting in the cinema (bioscope, theatre) you are the first person to discover a fire (see smoke and fire)?
3. Why should we keep away from bad company?
4. Why should people pay taxes?
5. Why are shoes made of leather?
6. Why does land in a city cost more than land in the country?
7. Why must a motor vehicle be licensed before it may be used?
8. Why are laws necessary?
9. Why must a person who wishes to travel outside his own country obtain a passport?
10. Why are people who are born deaf usually unable to talk?

Toets 2

ALGEMENE BEGRIP

Aanwysings

Sorg dat die toetspersoon luister wanneer u die vrae stel. Jong toetslinge en kliniese pasiënte vind dit soms moeilik om die hele vraag te onthou wanneer dit slegs eenmaal gestel word. Dit is derhalwe wenslik om die **vraag te herhaal** indien geen antwoord binne tien tot vyftien sekondes verkry word nie, **maar moenie die bewoording verkort of verander nie.**

Sê: "Nou gaan ek aan u 'n paar vrae stel en ek wil hê dat u my moet vertel wat u in elkeen van die gevalle dink. Daar is geen vasgestelde antwoord nie. Sê net wat u dink. Hier is die eerste een.........."

Skryf die toetsling se antwoorde woordeliks neer. As die antwoord baie breedvoerig is en hy so vinnig praat dat sy volle antwoord nie neergeskryf kan word nie, stip die belangrikste punte aan en probeer om soveel as moontlik van die antwoord te benou.

Dit is somtyds nodig om die toetsling aan te moedig. Dit kan gedoen word deur middel van aanmerkings soos: "Ja?", "Gaan voort", ens. As 'n antwoord nie duidelik is nie, sê dan: "Verduidelik asb. verder", of "Kan jy dit vir my 'n bietjie duideliker maak?" Moenie enige vraag vra wat 'n aanduiding kan gee van die soort antwoord wat verlang word nie.

L.W.: Moet nooit oorgaan na die volgende vraag voordat seker gemaak is dat die betekenis van elke antwoord duidelik is nie. Toetsafnemers word aangeraai om die Gids vir Toekenning van Punte voor hulle te hou gedurende toepassing van die toets, veral aangesien bepaalde antwoorde wat verduideliking vereis hier aangegee word.

bv. Vraag 2 "Gaan vertel dit", "Die bestuurder in kennis stel".

Hier moet die toetsafnemer vasstel wat die toetsling in gedagte het en mag volle punte gee slegs waar die toetsling dit duidelik maak dat van die bestuur verwag word om in te gryp om paniek te voorkom en om te sorg dat die vuur geblus word.

Dit is belangrik om **sulke verduidelikings neer te skryf.** Moenie net "Verduidelik" aanteken nie.

L.W.: Ingeval meer as een antwoord gegee word, moet die toetspersoon gevra word watter een hy as die belangrikste beskou en punte moet hiervolgens toegeken word.

Stel al die vrae, behalwe vir persone met baie lae intelligensie.

Toets 2

ALGEMENE BEGRIP

Toekenning van Punte

Toekenning van punte in hierdie toets is 2, 1 of 0, na gelang van die veralgemening en gehalte van die antwoorde. Dit word derhalwe weer beklemtoon dat die toetsafnemer **moet volhou ten einde presies vas te stel wat bedoel word wanneer antwoorde nie duidelik is nie.** Dit is veral belangrik in die geval van **eenvoudiger persone wat hulself swak uitdruk,** of van persone wat ontwykend antwoord, maar wat skynbaar die korrekte beginsel in gedagte het. Tensy twyfel-

Toets 2

ALGEMENE BEGRIP

Vrae

1. Wat behoort mens te doen as jy in die straat 'n koevert optel wat toegeplak, geadresseer en van 'n nuwe seël voorsien is?
2. Wat sal u doen as u die eerste persoon is wat 'n brand ontdek (of rook en vlamme sien) terwyl u in 'n bioskoop (of teater) sit?
3. Hoekom behoort 'n mens slegte geselskap te vermy?
4. Hoekom moet 'n mens belasting betaal?
5. Waarom word skoene van leer gemaak?
6. Waarom is grond duurder in die stad as op die platteland?
7. Waarom moet 'n motorvoertuig gelisensieer wees voordat dit gebruik mag word?
8. Hoekom is wette nodig?
9. Waarom moet 'n persoon wat buite sy eie land wil reis 'n paspoort besit?
10. Waarom kan mense wat doof gebore is gewoonlik nie praat nie?

GENERAL COMPREHENSION
ALGEMENE BEGRIP

RESPONSE/ANTWOORD

1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

REMARKS
OPMERKINGS ....

....

....

....

....

WMS VISUAL REPRODUCTION *DELAYED RECALL*

Testee's Name:______________________________

Requirements: 3 cards [not shown to P]
pencil
1 piece A4 paper

Not timed

Instructions: *All drawings to be drawn on one piece of A4 paper.*
"Earlier you memorised designs off cards presented to you for 10 seconds. I would like to see how many of those designs you can remember and draw now."

SCORE:

Card 1: ________________

Card 2: ________________

Card 3: ________________

Notes or Observations:

WMS : ASSOCIATE LEARNING - *IMMEDIATE RECALL*

Testee's Name:______________________________

Requirements: Lists of words [below, or on answer sheet]

NOT TIMED

Instruction: "I am going to read you a list of words, 2 at a time. Listen carefully, because after I am finished I shall want you to remember the words that go together. For example, if the words were EAST-WEST; GOLD-SILVER; then when I would say the word EAST, I would expect you to answer (*pause*) WEST. And when I say the word GOLD, you would of course, answer (*pause*) SILVER. Do you understand?"

"Now listen carefully to the list as I read it." *P.T.O. for list of words.*

SCORE:

First Recall	Second Recall	Third Recall
TOTAL ___ ___	**TOTAL** ___ ___	**TOTAL** ___ ___

Easy: 1.	___	Hard: 1.	___
2.	___	2.	___
3.	___	3.	___
A Total	___	B Total	___

Score: A/2 + B = ___

Read 1 pair every 2 seconds.

First Presentation			Second Presentation			Third Presentation		
Metal	-	Iron	Rose	-	Flower	Baby	-	Cries
Baby	-	Cries	Obey	-	Inch	Obey	-	Inch
Crush	-	Dark	North	-	South	North	-	South
North	-	South	Cabbage	-	Pen	School	-	Grocery
School	-	Grocery	Up	-	Down	Rose	-	Flower
Rose	-	Flower	Fruit	-	Apple	Cabbage	-	Pen
Up	-	Down	School	-	Grocery	Up	-	Down
Obey	-	Inch	Metal	-	Iron	Fruit	-	Apple
Fruit	-	Apple	Crush	-	Dark	Crush	-	Dark
Cabbage	-	Pen	Baby	-	Cries	Metal	-	Iron

Wait 5 seconds before beginning to test the recall and then wait at least 5 seconds before moving onto the next pair.

First Recall	Easy	Hard	Second Recall	Easy	Hard	Third Recall	Easy	Hard
North	____		Cabbage		____	Obey		____
Fruit	____		Baby	____		Fruit	____	
Obey		____	Metal	____		Baby	____	
Rose	____		School		____	Metal	____	
Baby	____		Up	____		Crush		____
Up	____		Rose	____		School		____
Cabbage		____	Obey		____	Rose	____	
Metal	____		Fruit	____		North	____	
School		____	Crush		____	Cabbage		____
Crush		____	North	____		Up		____
TOTAL	____	____	**TOTAL**	____	____	**TOTAL**	____	____

Easy:	1.	____	Hard:	1.	____
	2.	____		2.	____
	3.	____		3.	____
	A Total	____		B Total	____

Score: A/2 + B = ____

WMS : ASSOCIATE LEARNING - *IMMEDIATE RECALL* AFRIKAANS

Testee's Name:______________________________

Requirements: Lists of words [below, or on answer sheet]

NOT TIMED

Instruction: "Ek sal nou vir u 'n lys woorde lees, twee op 'n slag. Luister goed want as ek klaar is will ek dat u die woorde onthou wat saamhoort. Byvoorbeeld, as die woorde OOS-WES, GOUD-SILWER is, wanneer ek die woord OOS sê, moet u antwoord (pause) WES. En as ek GOUD sê sal u natuurlik antwoord (pause) SILWER. Verstaan u?"

If the subject is clear as to the directions:

"Nou luister goed na die lys woorde." *P.T.O. for list of words.*

SCORE:

First Recall	Second Recall	Third Recall
TOTAL ___ ___	**TOTAL** ___ ___	**TOTAL** ___ ___

Easy:	1.	____	Hard:	1.	____
	2.	____		2.	____
	3.	____		3.	____
	A Total	____		B Total	____

Score: A/2 + B = ____

Read 1 pair every 2 seconds.

First Presentation			Second Presentation			Third Presentation		
Metaal	-	Yster	Roos	-	Blom	Baba	-	Huil
Baba	-	Huil	Luister	-	Duim	Luister	-	Duim
Breek	-	Donker	Noord	-	Suid	Noord	-	Suid
Noord	-	Suid	Kool	-	Pen	Skool	-	Winkel
Skool	-	Winkel	Op	-	Af	Roos	-	Blom
Roos	-	Blom	Vrugte	-	Appel	Kool	-	Pen
Op	-	Af	Skool	-	Winkel	Op	-	Af
Luister	-	Duim	Metaal	-	Yster	Vrugte	-	Appel
Vrugte	-	Appel	Breek	-	Donker	Breek	-	Donker
Kool	-	Pen	Baba	-	Huil	Metaal	-	Yster

Wait 5 seconds before beginning to test the recall and then wait at least 5 seconds before moving onto the next pair.

First Recall	Easy	Hard	Second Recall	Easy	Hard	Third Recall	Easy	Hard
Noord	____		Kool		____	Luister	____	
Vrugte	____		Baba	____		Vrugte		____
Luister		____	Metaal	____		Baba	____	
Roos	____		Skool		____	Metaal	____	
Baba	____		Op	____		Breek		____
Op	____		Roos	____		Skool	____	
Kool		____	Luister		____	Roos	____	
Metaal	____		Vrugte	____		Noord	____	
Skool		____	Breek		____	Kool	____	
Breek		____	Noord	____		Op		____
TOTAL	____	____	**TOTAL**	____	____	**TOTAL**	____	____

Easy:	1.	____	Hard:	1.	____
	2.	____		2.	____
	3.	____		3.	____
	A Total	____		B Total	____

Score: A/2 + B = ____

SA WAIS DIGIT SPAN

Testee's Name:______________________________

Requirements: SA WAIS Manual, p 29 [or below]
SA WAIS record form [or below]
pencil

Not timed

Instruction: **DIGITS FORWARD:**
"I am going to say some numbers. Listen carefully and when I have finished say them right after me." *Say the numbers in an even tone, one number per second.*

They fail the test after the incorrect repetition of __*both*__ *trials of a span. At this point the Digits Forward test is complete and the score is the best span number achieved. Thus if they fail both sets of 5 but passed one set of 4, their score is 4. If they get one set of 9 correct but fail both sets of 10, their score is 9. If they get 12 digits forward correct - then improvise until you have established their span - ie. until they fail twice in a row.*

3.	5, 8, 2	6, 9, 4
4.	6, 4, 3, 9	7, 2, 8, 6
5.	4, 2, 7, 3, 1	7, 5, 8, 3, 6
6.	6, 1, 9, 4, 7, 3	3, 9, 2, 4, 8, 7
7.	5, 9, 1, 7, 4, 2, 3	4, 1, 7, 9, 3, 8, 6
8.	5, 8, 1, 9, 2, 6, 4, 7	3, 8, 2, 9, 5, 1, 7, 4
9.	7, 5, 8, 3, 6, 3, 2, 7, 9	4, 2, 7, 3, 1, 8, 1, 2, 6
10.	6, 1, 9, 4, 7, 3, 5, 2, 9, 4	4, 7, 3, 9, 1, 2, 8, 3, 2, 7
11.	7, 4, 8, 6, 4, 9, 5, 8, 5, 3, 1	2, 6, 4, 9, 7, 3, 6, 1, 8, 5, 3
12.	8, 2, 5, 3, 7, 4, 6, 9, 2, 5, 3, 6	1, 7, 3, 6, 9, 5, 7, 2, 8, 4, 1, 8

P.T.O. for Digit Supraspan A and B.

DIGIT SUPRASPAN A (*Learning*):

After the second consecutive failure of a digit span on Digits Forward, say:
"I will repeat that one again and see if you can get it this time."

The first repetition of the previously failed span counts as learning trial 1 on this test. Continue to repeat this span until it is learnt correctly, or has not been learnt by 9 trials. In other words, the lowest possible score they can get on the supraspan test is 1 and that's of they get it correct the very first time the span is repeated. *Score below*

SCORE: SUPRASPAN A and B:

TRIAL 1 2 3 4 5 6 7 8 9 10

DIGIT SUPRASPAN B (*Sustained Learning*):

After they have the Supraspan A score you get a Supraspan B score. This is the score for the amount of time it takes them to get the supraspan correct TWICE IN A ROW.
"Let's see if you can get that right again."

If they have a supraspan A score of 4 trials and they are able to repeat the span on the 5th trial - they receive a supraspan B score of 5. If they get the 5th trial wrong - they would need to get the 6th and 7th trials correct to get a supraspan B score of7. Continue until the 10th trial if necessary. If they are still unable to get the span correct twice in a row they receive a score of 10+.

Score above

P.T.O. for Digits Backwards

DIGITS BACKWARD

"I am going to say some more numbers. This time I want you to say them to me backwards. For example, if I say 6 - 2 - 9, you say ......(wait for them to say 9 - 2 - 6)."

The test is failed after 2 consecutive failures of a span on Digits Backwards, and the score is the highest backwards span achieved.

2.	(2, 4)	(5, 8)
3.	2, 8, 3	4, 1, 5
4.	3, 2, 7, 9	4, 9, 6, 8
5.	1, 5, 2, 8, 6	6, 1, 8, 4, 3
6.	5, 2, 9, 4, 1, 8	7, 2, 4, 8, 5, 6
7.	8, 1, 2, 9, 3, 6, 5	4, 7, 3, 9, 1, 2, 8
8.	4, 7, 2, 6, 9, 1, 5, 8	7, 2, 8, 1, 9, 6, 5, 3
9.	2, 8, 4, 1, 7, 9, 5, 4, 6	8, 6, 9, 3, 5, 7, 1, 4, 2

SCORE:

Digits Forwards: ______________

Supraspan A: ______________

Supraspan B: ______________

Digits Backwards: ______________

Digits Difference: ______________ (Forwards minus Backwards)

FINGER TAPPING TEST B

Testee's Name:______________________________

Requirements: stop watch

TIMED: **Time to perform 20 taps (5 sets of 4 taps) per hand**

Time Limit: **No**

Instruction: "I would now like to repeat the finger tapping test that we did earlier. To refresh your memory, place both your elbows on the table *(examiner models what is required)* and touch each finger to your thumb in turn starting with your index finger *(examiner can again model what is required)*. Practice that. When I say go, I would like you to do this as fast as you can until I tell you to stop. Be sure to touch each finger and do not go backwards. Are you ready? Go..."

"I would like you to repeat this test using your other hand. Practice that. Are you ready? Go..."

SCORE:

Preferred hand: (RH / LH) __________seconds

Non-preferred hand: __________seconds

Notes or Observations:

WMS ASSOCIATE LEARNING *DELAYED RECALL*

Testee's Name:______________________________

Requirements: Lists of words [below, or on answer sheet]

NOT TIMED

Instruction: "Remember the pairs of words I read you earlier. I want you to see how many pairs you remember."

First Recall	Easy	Hard
North	___	
Fruit	___	
Obey		___
Rose	___	
Baby	___	
Up	___	
Cabbage		___
Metal	___	
School		___
Crush		___
TOTAL	___	___

SCORE:

Delayed recall = ___

WMS ASSOCIATE LEARNING *DELAYED RECALL* **AFRIKAANS**

Testee's Name: ______________________________

Requirements: Lists of words [below, or on answer sheet]

NOT TIMED

Instruction: "Onthou u die woorde wat ek vroe vir u gelees het. Ek will sien hoeveel van dir pare u kan onthou."

First Recall	Easy	Hard
Noord	____	
Vrugte	____	
Luister		____
Roos	____	
Baba	____	
Op	____	
Kool		____
Metaal	____	
Skool		____
Breek		____
TOTAL	____	____

SCORE:

Delayed recall = ____

APPENDIX IV

PRO-RATED IQ SCORES
AND LEVEL OF EDUCATION

RUGBY AND CRICKET PLAYING GROUPS

PRO-RATED IQ SCORES AND LEVEL OF EDUCATION - RUGBY GROUP

Player No.	Comp. (Scaled Scores)	Pic.Comp.	Pro-rated IQ	Level of Education (Years)
1(F)	12.5	11.0	115	13
2(F)	15.0	11.0	125	12
3(F)	11.0	14.5	123	12
4(F)	11.5	11.0	113	13
5(F)	8.5	12.5	104	13
6(F)	10.5	13.0	115	15
7(B)	12.5	14.5	129	15
8(F)	13.0	15.0	133	15
9(F)	12.5	15.0	132	15
10(F)	11.5	11.0	111	14
11(B)	11.0	12.5	115	16
12(B)	10.5	15.0	123	15
13(B)	12.5	15.0	132	15
14(B)	15.5	12.5	133	16
15(B)	11.0	12.5	115	15
16(B)	10.5	12.5	113	12
17(B)	12.5	12.5	121	15
18(F)	11.5	14.5	125	16
19(F)	12.0	12.5	119	14
20(F)	12.5	14.5	129	15
21(F)	9.0	9.5	94	12
22(F)	9.5	6.5	96	15
23(B)	12.5	15.0	132	15
24(F)	14.0	14.0	133	15
25(F)	13.5	12.5	125	16
26(B)	10.5	8.5	96	12

Key:

Comp. - Comprehension
Pic. Comp. - Picture Completion
(F) - Forward Player
(B) - Backline Player

PRO-RATED IQ SCORES AND LEVEL OF EDUCATION - CRICKET GROUP

Player No.	Comp. (Scaled Scores)	Pic.Comp.	Pro-rated IQ	Level of Education (Years)
27	13.0	11.0	117	12
28	10.0	14.5	119	13
29	11.5	12.5	117	12
30	10.0	14.5	119	13
31	14.5	15.0	140	15
32	12.5	12.5	121	14
33	13.5	12.5	125	15
34	10.0	14.5	119	16
35	9.0	10.5	98	12
36	12.0	14.5	128	15
37	14.0	14.5	136	12
38	15.0	9.5	119	13
39	12.0	9.5	107	12
40	13.5	14.5	133	16
41	12.5	14.5	129	12
42	12.0	8.5	103	11
43	12.0	12.5	119	15
44	11.0	12.5	115	15
45	15.0	13.0	133	16
46	11.5	12.5	117	13
47	14.0	13.0	129	15

Key:

Comp. - Comprehension Subtest
Pic. Comp. - Picture Completion Subtest