

*RHODES UNIVERSITY*

CUMULATIVE MILD HEAD INJURY IN CONTACT SPORT:  
A COMPARISON OF THE COGNITIVE PROFILES OF  
RUGBY PLAYERS AND NON-CONTACT SPORT CONTROLS  
WITH NORMATIVE DATA

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## ***Abstract***

This study investigates the effects of cumulative mild head injury on the cognitive functioning of elite rugby players. A comprehensive battery of neuropsychological tests was administered to top national (Springbok) rugby players (n=26), national Under 21 rugby players (n=19), and a non-contact sport control group of national hockey players (n=21). The test results of the Total Rugby group (Springbok Rugby and Under 21 Rugby players), the Under 21 Rugby group, the hockey controls, and the Total Rugby and Under 21 Rugby forward and backline players respectively, were each compared with established normative data. Results showed significant differences in the direction of a poorer performance relative to the norms for the Total Rugby and Under 21 Rugby groups, and for the Total Rugby Forwards and Under 21 Rugby Forwards, on tests sensitive to the effects of diffuse brain damage. On the other hand, the Hockey Control group and the Total Rugby Backs and Under 21 Rugby Backs tended to perform within the normal range or better than the norm on some tests. These results confirm the hypothesis that rugby players, and the forward players in particular, are at risk of adverse cognitive effects consequent on cumulative mild head injury. The theoretical implications are that the aggregate effects of multiple exposures to mild head injuries in the rugby players served to reduce their brain reserve capacities and acted as a threshold-lowering influence associated with symptom onset.

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- My co-researchers, Melissa Finkelstein and Michael Border.

## ***Declaration***

I declare that this dissertation is my own, unaided work. It is being submitted for a Master of Arts degree to Rhodes University, Grahamstown. It has not been submitted before for any degree or examination in any other university, nor has it been prepared under the aegis or with the assistance of any other body or organization or person outside Rhodes University, Grahamstown.

Lisa Clare Bold

August 1999.

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## ***Introduction***

The aim of this research study was to investigate the cognitive sequelae consequent on cumulative mild head injuries in elite rugby players.

In recent years, scientific and clinical interest has produced a growing amount of research on the potential hazardous effects of mild head injury. The complexity of the subject, however, leaves many questions unanswered. Whilst there is a significant body of research on the effects of a *single* mild head injury, there is more limited research on the *cumulative* effects of *multiple* mild head injuries. In order to address this situation, researchers have identified contact sport players as an accessible 'laboratory' population within which to investigate the effects of cumulative mild head injury (for example: Barth, Alves, Ryan, Macciocchi, Rimel, Jane & Nelson, 1989; Maddocks & Saling, 1991, Shuttleworth Jordan, Balarin & Putschert, 1993). Contact sports players such as boxers, soccer players, American footballers, Australian Rules football players and rugby players are at greater risk than the general population for sustaining *multiple* mild head injuries because of the physical nature of the play. Thus, the research question is whether or not these sports playing populations exhibit the cognitive and behavioural deficits indicative of mild head injury. Initially, research focussed on the contact sport of boxing, however, more recently, research has moved onto the investigation of more subtle influences of head injuries sustained in other contact sports. Much of the research in this area has been undertaken in the United States of America, the United Kingdom, Norway and Australia, specifically on boxing, soccer, American football, Australian Rules football and rugby league. Minimal research has been undertaken in South Africa, which is problematic in that population demographics differ in each country. Furthermore, rugby union, as distinct from other contact sports, is played in South Africa and the scrumming and tackling manoeuvres involved in the game may expose players to an increased risk of mild head injury. There have been a few tentative studies on rugby union in South Africa showing the adverse effects of cumulative mild head injuries (Dickinson, 1998; Reid, 1998; Shuttleworth et al., 1993). However, further research is needed, not only, in order to investigate the specific cognitive effects of *cumulative* mild head injury in rugby union as distinct from other contact sports, but also, to examine such effects within the South African rugby playing population.

In particular, elite rugby players represent a good target group in which to investigate *cumulative* mild head injury effects because of the intensity of the play and their long term commitment to the game. Furthermore, rugby forward players, relative to the backline players, are at a greater risk of exposure to *multiple* mild head injuries as a result of their involvement in scrumming, thus, making the investigation of position of play extremely valuable.

Aside from the neuropathological aspects of mild head injury in rugby, the game of rugby in South Africa is associated with several sociopolitical issues. It performs a significant function in nation-building, with players becoming national heroes through extensive media coverage. In addition, at the professional level, considerable sums of money are involved. Further, historically, rugby has tended to be the most popular winter sport at English and Afrikaans secondary schools and in tertiary educational systems. In the light of these factors, it is crucial that the realities of the consequences of playing the game are identified so that players can make an informed choice about their participation. In addition, consciousness among coaches, sports administrators, health professionals and spectators needs to be raised so that the cognitive-behavioural difficulties following cumulative mild head injury are appreciated and understood.

Thus, against this context of the need for research into the effects of *multiple* mild head injuries in rugby, the present research was initiated. This study forms part of a larger national, long term prospective research project on mild head injury in contact sport in South Africa undertaken by Rhodes University in conjunction with the South African Rugby Football Union (SARFU) and the Sports Science Institute in Cape Town. The initial phase of the research was instituted in 1997, and examined neuropsychological test performances of professional rugby players and a matched non-contact sport control group of professional cricket players. The data were broken up into three separate studies, namely, a direct comparison between the rugby and cricket groups, a comparison of the rugby and cricket groups, relative to normative data, and a comparative analysis of the percentage of individuals with cognitive deficits and postconcussive symptomatology in the rugby and cricket groups. Taken together, findings from the initial phase of the research showed that rugby forward players in particular were disproportionately poor on tests sensitive to the effects of diffuse brain damage. The three-way data analysis was successful in providing a rich data source, but certain methodological problems became evident, namely the small sample size and that the cricket players were not an ideal control group in that many had a

history of playing rugby and they were observed to lack motivation on testing. Therefore, a follow up phase of research was introduced in 1998 by three Clinical Psychology Masters researchers, one of whom includes the present researcher. This second phase of the research used the same breakdown of three-way analyses, but expanded the sample size to include a broader age and educational range of rugby players. Thus, in addition to the professional rugby players tested in the initial phase of the research, national Under 21 rugby players were included. Furthermore, in the second phase of the research, the non-contact sport control group consisted of national hockey players, instead of the cricket players. This was considered preferential because the hockey players play their sport during the same season as rugby and therefore do not have a history of playing rugby.

As noted in the title of this thesis, the focus for the current study was a comparison of the cognitive profiles of rugby players and non-contact sport matched controls to an appropriate normative group. An additional focus was the comparison of the cognitive profiles of rugby forward players and rugby backline players, relative to the normative data. Furthermore, the current study was located within the theoretical context of brain reserve capacity theory. The latter focus served to address the lack of theoretical speculation evident in previous studies on mild head injury. Although Reid (1998) partially addressed this problem by integrating his empirical findings with brain reserve capacity theory, the theme was developed further in the current study.

## CHAPTER 1

### ***Literature Review***

This chapter reviews the current literature available on mild head injury in general, with a focus on definition, incidence, mechanisms of injury, pathophysiology, and cognitive-behavioural sequelae in terms of neuropsychological research and the post-concussive syndrome. Thereafter, mild head injury in sport is discussed, with a particular emphasis on contact sports. Neuropsychological research in relation to boxing, soccer, American football, Australian Rules football, rugby league and rugby union is reviewed in order to provide empirical background for the present study. Finally, a theoretical context for outcomes following mild head injury is proposed, with hypothetical indications for this study.

#### **1.1 MILD HEAD INJURY IN GENERAL**

##### **1.1.1 Concerning Terminology**

###### **1.1.1.1 Closed Head Injury versus Penetrating Head Injury**

Head injury is a wide term that can be applied to anything from a mild bump on the head to a severe penetrating injury (Boll, 1983). The broad distinction between closed versus penetrating head injuries tends to be clear. Closed head injuries, which are the focus of the present study, are defined as injuries in which damage occurs as a result of a blunt impact to the head, either from a moving object or from the head being brought to a stop as a result of collision with a static or slower moving object (Levin, Benton and Grossman, 1982). In contrast, penetrating head injuries are head wounds produced by knives, sharp instruments, bullets or fragments of shells (such injuries are beyond the scope of this study and, therefore, are not discussed further). Closed head injuries constitute a spectrum of disorders which range from mild to moderate to severe, depending on the extent of the disruption to the neuroanatomy and neurophysiology of the brain (Lehman and Ravich, 1990).

###### **1.1.1.3 Classification of Severity**

Traditionally, the severity of a head injury is classified during the acute period of hospitalization on the basis of alteration of consciousness level (Glasgow Coma Scale, abbreviated to GCS), duration of unconsciousness (loss of consciousness or LOC), and

changes in orientation and memory (post traumatic amnesia or PTA). There tends to be more agreement concerning the classification of severe head injury than in the milder range (Satz, Zaucha, McCleary, Light, Asarnow and Becker, 1997). In a severely head injured patient, evaluation using the aforementioned parameters is fairly easy in that the duration of the coma is defined specifically, in terms of different levels of responsiveness, which is crucial to the prediction of the outcome of the head injury (Teasdale and Jennet, 1974). However, the use of these parameters for measuring severity become unreliable or inapplicable in the milder range. Mild head injury patients usually have transient symptoms of headaches, dizziness, confusion, none or a brief loss of consciousness, a generally intact sensorium, no abnormal neurological signs, and brief or no hospitalization (Rimel, Giordani, Barth, Boll and Jane, 1981). More specifically, a study by Williams, Levin and Eisenberg (1990) determined that head injuries generally classified as mild can be separated into subgroups depending on radiological abnormalities or not, and that those with abnormalities on CT scans tend to exhibit neurobehavioural outcomes more closely linked to head injuries generally classified as moderate. These findings highlight that classification of mild head injury confronts researchers with a fundamental measurement and definition problem. More recently, it has been argued that:

*severity of head injury is really a dimension. Assigning labels such as "mild" and "minor" to arbitrary cut points along that dimension so as to establish categories of severity only ends up reifying the arbitrary cut points. The critical need is not to establish a consensus about the definition of the terms "mild and moderate closed head injury". What is needed is an operational definition of closed head injury severity along multiple dimensions (e.g. loss of consciousness and posttraumatic amnesia) (Asarnow et al.,1995, p. 119).*

#### 1.1.1.4 Defining Mild Head Injury

*At present, there is no acceptable definition of mild concussion or mild head injury that has achieved widespread knowledge (Binder, 1986, p. 337).*

The difficulty in the classification of severity of head injury in the milder range has resulted in controversy surrounding a viable definition of mild head injury. In the literature, mild head injury is referred to in many different ways, for example, mild traumatic brain injury (Alexander, 1995; Lezak, 1995), cerebral concussive injury (Gennarelli, 1987; Ommaya and Gennarelli, 1974), and minor head injury (Barth, Macciocchi, Giordani, Rimel, Jane and Boll,

1983; Dikmen, McLean and Temkin, 1986) to name a few.

Rimel et al. (1981) define mild head injury as a brain injury resulting in a loss of consciousness of 20 minutes or less, a GCS score of 13 or more, and the need for 48 hours or less of hospitalization. Subsequently, many researchers made use of this definition, although many others devised their own. Consequently, inconsistencies arose in terms of patient selection for research on the neurobehavioural sequelae of head injury and disparities in outcome resulted (Williams et al., 1990). In a recent attempt to reach consensus on the definition of mild head injury for research purposes, Esselman and Uomoto (1995, in Satz et al., 1997) in association with the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitative Medicine proposed that mild head injury be defined as, at least one of the following: (1) Any period of loss of consciousness which is less than 30 min, with a Glasgow Coma Scale (GCS) rating between 13 and 15 following the LOC; (2) Post traumatic amnesia is present for less than 24 hours, but usually for a few minutes or ours; (3) Any alteration in mental state at the time of the incident (e.g. dazed, confused, disoriented), and; (4) Focal neurological deficit(s) (e.g. double vision, loss of balance, taste or smell) which may or may not be transient.

Although, this definition of mild head injury does suffer from the use of arbitrary cut points which have not been empirically validated, Satz et al. (1997) argue that it is advantageous for the following reasons: (1) It covers a broader range of severity than is traditionally used, which encourages investigation of participants from the extreme tail of the milder injury spectrum; (2) It encourages the investigation of patients who have not been hospitalised; (3) It integrates criteria which are used clinically and; (4) It includes the most widely used measures of severity. Thus, it was decided that this definition of mild head injury would be adopted for the purposes of the current study.

#### 1.1.1.5 Defining Concussion

Similar to mild head injury, the evaluation of concussion is controversial because there is no universally accepted definition or measure of severity. In some instances concussion refers to a form of head injury within the milder range, while at other times, it is used interchangeably with mild head injury, or it can refer to a grade of head injury which is fatal and culminates in death which is not 'mild' at all.

The traditional definition of concussion suggested by the Congress of Neurological Surgeons (1966) was "a clinical syndrome characterized by immediate and transient post-traumatic impairment of neural functions, such as alteration of consciousness, disturbance of vision, equilibrium, etc. due to brain stem involvement." (quoted in Cantu, 1992). Thus, concussion was thought to be spontaneously reversible, but more recently, evidence indicates that concussion cannot occur without damage to nerve cells. This has resulted in calls to revise the definition (Maddocks and Saling, 1991). Lezak (1995) has defined concussion as immediate disturbances in neurological functioning created by the mechanical forces of rapid acceleration/deceleration of the brain inside the skull as a result of a shock, jar or blow to the head. However, concussion does not necessarily require a direct head impact, rather rapid acceleration is sufficient to set the above mechanical forces in motion (Boll, 1983).

Further confusion around the definition of concussion arises when the term is graded for severity. For example, Cantu (1992) classifies concussion as follows: (1) Mild: no LOC, PTA < 30 minutes; (2) Moderate: LOC < 5 minutes, PTA 30 minutes to < 24 hours; (3) Severe: LOC > 5 minutes, PTA > 24 hours. In contrast, Torg's (1982) Grade 1 concussion refers to being dazed and confused, with PTA and LOC, and moves through to a Grade 6 concussion which refers to death as a result of the head trauma. Cantu (1997) suggests that the shortage of conclusive scientific data is the main reason for the differences in these guidelines, which are predominantly based on anecdotal and clinical experience. The scope of Cantu's (1992) and Torg's (1982) classifications of concussion move beyond the definition of a mild head injury adopted above (see section 1.1.1.4, p. 6) in that they include a wider range of symptoms and severity.

On the other hand, Gennarelli (1987) provides definitions of concussion which fall within the parameters of a mild head injury adopted above. According to Gennarelli, a mild concussion is defined as head trauma with no loss of consciousness and a short period of confusion or disorientation, and a classical cerebral concussion is defined as a reversible coma accompanied by cardiovascular and pulmonary function changes and neurological abnormalities which dissipate within 20-30 minutes of the head trauma. In that the neuropathological changes following the head trauma subside within 30 minutes, these definitions of mild concussion and classic cerebral concussion can be subsumed under the definition of a mild head injury adopted above. Thus, for the purposes of the present study, Gennarelli's (1987) definitions of concussion have been adopted.

In addition to the term, concussion, the literature on head injury in sport introduces another term, that of a sub-concussive injury. The latter term refers to a head injury that involves relatively subtle changes in consciousness which are difficult to detect and usually last seconds to minutes (de Villiers, 1987). Again, this term can be subsumed under the definition of a mild head injury adopted above, albeit at the most benign tail of the spectrum.

In sum, for the purposes of the present study, *mild head injury can be understood to encompass the conditions of mild concussion, classical cerebral concussion and sub-concussive injuries*. In addition, for the purposes of this study, the term, mild head injury, as opposed to minor head injury or mild traumatic brain injury has been used. Terminology may differ, however, where a particular researcher's work is reviewed.

### **1.1.2 Incidence and Prevalence**

Head injuries are a highly prevalent neurological disorder. Approximately three million people in the United States sustain a closed head injury every year (Levin et al., 1987). Males tend to have head injuries at a ratio of two to one over females (Boll, 1983). Patients who exhibit persistent symptoms are estimated at 27/100 000 (Alexander, 1995). It is further estimated that 90% of people who sustain head injuries fall into the category of mild, making mild head injury one of the most common neurological disorders (Satz et al., 1997). However, the prevalence of mild head injury is often not recognized because patients do not seek hospitalization and recover on their own, or persisting symptoms are viewed by others as malingering, or seeking compensation in litigation (Alexander, 1995).<sup>1</sup>

The annual incidence of mild head injury across all age groups is estimated at 327 000 hospitalised cases in the United States, although the accuracy of this figure is uncertain (Binder, 1997). Prevalence studies in Sweden found that 21-26% of adult males reported a history of mild head injury, and Canadian high school students reported a prevalence of concussion of 37% for males and 23% for females (Binder, 1997). The problems of identifying incidence of mild head injury are made more difficult when injuries occur in childhood because sequelae may remain undetected, or the incident may never be reported, or symptoms are masked by the child's psychological maturation rate. A survey of mild head

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<sup>1</sup>A study by Templar, Kasiraj, Trent & Trent (1992) found that the incidence of head injuries needs to be adjusted in the upward direction given the prevalence of undocumented and unattended head injuries in the prison and college football populations.

injury incidence in high school and university students found that mild head injury incidents are far more prevalent than hospital surveys document (Segalowitz and Lawson, 1995).

### **1.1.3 Mechanisms of Injury and Pathophysiology**

Mechanically induced diffuse axonal injury accounts for the pathophysiology involved in closed head injury which occurs on a continuum from severe to mild head injury (Blumbergs, Scott, Maavis, Wainwright, Simpson & McLean, 1994). Thus, the neuropathology of mild head injury is the same as in severe head injury, there is just less damage (Alexander, 1995). In severe head injury rapid acceleration-deceleration forces (e.g. motor vehicle accident and falls from >20ft. heights) and rotational forces (e.g. whiplash) produce damage to the brain. The same process is at work in mild head injury but is typically associated with a less severe accelerative-decelerative force (e.g. blunt head trauma) (Satz et al., 1997). Rapid linear and rotational forces in the brain produce shear stresses and strains as the brain swirls around inside the skull and impacts on hard structures. Diffuse microscopic lesions are produced in the deep white matter spreading from the cortex to the brain stem (Strich, 1961). The lesions are the result of stretching and tearing of small blood vessels and groups of nerve fibres, and the tearing of nerve fibres by a crossing vessel (Oppenheimer, 1968). This diffuse axonal injury results in localised transport failures in the axon, and vascular injury produces petechial hemorrhages or local and focal oedema (Alexander, 1995). The pattern of microscopic destructive foci inflicted on the brain is still visible many months post injury, and is reported to be responsible for the cognitive deficits consequent on even mild head trauma (Alexander, 1995). Oppenheimer (1968) highlights the point that that if such injuries are repeated, such as in boxing, a progressive cumulative loss of tissue and of nervous function occurs, resulting in permanent brain damage.

A variety of research studies provide direct and indirect evidence of neural damage consequent on mild head injury. For example, researchers have been able to reproduce mechanical impact and non-impact head injuries which vary in intensity in animals. In a study on monkeys subjected to a solitary blow with a momentary loss of consciousness, researchers found a disruption of axons in the animals' brains (Jane, Steward and Gennarelli, 1985). These observations in animals are similar to lesions found in postmortem examinations of patients who had sustained mild head injuries (Oppenheimer, 1968). Furthermore, studies on brainstem-evoked potentials in patients have found that after concussion these are altered, which is regarded as indirect evidence of the mechanism of

axonal degeneration (Povlishock and Coburn, 1989). Axonal degeneration in the brainstem is expected to have disruptive effect on cortical arousal and hence on cognitive performance (Gentilini, et al., 1985). This axonal degeneration may be due to insult to the brainstem itself or to cortical and diencephalic structures which lead to transient changes in arousal level (Parasuraman, Mutter and Molloy, 1991). A study by Rasmusson, Brandt, Martin and Folstein (1995) showed that neural damage incurred as a result of head trauma may be a predisposing factor in Alzheimer's Dementia, particularly in the absence of a clear genetic contribution.

#### **1.1.4 Cognitive-Behavioural Sequelae**

The presence of cognitive-behavioural sequelae following severe head injury is extensive and uncontroversial (Satz et al., 1997). On the other hand, there is much debate on sequelae following mild head injury. Initially, mild head injuries were thought to have relatively benign consequences and patients, who did seek medical treatment, tended to be discharged from hospital with normal neurological signs after a brief period of observation (Totten and Buxton, 1979). In the 1980s, however, the debate on the effects of mild head injury was renewed. Researchers highlighted that symptoms of mild head injury are often attributed to other causes, and that, although mild head injury does not call for significant medical attention, it has potentially serious cognitive and behavioural outcomes (Boll, 1983).

##### **1.1.4.1 The Post-Concussive Syndrome**

Several patients complain of somatic, cognitive, emotional and sensory disabilities consequent on mild head injury, constituting what is termed the "post-concussive syndrome" (Benton, 1989). Assessment of this syndrome, however, is difficult because the range of symptoms varies depending on the individual, and the subtle cognitive effects are not easily documented, except by neuropsychological testing (Segalowitz and Lawson, 1995). Anderson (1996) highlights that symptoms may include one or more of the following: Somatic - headache, dizziness, insomnia, vomiting, fatigue, loss of appetite, drowsiness, blurred vision, strabismus, menstrual irregularities, decreased noise tolerance, sensitivity to medication or alcohol, clumsiness, postural changes; Neurocognitive - impaired attention and concentration, memory and learning disorders, reduced mental flexibility, slowed reaction time, impaired decision making, impulsivity, speech difficulties, mental fatigue; Neuropsychiatric - depression, anxiety, emotional lability, lowered frustration tolerance, somatisation, denial of symptoms, apathy, lack of spontaneity, personality changes.

Patients with mild head injury are a heterogeneous population with subgroups of patients in which post-concussive symptoms disappear a few days after the injury, however in others, symptoms may persist for weeks, months or years after injury (Bohnen, Jolles and Twijnstra, 1992). Some individuals remain symptomatic, which ranges from a particular symptom, for example, headaches, to an entire symptom complex. The latter has been referred to as the permanent post-concussive syndrome (Alexander, 1995; Dikmen, Temkin & Arsmiden, 1989). Researchers have implicated the following factors in the development of permanent post-concussive syndrome: female sex, low socioeconomic status, prior mild head injury, associated systemic injury (Binder, 1986; Gualtieri, 1995), and ongoing litigation (Alexander, 1995; Raskin, Mateer and Tweeten, 1998), however no one factor is sufficient to account for more than a few of the cases (Alexander, 1995). Furthermore, researchers have had difficulty in identifying the psychological factors involved, and controversy exists as to whether or not such factors do play a part. Certain psychiatric symptoms derive in a direct manner from organic brain lesions, for example any intellectual impairment can be attributed to neuronal damage, whereas emotional and behavioural determinants are more complex (Lishman, 1988). Depression, guilt, anxiety, or vocational and educational interruptions, and changes in family roles are less amenable to objective measurement, and vary in relation to other factors such as environment and personality, which have nothing to do with the brain damage itself. It appears that both somatic and psychological factors play a role in the development of the post-concussive syndrome and that both operate together and may aggravate each other (Lishman, 1988). In the light of this, Alexander (1995) suggests that treatment of the permanent post-concussive syndrome should aim at a mixture of medical treatments and psychological management.

#### 1.1.4.2 Objective Neuropsychological sequelae

Neuropsychological studies provide objective evidence of impaired brain functions and in so doing, explain the patient's subjective complaints of disruptions in psychosocial functioning (Dikmen, McLean and Temkin, 1986). Whilst the following review of neuropsychological studies on mild head injury is not exhaustive, it does highlight the relevant literature and pertinent issues in the field, and also, provides an empirical background for the current study. Where appropriate, the studies are discussed individually in order to emphasize idiosyncratic aspects such as patient selection, neuropsychological test battery, functions measured, time elapsed post injury and outcome.

#### 1.1.4.2.1 *Review of Neuropsychological Research*

Several neuropsychological studies provide strong evidence of impairment in cognitive functioning following a mild head injury (for example, Barth et al., 1983; Bohnen, Jolles and Twijnstra, 1992; Gentilini, Nichelli and Schoenhuber, 1989; Rimel et al., 1981, to name a few). Such impairments preferentially involve deficits in attention and concentration, memory and rate of information processing. These impairments are especially evident in the acute and sub-acute phases following mild head injury, however, evidence of effects over the long term, is less conclusive.

In a pioneering study, Gronwall and Wrightson (1974) compared the performance of mild head injury patients (PTA < 1-24 hours) with and without post-concussion symptoms using the Paced Auditory Serial Addition Test (PASAT), which is sensitive to subtle changes in information processing capacity. Subjects were tested several times over a period ranging from 24 hours to 70 days post injury. Scores were reduced for mild head injury patients initially, but improved over further testing. Improvements were related to reductions in post injury symptoms. Importantly, the researchers were the first to suggest that a slowed rate of information processing may contribute to the development of the post-concussion syndrome.

Consistent with Gronwall and Wrightson's (1974) finding of deficits in information processing, is a study by Leininger, Gramling, Farrell, Kreutzer and Peck (1990). The researchers investigated 53 symptomatic mild head injury patients referred for neuropsychological evaluation between 1 and 22 months post injury. These individuals performed more poorly than uninjured controls on four of the eight tests. Deficits were most evident on tests of reasoning, information processing and verbal learning. Patients who lost consciousness during injury obtained similar scores to those who experienced disorientation or confusion but no loss of consciousness.

Gronwall (1989) takes up the issue of slowed information processing, and highlights that this function may be related to that of attentional deficits as follows: mild head injured patients lack the capacity to analyse several items of information simultaneously because they are inattentive, distractible and forgetful. This hypothesis is supported in a study by Gentilini, Nichelli and Schoenhuber (1989), which used a sustained attention task, timing manual reaction response to a stimulus in the lateral visual field. Mild head injury patients (GCS 13-15, loss of consciousness < 20 minutes, hospitalisation < 3 days, negative neuro-imaging examination) were tested at one and three months post injury. Performance was impaired on

the initial and later tests. In addition, Rimel et al. (1981) assessed 538 mild head injury patients at three months post injury and found deficits in attention, concentration, memory and judgement. The latter study served to highlight the large number of mild head injury patients who were still experiencing difficulties, three months post injury.

In a bid to investigate the relationship between cognitive, emotional and behavioural sequelae following mild head injury, Barth et al., (1983) examined the same subject pool as Rimel et al. (1981), using an extensive neuropsychological battery including the Wechsler Adult Intelligence Scale, or the Wechsler Intelligence Scale for Children Revised, the Wide Range Achievement Test, the Halstead-Reitan Neuropsychological Test Battery, and the Minnesota Multiphasic Personality Inventory. Patients were also tested three months after injury and results demonstrated a trimodal distribution of minimal, mild, and moderate to severe neuropsychological impairment. The impairment was related to rate of information processing, and correlated highly with age, education, visuomotor dysfunction, and deficits in memory. The authors highlight several implications of their results: (1) Patients with what appears to be insignificant periods of unconsciousness or post traumatic amnesia, may show impairment; (2) Less educated patients have greater difficulty coping with their cognitive sequelae; (3) Assessment batteries should include measures of attention and concentration skills, visuomotor functioning, memory abilities and emotional status in order to identify individuals at risk for school or employment failure, and; (4) Adaptation can be improved by informing patients that mild head injury has the potential to impair normal functioning.

Bohnen, Jolles and Twijnstra (1992) extended the focus on the relationship between cognitive deficits and emotional sequelae, and examined whether or not cognitive deficits are limited to a subgroup of mild head injury patients, namely those with subjective complaints. The researchers used a visual computerized version of the Auditory Verbal Learning Test, the Stroop Colour Word Interference Test and a computerized divided attention task. They found that patients with post-concussive symptoms performed less well on tests of divided and selective attention than patients without post-concussive symptoms and healthy controls. They concluded that cognitive deficits may be present six months after mild head injury when post-concussive symptoms persist.

Not all research, however, has demonstrated cognitive impairment consequent on mild head injury. Gentilini et al. (1985) compared 50 mildly head injured patients with 50 normal controls and found no conclusive evidence that mild head injury causes cognitive impairment

one month after trauma. Consistent with this finding, Dikmen, McLean and Temkin (1986) compared twenty subjects with mild head injury to an uninjured group at 1 and 12 months post injury on a battery of neuropsychological and psychosocial measures. The results showed that a single mild head injury is associated with mild but non-significant difficulties at 1 month after injury. A further study examined neurobehavioural outcomes at three months post injury and had mainly null findings (Levin, Mattis et al., 1987). However the researchers take up the issue of future risk factors in their discussion and caution that despite null outcomes, unknown long range or delayed effects may result from mild head injury.

It is evident from the review of neuropsychological studies thus far, that there is considerable variability in outcome in the mild head injury range. As a result, limited conclusions can be drawn (Macchiocchi, Barth & Littlefield, 1998). Much of the disparities in outcome can be accounted for by the methodological constraints implicit in the research. Studies vary in terms of developmental stage of the patient, definition of mild head injury, number and types of neuropsychological functions tested, length of follow-up period, referral method, and control for pre-existing risk factors. Where global measures of neuropsychological functioning are employed such as the Wechsler Verbal or Performance Intelligence scores, the issue of whether or not the tests are sensitive to the anticipated effects is often not addressed. Moreover, a major weakness in some studies is the lack of a control group or the lack of a repeated measures control group to account for practice effects. In addition to the methodological problems, the tendency in journals to report significant rather than null outcomes further serves to confound the picture of outcome research.

#### 1.1.4.2.2 *Meta-analytic Reviews of Neuropsychological Research*

More recently, several meta-analytic reviews have appeared which report predominantly null outcomes in neuropsychological research (Binder, 1997; Binder, Rohling, & Larrabee, 1997; Satz et al., 1997). These have dampened concern regarding the deleterious effects of mild head injury and have been pessimistic regarding the detection of brain damage via neuropsychological assessment. In their meta-analytic review, Binder and colleagues found that persistence of cognitive deficit is small, although they do concede that some problems may remain. They found that attentional measures tend to be the most sensitive indicators of dysfunction and that the injury severity accounted for more variability in outcome than the neuropsychological function. The data indicated that mild head injury patients tend to have more psychosocial problems prior to injury and the researchers conclude that alternative

medical and psychiatric explanations ought to be considered in assessing persistent sequelae (Binder, 1997). In the meta-analytic review of mild head injury in children, Satz et al. (1997) showed that the majority of studies produced null outcomes on neuropsychological, academic and psychosocial measures. Furthermore, it was the methodologically stronger studies which tended to produce the null outcomes. These authors raise some crucial points in contextualizing their reviews. Satz et al. (1997) suggest that certain pre-existing risk factors may influence recovery. While, Binder (1997) indicates that cognitive deficit may only become evident under stressful conditions, and that effects may be so variable that difference between patients and controls may be obscured.

In a response to these apparently null outcomes, Shuttleworth-Jordan (1999) highlights several issues: (1) The meta-analytic reviews *decontextualize* the absence of sequelae and as a result tend to imply there has been no brain injury. This ignores the possibility that mild head injury "may nevertheless cause permanent (albeit *subclinical*) brain injury" (p. 7), which *in itself acts as a risk factor* for future impairment. Furthermore, symptoms may manifest in association with other superimposed neurological stressors or over the long term; (2) The reviews are concerned with studies, which are based on group mean scores, and thus significant variability in the sample is not addressed. As a result, conclusions of mainly null outcomes may be premature. Increased variability on tests sensitive to the effects of diffuse brain damage may show that some individuals are well preserved following a mild head injury whereas a significant proportion of individuals are not (Shuttleworth-Jordan, 1999).

#### 1.1.4.2.3 *Persisting Effects of Mild Head Injury*

The emphasis in neuropsychological research on the acute and post acute phases following mild head injury has resulted in minimal investigation of the persistence of cognitive deficit and the long term effects. As noted above, as early as 1974, Gronwall and Wrightson suggested that a reduction the rate of information processing is an important factor in the development of the post-concussive syndrome. In an attempt to investigate the persisting effects of mild head injury, Klonoff and Lamb (1998) assessed 9 patients who complained of persisting symptoms, and although the subjects obtained low test scores, the authors attribute these to psychogenic factors such as psychiatric disability and/or malingering. In contrast, in a further study which explores psychological factors that influence cognitive functioning, Raskin, Mateer and Tweeten (1998) examined 148 mild head injury subjects with a mean of 21 months post injury, on both personality and neuropsychological measures. They found

attentional and working memory deficits, relative to normative data, and no direct correlation with personality and emotional factors. The researchers conclude that it is plausible that a neurological basis for persistent neuropsychological problems may exist.

Not many studies have addressed the issue of future risk factors superimposed on a mild head injury with resultant negative effects. One such study used alternative test conditions in order to test out this hypothesis. Parasuraman, Mutter and Molloy (1991) found that during the first month after mild head injury, vigilance performance is not impaired under normal task conditions, but may be impaired under task conditions which require sustained effortful processing. A further study with regard to risk factors, by Ewing, McCarthy, Gronwall and Wrightson (1980) found that even when there appears to be a full recovery after a mild head injury there is a residual effect which results in an increased vulnerability to a second central nervous system stressor such as alcohol, hypoxia, fatigue, an additional cognitive task, or a further head injury. The researchers used an auditory vigilance task to assess performance of mild head injury patients who had sustained injuries two years earlier, and a matched control group. The mild head injury patients showed substantial recovery by the time of testing, therefore all subjects were tested under conditions of mild hypoxia to augment any group differences. The mild head injury group was found to be significantly less accurate in detecting auditory targets than was the control group. In the light of the notion of unknown long range or delayed effects of mild head injury, Mortimer et al. (1991) have found an association between prior head trauma and Alzheimer's disease, albeit not specifically with respect to mild head injury. Spear (1995) furthers this issue hypothetically in relation to professional footballers and examines the question as to whether or not they are at risk for developing dementia.

#### 1.1.4.2.4 *Cumulative Effects of Mild Head Injury*

The emphasis in neuropsychological research on investigation of a *single* episode of mild head injury has resulted in limited literature on the *cumulative* effects of mild head injuries. Gronwall and Wrightson, (1975) conducted a study on single concussion and multiple concussion patients and found that subjects with multiple head injuries showed cognitive symptoms and that these patients with a second or third concussive episode took longer to recover than after a single mild head injury. The latter is confirmed by Gronwall (1989), who found that older patients and those with a previous head injury showed impaired information processing abilities on the PASAT and took longer to recover than the group with a single

episode of mild head injury. These findings confirm that outcome after mild head injury is influenced by demographic and pre-morbid characteristics, that is, pre-existing risk factors. Furthermore, with regard to the aggregation of mild head injury effects, there is a growing body of literature, particularly within the area of contact sport, that points to the presence of chronic neuropsychological deficits. This evidence is discussed in more depth below (see section 1.2, p. 17).

#### 1.1.4.2.5 *Summary*

It is evident that the neuropsychological literature to date indicates that absence of symptoms following a mild head injury doesn't necessarily mean that the effects are innocuous. Rather, research using alternative test conditions, or examining superimposed neuropathological variables, or the aggregation of multiple mild head injuries highlights the potential deleterious effects of mild head injury.

## **1.2 MILD HEAD INJURY IN SPORT**

A sportsman describes a mild head injury in sport as follows:

*Getting hit in the head so hard that your memory is affected, although you can still walk around and sometimes even continue playing. You don't feel pain, and the only way other players or the coaches know you've been dinged is when they realize you can't remember the plays* (quoted in Yarnell and Lynch, 1973, p.196).

As noted in the introduction, the expanding awareness of the sequelae of mild head injury in general has led to an increased interest in such effects in sport. Most sports carry a risk of mild head injury, however, the risk is greatest in contact sports such as boxing, wrestling, the martial arts, rugby and soccer, which expose players to cumulative brain insults (Anderson, 1996). Usually most cases of head injury go unreported because athletes fear elimination from a game, being seen as a failure or letting down a team, coach or school (Barth et al., 1989). Despite this, there is a high incidence of mild head injuries in contact sports. Furthermore, the incidence may be underestimated because sub-concussive injuries involving relatively subtle changes in consciousness are difficult to detect and are not specifically looked for by coaches or medical personnel (De Villiers, 1987). Recently, Macciocchi et al. (1998) emphasize that the long term effects of mild head injury, particularly in contact sports has not been adequately researched. These factors imply that head injury in sport needs to be

taken seriously. Extensive research is required focussing on outcome, reducing the rate and severity of head injury, optimal recovery, assessing the effects of repeated injuries, and using sports injury as a model for mild head injury in the general population (Barth et al., 1989). With regard to the latter point, Maddocks, Saling and Dicker (1995) assert it is likely that head injury suffered in sport involves smaller acceleration/deceleration forces and therefore results in a milder form of injury, thus making research on head injury in sport a good means to understanding mild head injury in general.

The following sections review the various contact sports of boxing, soccer, American football, Australian Rules football, rugby league and rugby union. A brief overview of the incidence of mild head injuries in each sport is discussed, and neuropsychological research conducted in each area, is examined.

### **1.2.1 Boxing**

Although there is limited information on head trauma in some sports, moderate and severe head trauma in boxing has obtained considerable attention, because the goal of boxing is to render one's opponent unconscious through successive blows to the head. As early as 1928, Martland identified a syndrome referred to as "punch drunk", where boxers exhibit various neurological symptoms such as mild confusion and unsteady gait. This syndrome degenerates into a movement disorder similar to Parkinson's disease. Diffuse cerebral atrophy has been found in boxers and has been referred to as "chronic boxer's encephalopathy" (Serel and Jaros, 1962, in Barth et al., 1989), "dementia pugilistica" (Lampert and Hardman, 1984) and "traumatic boxers' encephalopathy" (Mawdsley and Ferguson, 1963, in Barth et al., 1989).

Neuropsychological studies on head injury in professional boxers have found evidence of cognitive deficit (Haglund and Eriksson, 1993) and in particular demonstrate impaired concentration and attention, poor immediate and delayed memory and new learning and slowed information processing (Heilbronner, Henry and Carson-Brewer, 1991). A study conducted by Kaste et al. (1984) examined amateur and professional boxers and found the majority showed mild impairments on the Trail Making Test. The authors concluded that repeated concussions have cumulative effects and that the neuropathology may be irreversible. A further study by Casson et al. (1984) found impaired scores for boxers on one or more neuropsychological tests including the Trail Making Test, Digit Symbol Test, Wechsler Memory Scale, and recall of Bender Visual-Motor Gestalt designs. In addition there was a significant correlation between impaired neuropsychological test score, abnormal

CT scan, age and number of professional fights. These findings lend support for a direct relationship between length of boxing career and the presence of brain damage. Consistent with these results is the study by Drew, Templar, Schuyler, Newell and Cannon (1986) in which 19 professional boxers were tested on the Halstead-Reitan Neuropsychological battery, the Quick Neurological Screening Test and the Randt Memory Test. These authors conclude that cognitive deficit in boxers tends to be "the rule rather than the exception" (Drew et al., 1986, p. 525).

Mild head injury in boxing has not received as much attention as moderate to severe head trauma. Research in this area has tended to focus on amateur and young professional boxers because their boxing careers are shorter, they are more closely supervised, and they have had less knockouts (Barth et al., 1989). Neuropsychological studies into the effects of mild head injury on immediate and long term functioning in amateur boxers remains unclear. McLatchie et al. (1987) studied 20 active amateur boxers and found that they performed more poorly than controls on several neuropsychological measures. On the other hand, Levin et al. (1987) found no significant neuropsychological impairment in their study on amateur and professional boxers in relation to matched controls. Consistent with these findings are studies by Brooks, Kupshik, Wilson, Galbraith & Ward (1987) and Butler, Forsyth, Beverly & Adams (1993) which found no evidence for significant cognitive deficit among amateur boxers and no correlation between number of fights and cognitive performance. However, these studies lacked methodological rigour in that samples were voluntary. In addition, the study by Butler et al. (1993) used rugby players as one of their control groups, which is problematic in the light of increasing evidence that rugby players are susceptible to cognitive sequelae consequent on mild head injury.

A significant factor to be considered in assessing long term effects of head trauma in boxing is the cumulative effects of blows to the head which do not necessarily result in being knocked out. A neurological study by Casson, Sham, Campbell, Tarlau and DiDomenico (1982) examined 10 mild head injured professional boxers and found abnormalities in EEG results, CT scans and neurological examinations. No boxer had been knocked out more than twice and thus they argued that multiple subconcussive blows to the head were more likely to account for the abnormalities.

### 1.2.2 Soccer

Research on soccer (generally assumed to be a non-contact sport) shows that mild head injuries may occur as a result of heading the ball or striking the head of another player, or the ground. In Norway, the incidence of head injuries in soccer is between 4 and 22% (Tysvaer, 1992). In America, a study by Barnes, Cooper, Kirkendall, Jordan and Garret (1998) examined the incidence of concussion in elite male and female soccer players and found that, based on concussion history, it is likely that 50% of men and 22% of women will sustain a concussion in a ten year period. This study was limited by reliance on accurate recall and player's own determination as to what constitutes a concussion. A study of elite college soccer players reports a 28% proportion of concussion to other injuries over a period of two years in the United States (Boden, Kirkendall and Garrett, 1998). The authors conclude that concussion in soccer has a higher incidence than was originally anticipated and that concussions don't just occur as a result of heading the ball. Furthermore, they point out that the deleterious effects of repeated concussions and sub-concussive impacts has yet to be established.

With respect to the neurological aspects, as distinct from the neuropsychological aspects to be dealt with subsequently, a study of head injuries in soccer found EEG abnormalities in players compared to non-football playing, uninjured controls (Tysvaer, Storli & Bachen, 1989). These abnormalities are ascribed to the cumulative effect of repeated heading of the ball. Consequently, researchers have become concerned that encephalopathy, similar to that in boxers may occur in sports such as soccer (Tysvaer, 1992; Green and Jordan, 1998). Jordan, Green, Galanty, Mandelbaum and Jabour (1996) set out to test this hypothesis on the United States national soccer team. Twenty soccer players and 20 age-matched male elite track athletes were compared on the basis of head injury symptoms and magnetic resonance imaging of the brain. The authors concluded that evidence of encephalopathy in soccer players relates more to acute head injuries incurred during the game than from repetitive heading. Jordan (1996) argues that this conclusion is overstated because diagnosis of encephalopathy is made clinically in association with neurological data which includes neuropsychological assessment. He also points out that the small sample size and inappropriate control group are further limitations of the study. Another recent study by Spear (1995) has established a link between head injury in soccer and the risk of developing dementia. The researcher suggests that soccer players are at greater risk than the general population for recurrent mild head injury and that the amyloid deposition associated

with such injuries can cause pathological changes similar to Alzheimer's disease.

With respect to the neuropsychological aspects of mild head injuries in soccer, there appears to be limited research. Abreau, Templar, Schuyler and Hutchinson (1990) investigated 31 soccer players and 31 tennis players on the Ravens Progressive Matrices, Symbol Digit Modalities, Perceptual Speed and PASAT tests, and self-reported post concussional symptomatology. They found no significant differences between the groups on cognitive tests, but did find a negative correlation between the number of games played and performance on the PASAT. This suggests compromised information processing abilities as a result of cumulative mild head injury. Furthermore a greater number of soccer players reported post concussive symptoms after a game. The small sample size, and lack of premorbid data and repeated post-injury testing, imply that the study tentatively supports the deleterious effects of mild head injury, however no conclusions can be drawn about the permanency of such effects. A study by Tysvaer and Lochen (1991) examined 37 former soccer players of the National Football Team of Norway on an extensive battery of neuropsychological tests. Results indicated that 81% of the players exhibited mild to severe deficits in attention, concentration, memory and judgement. They conclude that blows to the head by heading the ball provide convincing evidence of brain damage similar to those patients who have sustained mild head injuries. More recently, Matser, Kessels, Jordan, Lezak and Troost (1998) compared 53 active professional soccer players from several Dutch clubs with a control group of 27 elite non-contact sport athletes. Results of neuropsychological testing found that the soccer players exhibited impaired performances in memory, planning, and visuoperceptual processing when compared with control subjects. Soccer players' performance on the memory, planning and visuoperceptual tasks was inversely related to number of previous concussions and the frequency of heading the ball. In addition, forward and defensive players tended to exhibit more impairment than other field positions. These findings are in agreement with those of Tysvaer and Lochen (1991) who showed a higher degree of neuropsychological impairment in headers than in non-headers. Baroff (1998) reviews neurologic and neuropsychological findings from research on soccer. In contrast to the meta-analytic reviews by Binder et al. (1997) and Satz et al. (1997), which produced mainly null outcomes, Baroff (1998) finds support for persistent adverse effects in older professional soccer players which is attributed to brain damage following mild head injuries incurred in playing the game.

### 1.2.3 American Football, Australian Rules Football, Rugby League and Rugby Union

As distinct from boxing, in which direct blows to the head are central to the sport, and soccer, in which heading the ball is part of the game, most head injuries in American football, Australian Rules football, rugby league and rugby union occur as a result of stresses and impacts on the head and neck during blocking and tackling manoeuvres. In addition, some non-head impact contacts may also produce concussive and sub-concussive episodes through tackling and collisions between players. Thus, it is assumed that while each of these sports (American football, Australian Rules football, rugby league and rugby union) is different<sup>2</sup>, overall, the mechanics of the mild head injury are the same, that is, rapid acceleration-deceleration and rotational forces which produce shear stresses and strains on the brain as it swirls inside the skull and impacts on hard structures.

Each sport involves tackling manoeuvres, which predispose players to mild head injuries. A player, running at speed, is held and brought to the ground by an opponent, resulting in a sudden deceleration of that player, in order to prevent him from moving forward physically. In rugby league<sup>3</sup> and rugby union, only the player carrying the ball may be tackled whereas in American football and Australian Rules football, players who do not have the ball may be tackled or blocked. In addition, scrumming in rugby league and rugby union may also expose players to mild head injuries. In a scrum, forward players from each team bend down and link up against the forward players from the opposing team. The ball is placed between the two teams and players push against the opposing team in order to gain possession of the ball. A further source of mild head injury in rugby union is during 'rucks' and 'mauls' in which the player holding the ball is held down by an opponent, while players from both teams climb (sometimes head first) into the ruck or maul in an attempt to gain possession of the ball. Such situations are not part of the rugby league game, therefore it appears that rugby union players are at greater risk for mild head injury than rugby league players. Importantly, it is the game of rugby union which is played in South Africa and was the focus of the present research.

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<sup>2</sup> In American football, rugby league, and rugby union, points are scored by carrying, passing and grounding a ball into the scoring zone at the far end of the field, while in Australian Rules football the ball is carried to the far end of the field and kicked through the goalposts. Protective clothing in the form of helmets and shoulder pads is used in American football, and scrum caps may be used in rugby in order to protect the ears.

<sup>3</sup> Rugby league teams of 13 players are allowed 6 tackles with the ball. At the completion of each set of 6 tackles, the ball is immediately given to the opposition team to commence its set of 6 tackles. Thus, the same players are therefore both offensive and defensive players depending on which team has the ball (Gibbs, 1993).

Epidemiological and neuropsychological research into each of these sports is discussed below.

#### 1.2.3.1 American Football

Much of the literature available on football-related head trauma is provided by epidemiological, descriptive, retrospective studies and case studies (Barth et al., 1989). A study by Gerberich, Priest, Boen, Straub and Maxwell (1983) of 103 high school football teams revealed that sixty nine percent of players were concussed during one season but returned to play the same day, and that postconcussive symptoms were reported up to nine months later by some players. Albright, Mcauley, Martin, Crowley and Foster (1985) established the incidence of 175 head injuries per 100 players over an eight year period. A case study by Kelly et al. (1991) tells of a high school football player who died of diffuse brain swelling after repeated concussions without a loss of consciousness. Saunders and Harbaugh (1984) refer to the "second impact syndrome" in which a player may sustain a further brain insult before recovery from the initial concussion, resulting in rapid brain swelling and herniation which may have a catastrophic outcome.

With respect to neuropsychological research of American football, studies have tended to focus on the acute and subacute phase of a mild head injury. Barth et al. (1989) conducted a four year prospective study using 2300 football players from 10 universities. A nonequivalent repeated measures control group design was used to compare test scores of injured players with matched controls on the PASAT, DSST, TMT and on a symptom checklist. Players were assessed 24 hours, 5 days and 10 days after injury. Results indicated that injured players displayed impaired information processing performance relative to controls but that they recovered rapidly between 24 hours and 5 days and between 5 days and 10 days. These findings support studies of mild head injury in the general population which show neuropsychological deficit within days and weeks of the insult with a rapid recovery of function (Levin et al., 1987; McLean et al., 1984). The Barth et al. (1989) study is methodologically sound in that it made use of pre-injury data, and included a control group with repeated testing in order to account for practice effects on the test battery. However, it was limited in that the test battery was small and assessments did not examine the persistence of effects after the acute and subacute phases, despite results from other studies which indicate that mild head injury effects are evident up to 3 months post trauma (Barth et al., 1983; Rimel et al., 1981). It seems likely that the Barth et al. (1989) findings differ from

such research as a result of sample selection factors such as previous head trauma, multiple injury, alcohol use, psychosocial problems and premorbid functioning. Continued analysis of the Barth et al. (1989) data was undertaken by Macciocchi, Barth, Alves, Rimel and Jane (1996), however this study excluded players with multiple head injuries (more than one injury during the study period). Nine of the 183 players experienced transient loss of consciousness (<5min) whereas the remainder experienced no loss of consciousness. They concluded that single uncomplicated mild head injuries cause limited impairment with rapid resolution of symptoms and minimal prolonged sequelae. A further neuropsychological study of highschool football players was carried out at 24 hours, 30 days and 90 days post concussion using the Wechsler Memory Scale, the Selective Reminding Test, Paced Auditory Serial Addition Test, Symbol Digit Modality test, Stroop and the Trail Making test (Wilberger, Haag and Maroon, 1991, in Wilberger, 1993). Initial test scores were abnormal in 75% of the players. At 1 month, most scores had normalised except for the PASAT, SDM and the Stroop and at 3 months, the same tests showed continuing abnormalities.

#### 1.2.3.2 Australian Rules Football

With respect to epidemiological research, the incidence of injuries to the head and neck region in Australian Rules football is estimated at 25% (Dicker et al., 1986, in Maddocks, Saling and Dicker, 1995). Minimal neuropsychological research is available on the sport. Maddocks and Saling (1991) used baseline premorbid data on players and a matched control group. Concussed players and controls were assessed on two separate occasions using the following neuropsychological battery: Digit Symbol Substitution Test (DSST), the PASAT, a Four Choice Reaction Time measure involving decision time and movement time. They found impaired information processing and reduced reaction times in the concussed players relative to the controls. The study was methodologically sound in comparison to other mild head injury studies in that it was a prospective study which made use of pre-injury data, and it included a control group with repeated testing in order to account for practice effects on the test battery, however, a limited battery was used. A further study by the Maddocks and Saling group of researchers aimed at examining the more persistent effects of mild head injury. They investigated Australian Rules footballers at 6 months post injury using the Digit Symbol subtest. However, scores did not differentiate concussed from non-concussed players (Maddocks, Saling & Dicker, 1995). A problem with this study was the absence of a non-rugby playing control group. Cremona-Meteyard and Geffen (1994) compared Australian Rules football players who had sustained mild head injuries with non-injured sportsmen.

They used a cued reaction time task to measure visuospatial attention. Subjects were tested at two weeks and results indicated that mild head injured players were unable to act quickly in response to expected spatial events. This impaired performance was still evident one year post injury but reaction time had improved. These researchers conclude that players who have sustained concussion are at risk for impaired playing performance.

#### 1.2.3.3 Rugby League and Rugby Union

Studies of the various forms of rugby show a high incidence of head and neck injuries, particularly among forward players. In Australia, a three year survey by Seward, Orchard, Hazard & Collinson (1993) found that concussion was one of the most frequent injuries in rugby league players. This research is consistent with a study conducted in England by Stephenson, Gissane and Jennings (1996) which investigated the incidence of injury in professional rugby league over four playing seasons. The most frequently injured site was the head and neck region and forwards had a higher injury rate than backs. The authors conclude that injury in rugby is the result of the high amount of bodily contact in the game and that forwards tend to be involved in more collisions than backs and thus have higher injury rates. Similarly, in South Africa, concussion is the most common injury in rugby union<sup>4</sup> making up 20% of all injuries, and furthermore, the players in the highest teams tend to be at greater risk of obtaining a mild head injury (Nathan et al., 1983). During a season, approximately 10 % of schoolboy rugby players sustain a concussion (Roux et al., 1987), and this figure may underestimate the actual incidence since most concussive episodes and sub-concussive hits on the head with changes in consciousness rather than loss of consciousness, go unreported.

Although epidemiological studies highlight that rugby players are at risk for cumulative mild head injury, neuropsychological studies have tended to focus on the acute and subacute phase of a single mild head injury. A study in Australia of professional rugby league players in the acute phase after brain trauma examined speed of information processing using the Symbol Digit Modalities Test, the Digit Symbol Substitution Test and the Speed of Comprehension Test (Hinton-Bayre, Geffen and McFarland, 1997). The measures of speed of information processing were sensitive to impairment in the postacute phase but the untimed word recognition task (Spot the Word) was not. Speed of Comprehension was more sensitive to

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<sup>4</sup> According to Seward et al. (1993) at elite level, rugby union is a safer game to play than rugby league or Australian Rules football, however this is with respect to frequency of injuries of all types and not with respect to head injuries in particular.

postinjury impairment than either the DSST or SDMT. The poor performance on DSST and SDMT in the postacute phase is consistent with previous research (Barth et al., 1989; Maddocks and Saling, 1991). Hinton-Bayre et al. (1997) note that studying the effect of a single mild head injury in a sport in which the majority of players have previous head injuries is problematic.

In South Africa, a study of rugby union players examined the persistent effects of cumulative mild head injury (Shuttleworth-Jordan, Balarin and Puchert, 1993). The researchers investigated neuropsychological functioning in concussed and non-concussed players on the following tests: Denckla Finger Tapping, Purdue Pegboard, SAWAIS Digits Forward and Digits Backwards subtests, Digit Supraspan and the Trail Making Test. The study involved two levels of analysis: (1) pre- and post-season differences between non-concussed players and matched controls, and; (2) test differences between concussed players and matched controls at pre-season, five days, one month, two months and three months post-season. Results showed that rugby players, relative to the controls, exhibited deficits on the Purdue Pegboard and on the TMT. However, the significantly faster test scores, relative to the controls, on the Finger Tapping test were inconsistent with these results, and the authors suggest that this may be explained by the highly developed hand motor skills, which are required at elite rugby level. Further analysis found that the forward players showed more impairment than the backline players on the range of tests, and that this may be explained by the fact that they are the players who do the scrumming. The authors conclude that the repeated head to head or head to torso pressure and collisions, predispose these players to cumulative brain damage effects. These results corroborate Barth et al.'s (1989) findings that players in the offensive line and who engage in blocking have the highest percentage of head injuries. In many instances impairment in the rugby players was still evident three months post trauma, which suggests that players may not recover entirely. While this study overcame some of the methodological limitations of previous research such as use of baseline premorbid data and the repeat testing of control groups to account for practice effects as well as investigating the effects of previous concussive or unreported sub-concussive head injury, it was problematic in that only a random selection of rugby players and controls were tested for the post-season assessment of the non-concussed rugby group. This may have influenced the results because individual fluctuations were less well controlled for than if the full samples had been repeated. Further limitations were the small number of concussed subjects and the limited test battery. However, despite this, the study offers strong evidence for

compromised functions in rugby players on tests sensitive to brain damage.

In order to build on neuropsychological research in South Africa into the cumulative effects of mild head injury, a long term prospective project was initiated in 1997 as noted in the introduction. Cognitive test performances of professional rugby players (n=26) and a matched non-contact sport control group of professional cricket players (n=21) were examined. Data were broken up into three separate research studies, namely: (1) A direct comparison of mean scores and standard deviations of rugby versus cricket players across neuropsychological tests (Ancer, 1999); (2) A comparison of rugby and cricket mean scores and standard deviations, with appropriate normative data across all tests (Reid, 1998); (3) A comparison of the percentage of rugby versus cricket players showing cognitive deficit in test scores, as well as a comparison of the frequency of reported post-concussive symptomatology (Dickinson, 1998). Results on Ancer's (1999) study are still pending. Dickinson's (1998) study showed that a significantly higher percentage of rugby players were impaired on visuo-perceptual tracking, speed of information processing and attention, relative to the controls. Results of Reid's (1998) study did not reveal significant differences in mean score comparisons between rugby and cricket groups relative to the norms on tests sensitive to the effects of diffuse damage. However, a pattern of increased variability among the rugby players became evident, relative to the variability of the normative group, which was not apparent for the control group. Further mean score comparisons in Reid's study found that forward players, relative to the norms, were disproportionately poor on tests sensitive to the effects of mild head injury.<sup>5</sup> Dickinson (1998) made a similar finding, in that players in forward compared with backline positions, were most susceptible to impairment, and further, she demonstrated that they tended to report more post-concussive symptomatology. Problems with the research were the small sample size and that the cricket players were a problematic control group. Many cricketers had a history of playing rugby which may have confounded results, and secondly, they were tested post-season (as opposed to the rugby players who were tested pre-season) and thus were observed to lack motivation on testing. Together, these factors may have resulted in an underestimation of the cognitive deficit in the rugby players.

The current study was part of the follow up phase to the abovementioned research and aimed to replicate the methodology of Reid's (1998) study using a larger sample size and an

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<sup>5</sup> Reid has presented his results at the 22<sup>nd</sup>. mid-year annual meeting of the International Neuropsychological Society in Durban, South Africa (Reid, Shuttleworth-Jordan, Ancer, Dickinson, Radloff & Jakoet, 1999).

improved control group. Therefore, in addition to the data from the professional rugby players tested in the initial phase of the research, it was decided to use a group of under 21 national rugby players and non-contact sport group consisting of national hockey players. The rationale for the use of the national hockey squad was that hockey is played in the same season as rugby, which implied that hockey players would not have played both sports and thus served as an improved matched control group. A further rationale for the use of non-contact sport players as a comparison standard for the rugby players was based on Lezak's (1995) assumption of 'transituational performance across functions'. "According to this assumption, the performance level of most normally developed, healthy persons on most tests of cognitive functioning probably provides a reasonable estimate of their cognitive performance on all other kinds of cognitive tasks" (Lezak, 1995, p. 106). In other words, persons who perform well in one area, by and large, perform well in others. Thus, any individual capable of playing sport at a national level is likely to be particularly high functioning in other areas such as cognitive tasks.

The focus of the current study was a comparison of rugby players and non-contact sport controls with appropriate normative data. An additional focus was the comparison of the cognitive profiles of rugby forward players and rugby backline players, relative to the normative data. The rationale for this additional emphasis was that rugby forwards are at greater risk of multiple mild head injuries because of their involvement in scrumming.

The rationale for the methodological approach of norm comparison used in the current study was based on the following: (1) Traditionally, neuropsychological research has compared data with available norms (Lezak, 1995), and more specifically, research in the area of mild head injury has used a normative comparison method (Raskin, Mateer & Tweeten, 1998); (2) The normative perspective complements a direct comparative perspective between the groups because a more complete rendering of the situation is produced, since finding an ideal control group is often problematic. Although no formal comparisons have been made, it appears that sports playing groups as a whole are predisposed to head injuries, which may tend to confound results. Thus, comparisons with a normative group represents a more feasible option; (3) Whilst results from the initial phase of the research suggest that the professional rugby players in some instances have a higher general intellectual potential than the norms, this may not necessarily be representative of the rugby playing population as a whole, who may be more representative of the general population.

### **1.3 THEORETICAL CONTEXT FOR OUTCOME FOLLOWING MILD HEAD INJURY**

Shuttleworth-Jordan (1999) highlights that the levels of theoretical discourse outlined by Salthouse (1991) offer a useful context within which to locate outcome research following mild head injury. According to Salthouse (1991, in Shuttleworth-Jordan, 1999), the lowest level of the hierarchy of theoretical discourse refers to empirical data. The next level refers to descriptive generalisations, which integrate patterns of empirical data. The following level refers to models, which link theoretical concepts with empirical data in highly specific contexts. Further up the hierarchy are theories, which define broad causal relationships and the interrelations between sets of concepts. At the broadest level of theoretical discourse are frameworks, which provide concepts and principles but do not define causal relationships between them. Shuttleworth- Jordan (1999) argues that research on outcomes in mild head injury has tended to be devoid of theoretical speculation, rather, it has focussed on the data-gathering plane. Specifically, it is at the level of theories and models, that there are serious omissions in mild head injury outcome research. She asserts that "statements made about outcome in mild head injury have spurious validity unless they can be located and understood within causally-linked theoretical conditions, and the absence of theory in which to locate research may result in the misrepresentation of results" (Shuttleworth-Jordan, 1999, p.10). Therefore, in an attempt to address this problem, this study has been conceived within the theoretical framework of neuropsychology on a broad level, and the theory of brain reserve capacity on a more specific level.

The neuropsychological framework offers a broad set of concepts for describing cognitive performance in terms of functional modalities and their association with cerebral mechanisms. Lezak (1995) states that the primary concern of neuropsychology is the examination of cognitive impairment, which accompanies almost all brain dysfunction, in terms of identification and measurement of psychological deficits (cognitive, emotional, self direction and management). The process of measuring deficits involves determining an individual's cognitive functioning on a range of tests, and comparing the scores obtained to an

expected level or comparison standard, either individual or normative.<sup>6</sup> Discrepancies relative to the comparison standard may emerge for one test score, or a pattern of deficit may occur. The pattern of deficits is compared with patterns known to be associated with specific psychological or neurological conditions, and interpretations are made in association with the demographic data of the testee (Lezak, 1995).

### 1.3.1 Brain Reserve Capacity Theory

On a more specific theoretical level, this study explores the effects of cumulative mild head injury in rugby, in relation to the Satz (1993) theory of *brain reserve capacity* (BRC). This theory posits that each individual has a given brain reserve capacity which corresponds to an amount of functional brain tissue. The concept of BRC is linked to the notion of a *threshold factor*, which represents the critical amount of brain tissue at which normal functioning can be sustained prior to the presentation of a central nervous system disease. Individual differences in this brain reserve either protect an individual from or make him/her vulnerable to exhibiting symptoms of cerebral pathology (Satz, 1993). This supposition offers an explanation for individual differences in risk of impaired cognitive test performance associated with neural damage.

Satz links brain reserve capacity to adaptive behaviour, which is indirectly reflected in two psychosocial measures, namely, general intelligence and educational level. When these circumstances are favourable, the environment is sufficiently enriching to promote beneficial cortical effects such that, should neuronal disease occur, the greater brain reserve capacity acts as a protective factor and implies a lesser possibility of showing functional impairment. In other words, such an individual maintains a higher level of functioning even in the presence of brain damage. However, the less the brain reserve capacity, the greater possibility of manifesting functional impairment, because the brain reserve threshold is lower (Satz, 1993). Any reduction in brain reserve capacity as a result of cerebral pathology (e.g. alcoholism, Aids, Alzheimers disease), alone or in aggregate form, increases an individual's vulnerability to functional impairment. Head injury and age are two risk factors associated

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<sup>6</sup>Normative and individual comparison standards may be determined directly from population norms, premorbid test data or historical information, or indirectly, from test findings and observation. The norm is usually a score representing the average or median performance of some defined population. As a general rule, normative standards are only appropriate when the function being measured is well within the capacity of all intact individuals and doesn't vary greatly with age, sex, education or general mental ability. Individual comparison standards are used when a function that is normally distributed in the intact adult population is evaluated for change (Lezak, 1995).

with lowered brain reserve capacity, and although a head injured person may not manifest symptoms immediately, the aggregate effects of aging may further diminish neuronal reserves so as to push the individual beyond the critical threshold into detectable functional impairment (Jordan, 1997). Other risk factors which lower the brain reserve threshold include lower educational level (and by implication IQ), and the effects of high task challenge. Task challenge can refer to differing levels of complexity of cognitive task which becomes progressively more demanding such as to increase the possibility of demonstrating impairment. Gender is a further risk factor which may have a differential effect but the direction of such effects is not specified, although on the basis of Satz's work, Jordan (1997) tentatively infers that male gender may serve to enhance vulnerability to symptom onset. Thus, in the current study in order to examine the effect of cumulative mild head injury, variables which needed to be kept consistent between the comparative groups included gender, educational level and intelligence, and prior neurological disorder.

Jordan (1997) applies the Satz theory of brain reserve capacity in a study on the effects of aging across the adult life span, and develops a model of variability. She postulates that individual differences in brain reserve capacity following the onset of the neural aging process manifest as inter-individual variability on neuropsychological testing, that is, a scattered distribution of individual raw scores about the mean. Initially, subjects in the group show increased variability between them, however as more subjects show signs of impairment, variability reduces and the distribution of scores narrows. This variability effect is visually represented as a non-linear inverted-U effect which in mirror image assumes a shuttle shape, and is termed a 'Shuttle' bulge (Jordan, 1997). Shuttleworth-Jordan (1999) argues that this model can be extrapolated to any individual with accumulating degrees of brain damage, such as cumulative mild head injury. She has posed specific theoretical expectations from this model with respect to outcome following mild head injury in rugby as follows: (1) Rugby playing groups are likely to show increased variability in test performance, compared to non-contact sport controls. The variability may be explained by: firstly, the aggregate effects of mild head injuries superimposed on pre-existing individual differences in brain reserve capacity, and, secondly, the positional differences, in which forward players are exposed to an increased frequency of mild head injuries, compared to the backline players; (2) Rugby playing groups will show decreased variability as the effects of cumulative mild head injuries spread throughout the group, for example, in a subgroup of forward players; (3) Variability effects on tests known to be sensitive to diffuse brain damage

will be evident. Reid's (1998) study lends support for these hypothetical indications in that rugby players showed increased variability relative to controls on tasks sensitive to diffuse brain damage. Further, the forward players demonstrated reduced variability compared to the full rugby group, indicating that their heightened exposure to mild head injuries had resulted in neuropsychological impairment.

#### **1.4 HYPOTHESES**

The above hypothetical indications were developed and integrated with the aforementioned empirical data to form specific hypotheses for the present study. Thus, it was hypothesized that:

- (1) There would be significant differences in overall cognitive test performance in the rugby playing groups compared to the hockey players, relative to the normative data. These differences were expected to be in the direction of a poorer performance than the norm for the rugby playing groups, whereas, there would be no significant differences for the hockey players, relative to the norms. The differences were anticipated to be due to reduced brain reserve capacity in the rugby players, because of their greater exposure to mild head injuries. In particular, it was expected that the *cumulative* effects of mild head injuries, would serve as a threshold lowering factor associated with earlier symptom onset.
- (2) There would be significant differences in overall cognitive test performances in rugby forward players compared to the rugby backline players, relative to the normative data. In particular, it was anticipated that the rugby forward players would show impaired performances relative to the norms, whereas, the backline players would not be impaired relative to the norms. These differences were anticipated to be due to the reduced brain reserve capacity in the forward players as a result of the threshold altering effects of their heightened exposure to multiple head injuries in scrumming.
- (3) In the absence of significant differences in mean scores, there would be indications of increased variability in the rugby playing groups, compared to the control group, relative to the norms, and in the rugby forward groups, compared to the rugby backline groups, relative to the norms. It was anticipated that this increased variability would be due to a significant proportion of individuals in each group revealing neuropsychological impairment.

(4) There would be differential effects for the various tests in the battery with some showing more marked differences than others. In particular, it was expected that tests less sensitive to head injury effects would present less challenge to brain reserve capacity thresholds, and those tests sensitive to brain damage would present more challenge to brain reserve capacity thresholds.

Together, these hypotheses addressed the overall hypothesis that rugby players were likely to be more susceptible to the cognitive effects of cumulative mild head injuries as revealed by tests sensitive to diffuse brain damage, than non-contact sport players.

## CHAPTER 2

### ***Methodology***

#### **2.1 PARTICIPANTS**

The subjects for this study were drawn from professional rugby players, Springboks (n=26) and from Under 21 national rugby players (n=19). The Springbok rugby players were participants in the initial phase of the research (see section 1.2.3.3, p. 27) and included all those designated professional rugby players who were selected to undergo a pre-season psychological and medical evaluation at the Sport Science Institute in Cape Town in 1997. The Under 21 rugby players were drawn from those players who were designated to undergo a pre-season psychological and medical evaluation at the Sports Science Institute in 1998. The rationale for the use of the professional rugby players was the length of their playing careers and the high level of competition to which they are exposed which makes them an appropriate experimental group on which to investigate cumulative mild head injury. The rationale for the use of the Under 21 rugby players was to provide an increased sample size of elite national sportsmen.

The non-contact sport control group consisted of national hockey players (n=21). The national hockey players were all those who were selected to play in the 1999 season. The hockey players' were not tested at their pre-season evaluation because access was denied, nevertheless they were tested pre-season on an individual basis at their homes or place of work. The rationale for the use of the national hockey squad was as follows: The previous control group in the initial phase of the research made use of professional cricket players, however this group proved not to be an ideal control group, because many players had a history of playing rugby, and they were assessed post-season as opposed to the rugby players who were assessed pre-season, thus they were observed to be poorly motivated and fatigued. The hockey squad was regarded as being an improved control group because hockey is played in the same season as rugby, which implies that hockey players would not have played both sports on any regular or long term basis.

Exclusion criteria for participants in this study were as follows: a reported history of substance abuse or any neurological disorder; a history of a non-sports-related head injury; or a previous head injury of severity greater than mild. No participants were excluded on these grounds. The majority of players in both the rugby group and the non-contact sport control group reported at least one previous mild head injury. Although the non-contact sport control group had a high incidence of previous mild head injury, this was not used as an exclusion criterion because this would have effectively excluded them as a control group. The focus of the study was to examine the effects of cumulative mild head injury and not isolated incidents of mild head injury in a player's history.

Further exclusion criteria with respect to premorbid IQ were introduced in order to match the participants in each group as closely as possible. Any players' scores which fell in the upper (IQ score greater than 140) and lower extremities (IQ score less than 85) were excluded. Thus, the results of those participants whose IQ scores were within the range of 85 to 140 were analysed. As a result of these criteria the following participants were excluded: Springbok Rugby players - no exclusions; Under 21 Rugby players - 2 exclusions (IQs below 85); Hockey players - 2 exclusions (IQs above 140) (see Appendix IV).

Thus, the final sample consisted of the following groups: Total Rugby (Springbok Rugby players and Under 21 Rugby players together) (n=45), Under 21 Rugby players (n=19), and Hockey Control (n=21). In addition, the following subgroups were constituted: Total Rugby Forwards (n=26), Total Rugby Backs (n=19), Under 21 Rugby Forwards (n=11) and Under 21 Rugby Backs (n=8). Separate analyses of the Springbok Rugby players, the Springbok Rugby Forwards and the Springbok Rugby Backs were not included in the current study because these analyses were conducted as part of the initial phase of the research by Reid (1998).

Comparative demographic data of the participants including mean age, educational level and estimated premorbid level of intellectual functioning for each group appear in the following tables. These factors are known to affect performance on cognitive tests and therefore statistical comparison of the means for each group combination was undertaken. The method for the calculation of the estimated premorbid IQ is described later (see section 2.2.1.1, p.38). Although separate analyses of the Springbok Rugby group did not form part of the present study, their comparative demographic data have been included in this table for the sake of completion and for the purposes of the subsequent discussion.

**Table 1. Demographic Data of Participants and Between Groups Mean Comparisons**

Group	N	Age			Education			Estimated Premorbid IQ		
		Mean	SD	p-value	Mean	SD	p-value	Mean	SD	p-value
Total Rugby	45	24.20	4.40	0.3674	13.40	1.74	0.0307 *	115.42	12.17	0.0306 *
Hockey Control	21	23.24	2.98		14.30	1.24		122.00	8.91	
Springbok Rugby	26	27.46	2.73	0.0000 **	14.19	1.41	0.7213	119.19	11.96	0.3763
Hockey Control	21	23.24	2.98		14.30	1.24		122.00	8.91	
Under 21 Rugby	19	19.74	0.73	0.0000 **	12.32	1.57	0.0001 **	110.26	10.72	0.0005 **
Hockey Control	21	23.24	2.98		14.30	1.24		122.00	8.91	

(Significance Level: \* p<0.05; \*\* p<0.01)

**Table 2. Demographic Data of Rugby Players and Within Groups Mean Comparisons**

Group		n	Age			Education			Estimated Premorbid IQ		
			Mean	SD	p-value	Mean	SD	p-value	Mean	SD	p-value
Total Rugby	Forwards	26	23.96	4.40	0.6755	13.27	1.73	0.5608	114.81	12.21	0.6967
	Backs	19	24.53	4.50		13.58	1.77		116.26	12.40	
Springbok Rugby	Forwards	15	27.20	2.78	0.5791	13.87	1.41	0.1754 †	117.20	12.27	0.3312
	Backs	11	27.82	2.75		14.64	1.36		121.91	11.52	
Under 21 Rugby	Forwards	11	19.55	0.52	0.1900	12.45	1.86	0.6635	111.55	11.92	0.5562
	Backs	8	20.00	0.93		12.13	1.13		108.50	9.30	

(Significance Level: \* p<0.05; \*\* p<0.01)

With regard to age, the Springbok Rugby group was significantly older than the Hockey Control group (p<0.01). The Hockey Control group was significantly older than the Under 21 Rugby group (p<0.01). However, in each case, although the age differences were statistically significant (4,2 years and 3,5 years respectively), the mean ages for each group still fell within 5 years of each other.

With regard to education, there was no difference between Springbok Rugby and Hockey Control. However, Total Rugby and Under 21 Rugby differed significantly from the Hockey Control group in that the Hockey Control had a higher mean educational level in each case ( $p < 0.05$ ;  $p < 0.01$  respectively). On average, the hockey players have approximately a year more education than the Total Rugby group and two years more education than the Under 21 Rugby group. Despite these differences, all three groups have relatively high levels of education, that is, greater than 12 years.

With regard to estimated premorbid IQ, there was no difference between Springbok Rugby and Hockey. Again, however, Total Rugby and Under 21 Rugby were significantly different from Hockey Control in that, in both instances, the estimated premorbid IQ was higher for the Hockey Control than for the other two groups ( $p < 0.05$ ;  $p < 0.01$  respectively). The mean estimated premorbid IQ of Hockey Control fell in the lower limits of the superior range of intellectual functioning, while the Total Rugby group fell in the high average range, and the Under 21 Rugby group fell in the average range. In clinical terms, a 12-15 point difference would normally be regarded as significant. Hence, Total Rugby and Hockey Control differ by only 7 points and closely approximate each other in range. However, the 12 point difference between the estimated premorbid IQ of the Hockey Control and Under 21 Rugby groups is clinically significant (average versus superior range). In sum, it appears that the differences of age and education are negligible between these groups, with the exception of the lower estimated premorbid IQ of the Under 21 Rugby group.

For all the within rugby group mean comparisons there were no significant differences between the subgroups. The Total Rugby Forwards and Total Rugby Backs, Springbok Rugby Forwards and Springbok Rugby Backs, and Under 21 Rugby Forwards and Under 21 Rugby Backs were all well matched across the variables of age, education and estimated premorbid IQ.

## **2.2 MATERIALS**

The materials for the study included a consent form, a demographic questionnaire, a symptom checklist and a neuropsychological test battery. The questionnaire was designed to offer information on educational history, sporting history, previous head injuries and other exclusion-type criteria (see Appendix II). The symptom checklist was established to tap reported postconcussive symptomatology in players, however, this checklist was not part of the database for this study and has therefore been excluded from the appendices.

### **2.2.1 The Neuropsychological Test Battery**

The test battery was designed to include tests used regularly for neuropsychological assessment in order to measure cognitive functioning across a range of modalities including attention and concentration, memory/new learning, verbal fluency, visuo-perceptual tracking and fine hand motor dexterity (Lezak, 1995). Several of the tests were chosen on the basis of their documented sensitivity to the effects of diffuse brain damage which is typically associated with closed head injury. The test battery was administered in the following order (see Appendix III): South African Wechsler Adult Intelligence Scale (SAWAIS), Digit Symbol Substitution Copy, SAWAIS Digit Symbol Substitution Immediate Recall, Trail Making Test (TMT) parts A & B, Words-in-One-Minute Unstructured Verbal Fluency Test, "S" Words Fluency Test, Sequential Finger Tapping Test, SAWAIS Digit Symbol Substitution Delayed Recall, Wechsler Memory Scale (WMS) Visual Reproduction, SAWAIS Picture Completion subtest, SAWAIS Comprehension subtest, WMS Visual Reproduction Delayed Recall, WMS Paired Associate Learning subtest, SAWAIS Digit Span subtest, Digit Supraspan, Sequential Finger Tapping repeat trial, WMS Paired Associate Learning Delayed Recall. Each test is discussed in terms of the cognitive functions it measures, and those tests which are sensitive to detecting brain damage, are indicated.

#### **2.2.1.1 Tests of General Intellectual Functioning**

Previous studies on mild head injury were weakened because they lacked premorbid data and given that premorbid ability is highly correlated with level of impairment following head injury (Lezak, 1995), it was deemed necessary that such a measure be included. Furthermore, premorbid level of intellectual functioning is important in the ability to adjust to cognitive deficit consequent on brain damage (Lezak, 1995). In order to estimate premorbid ability, two subtests which measure general cognitive functioning were drawn from the SAWAIS. The SAWAIS Comprehension subtest measures verbal reasoning and is regarded as one of the best indicators of premorbid ability in the presence of diffuse damage (Lezak, 1995). The SAWAIS Picture Completion subtest mainly measures visual reasoning but also involves visuo-perceptual and verbal abilities, and is also regarded as a good estimate of premorbid intellectual functioning. Thus the estimated premorbid IQ was based on these two scores because they tend to hold in the presence of brain damage. Moreover two subtest scores were used because Lezak (1995) suggests the use of a cluster of scores is preferable to a single raised subtest in isolation which can result in spurious estimates. A pro-rated IQ was

calculated using normal standard scores (8,5+). This method was utilized for most participants except for where a defective score of less than 8,5 was recorded. In these cases clinical judgement was used and the premorbid IQ was calculated using the highest score only because the defective score was not consistent with the participant's high level of education which tends to correlate well with IQ. This occurred in three cases (see Appendix IV: Springbok Rugby - 1 player; Under 21 Rugby -1 player; Hockey Control - 1 player).

#### 2.2.1.2 Tests of Verbal Memory

The tests of verbal memory included the SAWAIS Digits Forward and Digits Backward, Digits Supraspan (A and B), WMS Paired Associate Learning subtest, and WMS Paired Associate Learning Delayed recall. SAWAIS Digits Forwards measures immediate verbal memory but primarily assesses the subject's ability to attend without distraction (Lezak, 1995). On the other hand, SAWAIS Digits Backward taps a working memory function since the subject has to store data mentally and then manipulate it in order to provide a response. Digits Forward and Digits Backward were used as separate tests because previous research has shown that the use of combined scores or of Digits Forward alone is not recommended because these scores lack the sensitivity to detect the subtle effects of cerebral impairment, in particular, Digits Forward tends to hold relative to Digits Backward in the presence of diffuse damage (Lezak, 1995). Digit Supraspan was included because it measures verbal new learning which is sensitive to the effects of brain damage. WMS Paired Associate Learning measures old and new associate learning ability, however learning of the new pairs of words is more affected by diffuse damage and thus these scores are dealt with separately. The delayed recall of the pairs is included because delayed memory is susceptible to the effects of diffuse brain damage (Lezak, 1995) and a study by Stuss et al. (1985) found slightly lowered scores on this test in mildly head injured subjects, relative to normal controls.

#### 2.2.1.3 Tests of Visual Memory

The tests of visual memory included the SAWAIS Digit Symbol Substitution Immediate recall, SAWAIS Digit Symbol Substitution Delayed recall, WMS Visual Reproduction, and WMS Visual Reproduction Delayed recall. The Digit Symbol Substitution Immediate recall taps a recent memory function and is effective in discriminating brain damaged subjects from controls (Hart et al., 1987, in Lezak, 1995). In rugby, it is likely that the high rate of impact to the head is likely to impair Digit Symbol Substitution performance however the high level of physical fitness may have a positive effect on this test performance. The WMS Visual

Reproduction is reportedly sensitive to the effects of head trauma (Lezak, 1995) and research indicates that it differentiates mild head injured patients from non-injured controls (Stuss et al., 1985 ).

#### 2.2.1.4 Tests of Visuo-perceptual Tracking

The tests of visuo-perceptual tracking included the SAWAIS Digit Symbol Substitution Copy and TMT (Part A and B). The Digit Symbol Substitution Copy subtest has been shown to be sensitive to the effects of concussion in American football (Barth et al., 1989) and Australian Rules footballers (Maddocks and Saling, 1991). Previous research on mild head injury using the Trail Making Test has shown it to be sensitive to the effects of diffuse brain damage (Kaste et al., 1992; Leininger et al., 1990; Reid, 1998; Shuttleworth-Jordan et al., 1993). In particular, TMT Part B is likely to be susceptible to brain dysfunction because it involves complex visuo-perceptual tracking, ability to shift response set and working memory (Lezak, 1995).

#### 2.2.1.5 Tests of Verbal Fluency

The tests of verbal fluency included the Words-In-One-Minute Unstructured Verbal Fluency test and the "S" Words Verbal Fluency test. Both these tests measure verbal productivity which may be affected by any brain dysfunction (Lezak, 1995).

#### 2.2.1.6 Tests of Hand Motor Dexterity

Finally the hand motor dexterity test was Denckla's Sequential Finger Tapping test. Lezak (1995) reports that this test is sensitive to the effects of diffuse brain damage. Shuttleworth-Jordan et al. (1993) included this test of hand motor dexterity and found better performances than the controls for rugby players. Thus, it is imperative that such a measure be included because hand motor co-ordination is intrinsic to rugby, and any deficit in this area may predispose players to further injury.

### **2.3 DATA COLLECTION**

As mentioned previously, research took place in two phases. Following an initial data collection there were three levels of analysis. Following the subsequent data collection, there were three further analyses using some of the data from the initial phase of the research.

The initial set of assessments of the Springbok Rugby and cricket players were done in 1997 by three Clinical Masters researcher and three assistants trained at Rhodes University. The second set of assessments on the Under 21 Rugby players and the hockey players was undertaken in 1998 and 1999 by a new set of three Clinical Masters students, one of whom includes the present researcher, and three trained assistants from Rhodes University. One of the researchers from the initial data collection carefully discussed the procedure with the new set of researchers in order to ensure consistency of administration over the two research phases.

In both assessment phases, each participant was tested individually with testing taking approximately two hours. The nature and purpose of the research was explained to the participant and questions were encouraged. In addition, written consent was obtained. Participants were informed that the data obtained in the testing would be used for group research and publication purposes only and that individual results would remain confidential and anonymous. Tests with standardised written instructions were administered by researchers and assistants trained in administration and scoring.

## **2.4 DATA PROCESSING**

Test protocols for the Springbok Rugby and cricket players were marked and checked by the initial set of three Clinical Masters researchers using the standardised procedure. Test protocols for the Under 21 Rugby players and the hockey players were marked and checked by the second set of three Clinical Masters researchers according to the standardised procedure. In order to achieve consistency of scoring over the two research phases, one of the researchers from the initial research phase checked the scoring of the second set of researchers.

Data for the second research phase was broken up for analysis to form three separate research projects:

- (1) A direct comparison of mean scores of Total Rugby players (U21 and Springbok) versus non-contact sport Controls (Hockey) across all neuropsychological tests. In addition, analyses were conducted for the following subgroups: Springbok Rugby vs. Hockey Control, U21 Rugby vs. Hockey Control; Total Rugby Forwards vs. Total Rugby Backs; Springbok Rugby Forwards vs. Springbok Rugby Backs and Under 21 Rugby Forwards vs. Under 21 Rugby Backs.

- (2) A comparison of the mean scores of Total Rugby players with appropriate normative data and a comparison of non-contact sport Controls (Hockey) with appropriate normative data, across all neuropsychological tests. In addition, the same subgroup analyses as outlined in (1) above, were conducted relative to the appropriate normative data, except for Springbok Rugby versus the Norms, Springbok Rugby Forwards versus Norms, and Springbok Rugby Backs versus Norms because these comparisons were undertaken in Reid's (1998) study as part of the initial phase of the research. Thus, comparisons were made for the following subgroups: Total Rugby Forwards, Total Rugby Backs, Under 21 Rugby Forwards, and Under 21 Rugby Backs, with the appropriate normative data.
- (3) A comparison of the percentage of players with cognitive deficit in rugby and hockey players, relative to a normative group, as well as a comparison of the frequency of cognitive deficit and post-concussive symptomatology. In addition, the subgroup analyses outlined in (1) above, were conducted.

This study focused on the second level of analysis: A comparison of the mean scores of Total Rugby players and non-contact sport Controls (Hockey) with appropriate normative data, across all neuropsychological tests. An additional focus was comparisons of the mean scores of the following subgroups: Total Rugby Forwards, Total Rugby Backs, Under 21 Rugby Forwards, and Under 21 Rugby Backs, with the appropriate normative data, across all tests.

#### **2.4.1 Selection of Normative Data**

In recent years there has been a surge of normative data collected for a broad spectrum of commonly employed neuropsychological tests on the basis of cross-sectional studies across a wide range of adult age groups. Thus, normative data was available for most of the tests included in the neuropsychological test battery. In this study the most appropriate normative data was selected in each case. Norms for the majority of tests were derived from research conducted by Shuttleworth-Jordan (1995) which established norms for an 18-25 year old South African university student population. While this normative group was composed of male and female subjects and the current study focused specifically on male subjects, these norms were nevertheless deemed most appropriate because the norm population closely matched the rugby and hockey playing groups in terms of other variables such as age, educational level and intellectual capacity (i.e. a relatively high educational and IQ level). Norms for "S" Words Structured Verbal Fluency Test were based on those derived from Yeudall (1986). As no established normative data exist for Digit Supraspan (A and B), Digit

Symbol Substitution Delayed Recall and for WMS Paired Associate Learning Delayed Recall, these tests were excluded from the final data analysis for this particular study. In addition, the Words in One Minute Unstructured Verbal Fluency test was excluded from the present study because the administration procedures differed between the initial phase of the research and the normative research. In the initial phase of the research, players were not given examples of everyday words during the reading of the instructions, while in the normative research, subjects were given examples of words by the tester which has a facilitatory effect on the production of words (Reid, 1998). Whilst it was possible to use this test in a direct comparison, it could not be used in relation to the norms.

#### **2.4.2 Statistical Analysis**

The following statistical investigations were made:

- (1) Means and standard deviations for each group were calculated, namely: Total Rugby (U21 and Springbok), Under 21 Rugby, Hockey Control, Total Rugby Forwards, Total Rugby Backs, Under 21 Rugby Forwards, Under 21 Rugby Backs.
- (2) Independent one sample t-tests were used to compare group mean scores across all tests with the known norm value for each of those tests<sup>1</sup>, yielding the following comparisons: Total Rugby (U21 & Springbok) and Hockey Control relative to the norms; Under 21 Rugby and Hockey Control relative to the norms. (As noted above, the cricket and Springbok Rugby groups were excluded from statistical analysis because these comparisons were undertaken by Reid in 1998.) In addition, the forwards and backs of the Total Rugby and U21 Rugby groups were compared with the norms. (As noted above, the Springbok Rugby Forwards and Springbok Rugby Backs comparison with the norms, were also excluded as these had been completed in Reid's (1998) research study).
- (3) In that the t-tests showed up multiple significant mean differences between the respective rugby groups and the norms, variability was not formally analysed.

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<sup>1</sup> The normality of distribution of variables was legitimately assumed given that the tests analysed in this study are the same as those used in Jordan's (1997) research which showed that assumption of normality of distribution was valid according to the Kolmogorov-Smirnov procedure.

### **2.4.3 Statistical Hypotheses for the Study**

It was hypothesised that:

- (1) There would be significant differences in the means of those neuropsychological tests sensitive to diffuse brain damage in the direction of a poorer performance for the Total Rugby group relative to the norms, and no significant differences for the means of the Hockey Control group relative to the norms.
- (2) There would be significant differences in the means of those tests sensitive to diffuse brain damage in the direction of a poorer performance for the Under 21 Rugby group relative to the norms, and no significant differences for the means of the Hockey Control group relative to the norms.
- (3) There would be significant differences in the means of those tests sensitive to the effects of diffuse brain damage in the direction of a poorer performance for the Total Rugby Forwards and the Under 21 Rugby Forwards relative to the norms, and no significant differences for the means of the Total Rugby Backs and Under 21 Rugby Backs, relative to the norms.

Together, these statistical hypotheses addressed the overall experimental hypothesis that rugby players were likely to be more susceptible to the cognitive effects of cumulative mild head injuries as revealed by tests sensitive to diffuse brain damage, than non-contact sport players.

## CHAPTER 3

### **Results**

In this chapter, the comparative results between the participants and the appropriate norms are presented in tabular form for each group, as follows:

Total Rugby versus Norms:	Table 3
Under 21 Rugby versus Norms:	Table 4
Hockey Control versus Norms:	Table 5
Total Rugby Forwards versus Norms:	Table 6
Total Rugby Backs versus Norms:	Table 7
U21 Rugby Forwards versus Norms:	Table 8
U21 Rugby Backs versus Norms:	Table 9

In each case, a mean score, a standard deviation, a t-statistic and a p-value are reported. The significant results are then synthesized across groups in order to render the complex array of results more accessible. Significant differences are described with respect to particular tests in each functional modality, namely (1) Verbal Memory, (2) Visual Memory, (3) Visuoperceptual Tracking, (4) Verbal Fluency, and (5) Hand Motor Dexterity. The nature and direction of these differences for the affected tests are then clarified for each of the relevant groups. A bar graph illustrating significant differences from the norm across the groups is included in order to depict the consistent pattern of deficit which emerges.

#### **3.1 NEUROPSYCHOLOGICAL TEST RESULTS: COMPARISON OF MEANS**

Comparison of group mean scores with norms for all the tests administered, appear below.

**Table 3: Total Rugby versus Norms**

Test	Norms			Total Rugby			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.0	45	6.91	1.24	-4.11 **	0.0002
Digits Backward	61	6.19	1.26	45	5.67	1.52	-2.31 *	0.0259
Digit Supraspan	61	2.37	1.59	45	2.84	2.31	1.38	0.1744
ALE easy - Imm	61	8.69	0.45	45	8.74	0.44	0.84	0.4052
ALE hard - Imm	61	8.57	2.91	45	8.36	2.66	-0.54	0.5908
Vis. Rep. Imm.	61	12.39	1.54	45	11.56	1.71	-3.27 **	0.0021
Vis. Rep. Del.	61	11.54	2.04	45	11.22	1.86	-1.15	0.2573
Dig. Sym. Copy	61	53.28	9.46	45	49.59	10.20	-2.43 *	0.0194
DS inc recall - Imm	61	7.32	1.68	45	7.14	2.05	-0.57	0.5690
Trail A	61	26.13	8.57	45	28.02	8.47	1.49	0.1422
Trail B	61	54.89	17.39	45	62.41	24.25	2.08 *	0.0435
Verbal FI structured	61	16.94	5.05	45	16.24	4.70	-0.99	0.3263
Finger t 1P	61	5.32	1.22	45	5.50	1.10	1.11	0.2749
Finger t 1np	61	5.48	1.12	45	5.47	1.16	-0.04	0.9660
Finger t 2p	61	5.32	1.22	45	4.95	0.83	-3.04 **	0.0040
Finger t 2np	61	5.48	1.12	45	4.95	0.86	-4.10 **	0.0002

Significance Level: \* p<0.05; \*\* p<0.01

**Table 4: Under 21 Rugby vs. Norms**

Test	Norms			Under 21 Rugby			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.0	19	6.21	1.23	-5.18 **	0.0001
Digits Backward	61	6.19	1.26	19	5.00	1.49	-3.48 **	0.0027
Digit Supraspan	61	2.37	1.59	19	3.58	3.10	1.70	0.1060
ALE easy - Imm	61	8.69	0.45	19	8.66	0.44	-0.32	0.7555
ALE hard - Imm	61	8.57	2.91	19	8.74	2.47	0.29	0.7717
Vis. Rep. Imm.	61	12.39	1.54	19	11.00	1.97	-3.07 **	0.0066
Vis. Rep. Del.	61	11.54	2.04	19	11.11	1.85	-1.02	0.3200
Dig. Sym. copy	61	53.28	9.46	19	45.47	10.45	-3.26 **	0.0044
D.S inc. recall - Imm.	61	7.32	1.68	19	7.71	1.44	1.18	0.2515
Trail A	61	26.13	8.57	19	28.50	7.69	1.34	0.1957
Trail B	61	54.89	17.39	19	67.56	30.14	1.83	0.0834
Verbal Fl. str.	61	16.94	5.05	19	14.53	4.41	-2.38 *	0.0284
Finger t 1P	61	5.32	1.22	19	5.98	1.11	2.59 *	0.0183
Finger t 1np	61	5.48	1.12	19	6.22	1.11	2.89 **	0.0098
Finger t 2p	61	5.32	1.22	19	5.24	0.90	-0.40	0.6905
Finger t 2np	61	5.48	1.12	19	5.29	0.78	-1.07	0.3002

Significance Level: \* p<0.05; \*\* p<0.01

**Table 5: Hockey Control vs. Norms**

Test	Norms			Hockey Control			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.0	21	7.05	1.16	-2.46 *	0.0233
Digits Backward	61	6.19	1.26	21	6.43	1.63	0.67	0.5101
Digit Supraspan	61	2.37	1.59	21	2.19	1.47	-0.56	0.5820
ALE easy - Imm	61	8.69	0.45	21	8.86	0.28	2.73 *	0.0128
ALE hard - Imm	61	8.57	2.91	21	9.43	1.50	2.62 *	0.0164
Vis. Rep. Imm.	61	12.39	1.54	21	12.19	1.54	-0.59	0.5586
Vis. Rep. Del.	61	11.54	2.04	21	11.76	1.55	0.66	0.5182
Dig. Sym. Copy	61	53.28	9.46	21	57.55	7.36	2.66 *	0.0151
D.S inc. recall - Imm.	61	7.32	1.68	21	7.50	1.71	0.48	0.6348
Trail A	61	26.13	8.57	21	24.59	8.25	-0.86	0.4013
Trail B	61	54.89	17.39	21	47.58	13.43	-2.50 *	0.0214
Verbal Fl. str.	61	16.94	5.05	21	16.62	4.35	-0.34	0.7390
Finger t 1P	61	5.32	1.22	21	5.42	0.68	0.68	0.5013
Finger t 1np	61	5.48	1.12	21	5.67	0.57	1.54	0.1390
Finger t 2p	61	5.32	1.22	21	5.01	0.73	-1.93	0.0676
Finger t 2np	61	5.48	1.12	21	5.20	0.69	-1.90	0.0721

Significance Level: \* p<0.05; \*\* p<0.01

**Table 6: Total Rugby Forwards vs. Norms**

Test	Norms			Total Forwards			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.0	26	6.89	1.34	-3.00 **	0.0061
Digits Backward	61	6.19	1.26	26	5.08	1.35	-4.19 **	0.0003
Digit Supraspan	61	2.37	1.59	26	2.85	2.28	1.07	0.2961
ALE easy - Imm	61	8.69	0.45	26	8.67	0.53	-0.16	0.8715
ALE hard - Imm	61	8.57	2.91	26	7.96	2.81	-1.11	0.2795
Vis. Rep. Imm.	61	12.39	1.54	26	11.58	1.27	-3.26 **	0.0032
Vis. Rep. Del.	61	11.54	2.04	26	11.39	1.63	-0.49	0.6305
Dig. Sym. copy	61	53.28	9.46	26	45.87	8.80	-4.30 **	0.0002
D.S inc. recall - Imm.	61	7.32	1.68	26	6.85	2.15	-1.12	0.2714
Trail A	61	26.13	8.57	26	29.73	8.18	2.24 *	0.0340
Trail B	61	54.89	17.39	26	68.14	25.73	2.63 *	0.0145
Verbal Fl. str.	61	16.94	5.05	26	15.62	4.96	-1.36	0.1851
Finger t 1P	61	5.32	1.22	26	5.72	1.11	1.79	0.0853
Finger t 1np	61	5.48	1.12	26	5.77	1.00	1.45	0.1608
Finger t 2p	61	5.32	1.22	26	5.14	0.89	-1.01	0.3205
Finger t 2np	61	5.48	1.12	26	5.14	0.81	-2.17 *	0.0395

Significance Level: \* p<0.05; \*\* p<0.01

**Table 7: Total Rugby Backs vs. Norms**

Test	Norms			Total Rugby Backs			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.00	19	6.95	1.13	-2.79 *	0.0121
Digits Backward	61	6.19	1.26	19	6.47	1.39	0.89	0.3851
Digit Supraspan	61	2.37	1.59	19	2.84	2.41	0.85	0.4043
ALE easy - Imm	61	8.69	0.45	19	8.84	0.24	2.78 *	0.0124
ALE hard - Imm	61	8.57	2.91	19	8.90	2.40	0.59	0.5629
Vis Rep Imm	61	12.39	1.54	19	11.53	2.22	-1.70	0.1072
Vis Rep Del	61	11.54	2.04	19	11.00	2.16	-1.09	0.2903
Dig. Sym. copy	61	53.28	9.46	19	54.68	9.97	0.61	0.5470
D.S inc. recall - Imm.	61	7.32	1.68	19	7.55	1.89	0.54	0.5986
Trail A	61	26.13	8.57	19	25.67	8.50	-0.23	0.8176
Trail B	61	54.89	17.39	19	54.56	20.15	-0.07	0.9444
Verbal Fl. str.	61	16.94	5.05	19	17.11	4.31	0.17	0.8690
Finger t 1P	61	5.32	1.22	19	5.22	1.04	-0.42	0.6795
Finger t 1np	61	5.48	1.12	19	5.08	1.27	-1.36	0.1908
Finger t 2p	61	5.32	1.22	19	4.68	0.65	-4.29 **	0.0004
Finger t 2np	61	5.48	1.12	19	4.70	0.90	-3.80 **	0.0013

Significance Level: \* p<0.05; \*\* p<0.01

**Table 8: Under 21 Rugby Forwards vs. Norms**

Test	Norms			U21 - Forwards			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.00	11	6.18	1.40	-3.52 **	0.0055
Digits Backward	61	6.19	1.26	11	4.55	1.44	-3.79 **	0.0036
Digit Supraspan	61	2.37	1.59	11	3.64	3.14	1.34	0.2105
ALE easy - Imm	61	8.69	0.45	11	8.59	0.54	-0.61	0.5559
ALE hard - Imm	61	8.57	2.91	11	8.09	2.84	-0.56	0.5887
Vis. Rep. Imm.	61	12.39	1.54	11	11.36	1.21	-2.82 *	0.0181
Vis. Rep. Del.	61	11.54	2.04	11	11.18	1.54	-0.77	0.4576
Dig. Sym. copy	61	53.28	9.46	11	43.00	9.56	-3.57 **	0.0051
D.S inc. recall - Imm.	61	7.32	1.68	11	8.00	1.25	1.81	0.1002
Trail A	61	26.13	8.57	11	28.42	6.67	1.14	0.2818
Trail B	61	54.89	17.39	11	69.12	35.53	1.33	0.2137
Verbal Fl. str.	61	16.94	5.05	11	14.18	4.98	-1.84	0.0959
Finger t 1P	61	5.32	1.22	11	6.11	1.40	1.89	0.0887
Finger t 1np	61	5.48	1.12	11	6.37	1.06	2.78 *	0.0193
Finger t 2p	61	5.32	1.22	11	5.42	1.12	0.28	0.7838
Finger t 2np	61	5.48	1.12	11	5.33	0.90	-0.57	0.5831

Significance Level: \* p<0.05; \*\* p<0.01

**Table 9: Under 21 Rugby Backs vs. Norms**

Test	Norms			U21 - Backs			t-Statistic	p-value
	n	Mean	SD	n	Mean	SD		
Digits Forward	61	7.67	1.00	8	6.25	1.04	-3.88 **	0.0061
Digits Backward	61	6.19	1.26	8	5.63	1.41	-1.14	0.2937
Digit Supraspan	61	2.37	1.59	8	3.50	3.25	0.98	0.3584
ALE easy - Imm	61	8.69	0.45	8	8.75	0.27	0.63	0.5456
ALE hard - Imm	61	8.57	2.91	8	9.63	1.60	1.87	0.1041
Vis. Rep. Imm.	61	12.39	1.54	8	10.50	2.73	-1.96	0.0906
Vis. Rep. Del.	61	11.54	2.04	8	11.00	2.33	-0.66	0.5331
Dig. Sym. copy	61	53.28	9.46	8	48.88	11.29	-1.10	0.3063
D.S inc. recall - Imm.	61	7.32	1.68	8	7.31	1.67	-0.01	0.9902
Trail A	61	26.13	8.57	8	28.61	9.40	0.75	0.4795
Trail B	61	54.89	17.39	8	65.43	22.88	1.30	0.2340
Verbal Fl. str.	61	16.94	5.05	8	15.00	3.78	-1.45	0.1899
Finger t 1P	61	5.32	1.22	8	5.80	0.59	2.33	0.0526
Finger t 1np	61	5.48	1.12	8	6.01	1.22	1.22	0.2614
Finger t 2p	61	5.32	1.22	8	4.99	0.41	-2.28	0.0566
Finger t 2np	61	5.48	1.12	8	5.24	0.64	-1.07	0.3190

Significance Level: \* p<0.05; \*\* p<0.01

## 3.2 SUMMARY OF SIGNIFICANT RESULTS BY TEST

### 3.2.1 Verbal Memory

#### 3.2.1.1 SAWAIS Digits Forward

For every group mean comparison relative to the normative data, a significant difference was revealed on the Digits Forward subtest in the direction of a *poorer* performance. The following groups were all highly significant comparisons in the direction of a *poorer* performance: Total Rugby versus the norms, Under 21 Rugby versus the norms, Total Rugby Forwards versus the norms, Under 21 Rugby Forwards versus the norms and Under 21 Rugby Backs versus the norms ( $p < 0.01$ ;  $p < 0.01$ ;  $p < 0.01$ ;  $p < 0.01$  respectively). Hockey Control relative to the norms and Total Rugby Backs relative to the norms were also significantly different in the direction of a *poorer* performance than the norm ( $p < 0.05$ ;  $p < 0.05$  respectively).

#### 3.2.1.2 SAWAIS Digits Backward

Several group mean comparisons relative to the normative data revealed a significant difference for the Digits Backward subtest all in the direction of a *poorer* performance than the norm. These included the following groups: Total Rugby versus the norms, Under 21 Rugby versus the norms, Total Rugby Forwards versus the norms, Under 21 Rugby Forwards versus the norms ( $p < 0.05$ ;  $p < 0.01$ ;  $p < 0.01$ ;  $p < 0.01$  respectively). On the other hand, the group mean comparisons relative to the normative data which did not yield a significant difference included: Hockey Control versus the norms, Total Rugby Backs versus the norms, and Under 21 Rugby Backs versus the norms.

#### 3.2.1.3 WMS Paired Associate Learning Immediate Recall

Several mean comparisons, relative to the normative data, revealed a significant difference on the immediate recall of WMS Paired Associate Learning (Easy) in the direction of a *better* performance than the norm. These included Hockey Control versus the norms and Total Rugby Backs versus the norms ( $p < 0.05$ ;  $p < 0.05$  respectively). In addition, Hockey Control versus the norms showed a significant difference for the immediate recall of the WMS Paired Associate Learning (Hard) in the direction of a *better* performance than the norm ( $p < 0.05$ ). There were no significant differences in the direction of a poorer performance relative to the normative data.

## **3.2.2 Visual Memory**

### **3.2.2.1 WMS Visual Reproduction Immediate Recall**

Several group mean comparisons showed significant differences from the normative data norm on WMS Visual Reproduction Immediate Recall test in the direction of a *poorer* performance. These included Total Rugby versus the norms, Under 21 Rugby versus the norms, Total Rugby Forwards versus the norms, and Under 21 Rugby Forwards versus the norms ( $p < 0.01$ ;  $p < 0.01$ ;  $p < 0.01$ ;  $p < 0.05$  respectively).

## **3.2.3 Visuoperceptual Tracking**

### **3.2.3.1 SAWAIS Digit Symbol Substitution Copy**

Certain groups revealed a significant difference from the norms in the direction of a *poorer* performance than the norm. These included Total Rugby versus the norms, Under 21 Rugby versus the norms, Total Rugby Forwards versus the norms, and the Under 21 Rugby Forwards versus the norms ( $p < 0.05$ ;  $p < 0.01$ ;  $p < 0.01$ ;  $p < 0.01$  respectively). However, the Hockey Control group showed a significant difference from the norm in the opposite direction, in that performance was *better* than the norm ( $p < 0.05$ ).

### **3.2.3.2 Trail Making Test Part A**

The Total Rugby Forwards showed a significant difference from the norms in the direction of a *poorer* performance on this test ( $p < 0.05$ ), whereas no other groups showed significant differences from the norm.

### **3.2.3.3 Trail Making Test Part B**

Two groups were significantly different from the norm in the direction of a *poorer* performance on the Trail B, that is, Total Rugby versus the norm and Total Rugby Forwards versus the norm ( $p < 0.05$ ;  $p < 0.05$  respectively). On the other hand, the Hockey Control group was significantly different from the norm in the direction of a *better* performance than the norm on this test ( $p < 0.05$ ).

### **3.2.4 Verbal Fluency**

#### **3.2.4.1 Structured Verbal Fluency**

The Under 21 Rugby group was significantly different from the norm in the direction of a *poorer* performance than the norm, on this test ( $p < 0.05$ ).

### **3.2.5 Hand Motor Dexterity**

#### **3.2.5.1 Finger Tapping Test**

Several mean comparisons relative to the normative data revealed significant differences on the Finger Tapping test but these differences appeared to go in varying directions depending on the group, and the first or second trial.

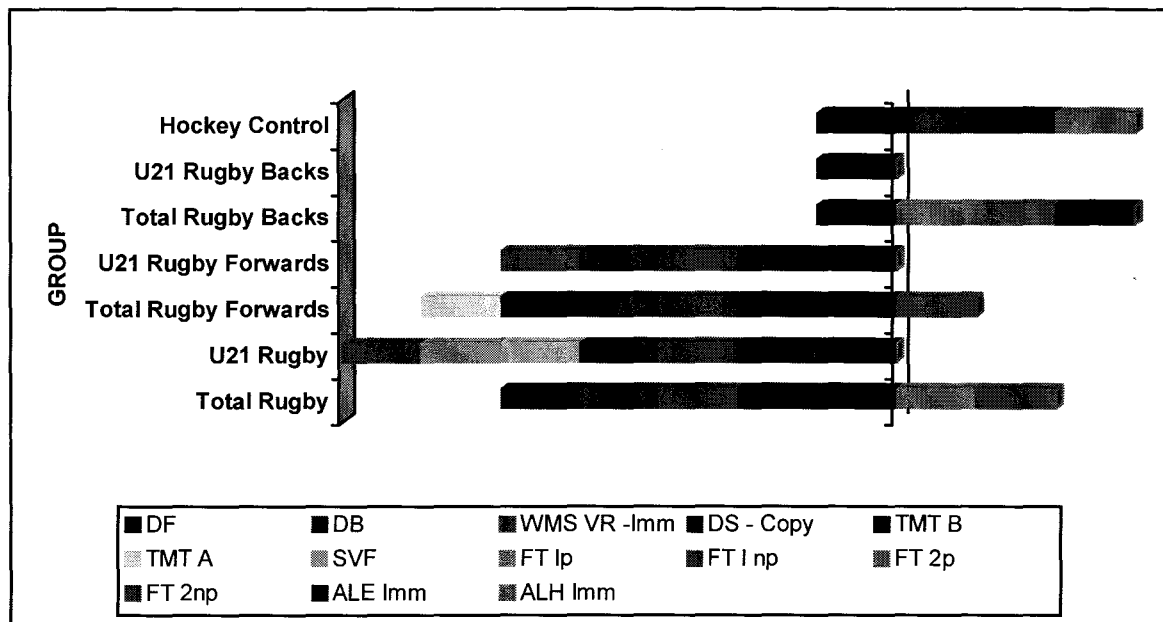
The Under 21 Rugby group was significantly different from the norm in the direction of a *poorer* performance on the first trial of the preferred hand ( $p < 0.05$ ). The Under 21 Rugby group and the Under 21 Rugby Forwards were significantly different from the norm in the direction of a *poorer* performance on the first trial of the non-preferred hand ( $p < 0.01$ ;  $p < 0.05$  respectively).

The Total Rugby group and the Total Rugby Backs were significantly different from the norm in the direction of a *better* performance than the norm on the second trial of the preferred hand ( $p < 0.01$ ;  $p < 0.01$  respectively). The Total Rugby, Total Rugby Forwards and Total Rugby Backs were significantly different from the norm in the direction of a *better* performance on the second trial of the non-preferred hand ( $p < 0.01$ ;  $p < 0.05$ ;  $p < 0.01$  respectively).

### **3.3 SYNTHESIS OF SIGNIFICANT RESULTS ACROSS GROUPS**

The following stacked bar graph depicts significant differences from the norm for each group across the specific tests that have been outlined above. The line across the centre of the graph represents the norm; bars on the left of that line indicate a *poorer* performance than the norm; and bars on the right of that line indicate a *better* performance than the norm. Of interest to the reader in the examination of the following graph, is the trend across the groups for the significant tests.

**Figure 1. Significant Differences of Group Mean from Norm**



The graph illustrates that the Total Rugby, Under 21 Rugby, Total Rugby Forwards and Under 21 Rugby Forwards tend to form a cluster and perform more *poorly* than the norm on the following tests: Digits Backward, WMS Visual Reproduction Immediate Recall and Digit Symbol Substitution Copy. This pattern is continued with Total Rugby and Total Rugby Forwards being significantly different in the direction of a *poorer* performance than the norm on the Trail Making Test Part B. In contrast, the Hockey Control not only performs within the normal range for two of these tests, that is, Digits Backward and WMS Visual Reproduction Immediate Recall, but also performs *better* than the norm for the other two tests, namely, Digit Symbol Substitution Copy and Trail Making Test Part B.

The graph also shows that some groups achieve statistically significant results on an isolated basis, for example, the Total Rugby Forwards were significantly different in terms of a *poorer* performance relative to the norm on the Trail Making Test Part A and the Under 21 Rugby group was significantly different in the direction of a *poorer* performance relative to the norm on the Structured Verbal Fluency test. In the Finger Tapping Test, Under 21 Rugby performed more *poorly* than the norm on the first trial of the preferred hand, and Under 21 Rugby and Under 21 Rugby Forwards were significantly different in terms of a *poorer* performance than the norm on the first trial of the non-preferred hand. On the other hand, Hockey Control was significantly different from the norm in terms of a *better* performance on the WMS Paired Associate Learning Immediate Recall (Easy and Hard) test, and the Total

Rugby Backs were *better* than the norm on the WMS Paired Associate Learning Immediate Recall (Easy). However, there is consistency in these results of the isolated groups in that, taken together, they are commensurate with the general trend for the rugby groups and the rugby forward groups to fall below the norm and for the hockey control and rugby backline groups to fall in the normal range or above the norm.

This trend across groups was not supported by the Digits Forward subtest and the second trial of the Finger Tapping Test. All the groups were significantly different from the norm in the direction of a *poorer* performance on the Digits Forward subtest, and Total Rugby and Total Rugby Backs were *better* than the norm on the second trial of the preferred and non-preferred hands of the Finger Tapping test, and Total Rugby Forwards were significantly *better* than the norm on the second trial of the non-preferred hand.

In sum, it becomes evident that the consistent pattern of deficit which emerges, is for the two rugby groups (Total Rugby and Under 21 Rugby) to perform more *poorly* than the norm across specific tests, while Hockey Control, not only tends to perform within normal limits across some of these tests, but also performs *better* than the norm for certain tests. Furthermore, with regard to the subgroup comparisons, a similar pattern is apparent in that the forward players (Total Rugby Forwards and Under 21 Rugby Forwards) perform more *poorly* than the norm across specific tests, while the backline players (Total Rugby Backs and Under 21 Rugby Backs) tend to perform within the normal range across some of these tests, and sometimes perform *better* than the norm across other tests.

### **3.3.1 Additional Examination of Results**

#### **3.3.1.1 Variability**

Whilst this study did not examine variability data specifically, further examination of Under 21 Rugby and Under 21 Rugby Forwards on the TMT Part B, indicates that although they do not achieve statistically significant results relative to the norms, their respective group means and standard deviations show that scores tend to fall below the norm together with considerable variability around the mean (Norm mean: 54.89, SD: 17.39; Under 21 Rugby mean: 67.56, SD: 30.14; Under 21 Rugby Forwards mean: 69.12, SD: 35.53). This trend is consistent with Total Rugby and the Total Rugby Forwards, which show deficit on this test.

## **CHAPTER 4**

### ***Discussion***

In this chapter, the experimental hypotheses are examined in relation to the results of the statistical analysis. The significant results are discussed and synthesized with previous empirical research. Then the broader theoretical implications of the results are explored and conclusions are drawn. Finally, the methodological strengths and limitations of the study are evaluated and recommendations for future research are made.

#### **4.1 AIMS AND HYPOTHESES OF THE STUDY**

This research set out to examine the cognitive effects which result from cumulative mild head injuries in rugby. The focus for this study was a comparison of the cognitive profiles of rugby players and non-contact sport matched controls to a comparable normative group. An additional focus was the comparison of the cognitive profiles of rugby forward players and rugby backline players, relative to the normative data. It was hypothesized that rugby players, compared to the non-contact sport hockey control group, would exhibit poorer performances relative to the normative group, on neuropsychological tests sensitive to the effects of diffuse brain damage. Further, it was hypothesized that rugby forward players, compared to rugby backline players, would show impaired performances relative to the normative data on tests sensitive to the effects of mild head injury. These hypotheses were based on the assumption that rugby players are liable to sustain more mild head injuries than hockey players, because of the physical nature of the play, and further, that rugby forward players are more likely to be exposed to such injuries than rugby backline players, because of the former's more intensive involvement in tackling and scrumming. In general, the results of this study indicate that rugby players compared to the hockey players show a pattern of significant differences, relative to the norms, on tests known to be sensitive to the effects of mild head injury. Furthermore, results indicate that rugby forward players compared to rugby backline players show a pattern of significant differences, relative to the norms, on tests known to be sensitive to the effects of mild head injury. Therefore, the above experimental hypotheses can be accepted. These findings are discussed in more depth below.

## **4.2 DISCUSSION OF SIGNIFICANT RESULTS**

### **4.2.1 Verbal Memory**

#### **4.2.1.1 SAWAIS Digits Forwards**

All groups showed impaired performances, relative to the norms, on this test which measures efficiency of attention or 'freedom from distractability' (Lezak, 1995). Scores may fall below normal limits in the first few months following head trauma (Lezak, 1995), however this test tends to hold well, relative to the Digits Backwards subtest, in the presence of diffuse brain damage. The lowered performance across all groups relative to the norms does not reflect the presence of brain damage but some other factor which affected all participants such as anxiety, inefficient attention, or an inappropriate normative score. This test was administered near the end of the neuropsychological battery therefore it seems unlikely that anxiety could have affected participants' performance. The question as to whether this normative score is an appropriate comparative standard would be best addressed by further research involving the use of a different norm. The global lowered scores may reflect all the participants' inefficient attention to the task which they regarded as somewhat simplistic in the light of their generally high intellectual ability, and then tended to utilize their intellectual resources more fully on the Digits Backward task. Generally, however, equivalence of the scores across all rugby groups and the control group implies that the test has held, and has not been subject to significant brain damage effects.

#### **4.2.1.2 SAWAIS Digits Backwards**

The Total Rugby and the Under 21 Rugby; and the rugby forwards in each of these groups, recorded a poorer performance relative to the norms on this subtest, whereas the Hockey Control and the rugby backline players were not significantly different from the norms. This test is primarily a test of working memory and is relatively sensitive to the effects of diffuse brain damage (Lezak, 1995). The impaired performances by the rugby players and the rugby forward players in particular, suggests that their ability to store information and to mentally reverse this information simultaneously, has dropped off relative to the norms. This finding is consistent with the study by Shuttleworth-Jordan et al. (1993) which found that rugby players, and forward players in particular, show a reduced level of functioning in working memory as measured by the Digits Backwards subtest. Furthermore, it confirms Reid's (1998) research which found impaired performances by rugby forward players relative to normative

data, compared with rugby backline players on the Digits Backwards subtest.

#### 4.2.1.3 WMS Paired Associate Learning Immediate Recall

The Hockey Control and Total Rugby Backs perform better than the norm on the easy pairs of this test and the Hockey Control group performs better than the norm on the hard pairs. Given that the easy pairs measure old acquired knowledge, what is of interest is the function of verbal new learning, reflected in the recall of hard pairs, and known to be sensitive the effects of diffuse brain damage (Lezak, 1995). This function appears to be highly developed in the Hockey Control group, whereas, the rugby groups, and the rugby forwards fall within the normal range. The implication is that the latter groups have dropped off into the normal range from their premorbid potential.

### **4.2.2 Visual Memory**

#### 4.2.2.1 WMS Visual Reproduction Immediate Recall

The rugby groups, and the rugby forward players in particular, recorded significantly poorer performances relative to the norms on this test. This finding is consistent with a study which showed that this test distinguished mild head injury patients from controls (Stuss et al., 1985). This test measures visual memory for designs, and is sensitive to the effects of head trauma with the delayed recall being more sensitive than the immediate recall (Lezak, 1995). Based on the composite rugby groups and the rugby forward groups poor performance on the immediate trial, it would be expected that they would exhibit a poor performance on the delayed trial if there was impairment in the visual memory function. However, this was not the case in that they did not differ significantly from the norms on the delayed trial. It is possible that the poor performance of the composite rugby groups and the rugby forward players on the immediate recall and the normal performance on the delayed trial reflects the presence of slowed information processing in these groups resulting in an improvement on the delayed task, and/or the poor performance on the immediate recall may reflect attentional problems consequent on compromised cerebral functioning.

### **4.2.3 Visuo perceptual Tracking**

#### 4.2.3.1 SAWAIS Digit Symbol Substitution Copy

Results show that the rugby groups and the rugby forwards in particular were impaired on this test relative to the normative data. This test measures sustained attention, response speed

and visuomotor co-ordination and is regarded as being highly sensitive to diffuse brain damage in that it has the capacity to detect deficits in functioning even with minimal damage (Lezak, 1995). Thus, it is evident that speed of information processing as measured by this test is impaired in rugby players and rugby forward players relative to the norms. The Hockey Control group performed better than the norms on this test, which further serves to accentuate the potency of the negative outcome for the rugby players. This result is consistent with other studies which have shown the Digit Symbol Substitution test as being sensitive to the effects of mild head injury in American football (Barth et al., 1989), in Australian Rules football (Maddocks and Saling, 1991), in rugby league (Hinton-Bayre et al., 1997) and in rugby union (Dickinson, 1998). However, this result is inconsistent with a study by Maddocks, Saling and Dicker (1995) which found normal performances in Australian Rules footballers on the Digit Symbol subtest at six months post injury. This inconsistency may be accounted for by the fact that games of rugby and Australian Rules football differ, and that Maddocks et al. (1995) investigated the effects of a single concussive episode and did not include a non-football playing control group, whereas the current study was concerned with the cumulative effects of several concussive episodes and had a control group. Thus, it appears that Digit Symbol reveals effects in the first weeks following a concussion (in accordance with previous research), but that persistence of deficit on this test may only become apparent after repeated exposure to mild head injuries.

#### 4.2.3.2 Trail Making Test

This test is highly sensitive to the effects of brain damage because it involves both motor speed and attention (Lezak, 1995). In particular, TMT Part B, involves more complex conceptual tracking and a greater degree of mental flexibility than Part A, because the individual is required to divide his/her attention between more than one stimulus at a time (Lezak, 1995). The impaired performance of the Total Rugby Forwards relative to the norms on the TMT Part A suggests a slowed capacity for visual scanning. This group performs better than the norm on the second trial of hand motor dexterity, which suggests it is not the motor component of this test which impairs their performance. The result of impaired performances relative to the norms on the TMT Part B for the Total Rugby and Total Rugby Forwards and for a strong trend in this direction for Under 21 Rugby and Under 21 Rugby Forwards suggests that playing rugby, and playing in forward positions in particular, contributes to deficits in mental flexibility, divided attention and visuoperceptual tracking. The superior performance of the Hockey Control group relative to the norms, on this test

accentuates the negative outcome for the rugby players. This finding is consistent with other studies which have found impaired performances on the TMT for mild head injury patients (Leininger et al., 1990), for boxers (Kaste et al., 1992), for American football players (Barth et al., 1989) and for rugby players (Dickinson, 1998; Reid, 1998; Shuttleworth-Jordan et al., 1993).

#### **4.2.4 Verbal Fluency**

##### **4.2.4.1 Structured Verbal Fluency**

The Under 21 Rugby group's lowered performance relative to the norm suggests that this group had difficulty with structured verbal fluency. This result may not necessarily reflect compromised cerebral functioning but may reflect the group's average intellectual potential in relation to the norms which derive from a university population that is likely to consist of subjects with an above average intellectual potential.

#### **4.2.5 Hand Motor Dexterity**

##### **4.2.5.1 Finger Tapping Test**

The Under 21 Rugby group and the forwards in this group, were impaired relative to the norm on the first trial of this test but on the second trial their performance fell within the normal range indicating improvement with practice. It seems likely that this result does not reflect hand motor slowing, but rather that their ability to process the information rapidly, may have been impaired on the initial trial. The faster performance than the norm for the Total Rugby groups and for the Total Rugby Backs on the second trial of this test is consistent with previous research which indicates that rugby players tend to exhibit enhanced hand motor dexterity relative to controls (Shuttleworth-Jordan et al., 1993).

#### **4.2.6 Synthesis**

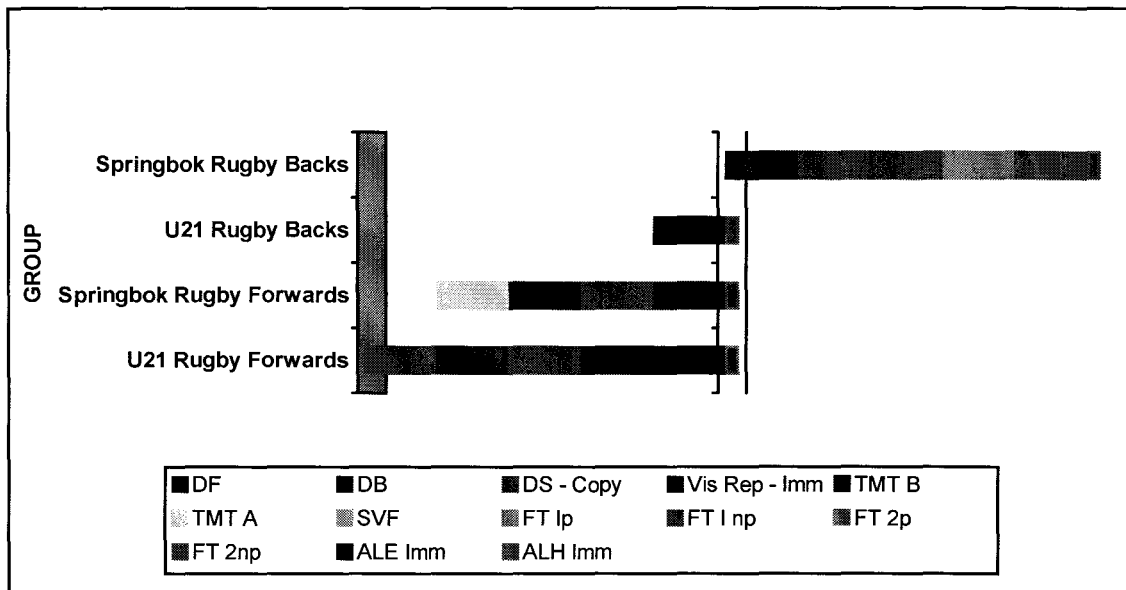
The following tests proved to be the most sensitive in detecting a pattern of significant difference for the rugby players compared to the hockey players, relative to the norms, and for the rugby forward players compared to rugby backline players, relative to the norms: SAWAIS Digits Backwards, WMS Visual Reproduction Immediate Recall, SAWAIS Digit Symbol Substitution Copy and Trail Making Test Part B. Taken together, these tests suggest impairment in the following functions: working memory, rate of information processing and visuoperceptual tracking at speed. The remarkably consistent pattern of deficit across the

same tests for the rugby players and particularly, the rugby forward players suggests that the effect points to a larger influence than just measurement artifacts. It appears that the compromised cerebral functioning on tests sensitive to the effects of diffuse damage in the rugby players reflects the *multiple* mild head injuries which they sustain in playing the game. Further, given the adequate performance of the rugby backline players on these tests, it seems likely that the evidence of cognitive deficit in the forward players reflects their increased frequency of mild head injuries. Although several other tests only revealed a significant difference for a single group relative to the norm, these isolated results were consistent with the pattern in which the full rugby groups, and the rugby forward players perform below the norm on specific tests, while the control group and the backline players fall in the normal range or above the norm for some tests.

#### 4.2.6.1 Synthesis of Results of Under 21 Rugby Forwards and Backs with Springbok Rugby Forwards and Backs

Given the consistent pattern of deficit, which emerged in the current results, it was decided to examine whether or not this pattern was consistent with the results for the Springbok Rugby players obtained by Reid (1998) in the initial phase of the research. Thus, the following stacked bar graph synthesizes the current results for the Under 21 Rugby Forwards and Under 21 Rugby Backs, relative to the norms, in relation to Reid's (1998) results for the Springbok Rugby Forwards and Springbok Rugby Backs, relative to the norms. Again, the line across the centre of the graph represents the norm; bars on the left of that line indicate a poorer performance than the norm; and bars on the right of that line indicate a better performance than the norm.

**Figure 2. Significant Differences of Under 21 Rugby Forwards and Backs, and Springbok Rugby Forwards and Backs, relative to Norm**



The graph illustrates that the Springbok Rugby Forwards and Under 21 Rugby Forwards form a cluster and perform more *poorly* than the norm on the following tests: Digits Backward and Digit Symbol Substitution Copy. In contrast, the Springbok Rugby Backs perform *better* than the norm on these two tests. Furthermore, several isolated tests for single groups relative to the norm are consistent with this trend for the rugby forwards to perform below the norm, while the rugby backs perform in the normal range or above the norm. The Under 21 Rugby Forwards perform more *poorly* than the norm on WMS Visual Reproduction Immediate Recall and on the first trial of the Finger Tapping non-preferred hand, and the Springbok Rugby Forwards perform more *poorly* than the norm on the Trail Making Test (Part A and B). In contrast, the Springbok Rugby Backs performed *better* than the norm on the first trial of the Finger Tapping Test non-preferred hand and on the second trial of the Finger Tapping Test (preferred and non-preferred hand). This trend across groups was not supported by the Digits Forward subtest. The Under 21 Rugby Forwards and Under 21 Rugby Backs were both significantly different from the norm in the direction of a *poorer* performance on the Digits Forward subtest. However, as noted above (see section 4.2.1.1, p. 59), the equivalence of the Digits Forwards subtest across all groups in the results of the current study, implies that this test has held, and hasn't been subject to significant brain damage effects. Therefore, this finding does not contradict the consistent pattern evident in the above graph.

Thus, the pattern of deficit for the rugby forwards to perform more *poorly* than the norm across specific tests, while the rugby backs perform in the normal range or *better* than the norm on certain tests, is consistent across the current study and that of Reid (1998). In addition, across the two studies, the Digit Symbol Substitution Copy and SAWAIS Digits Backwards appear to be the tests most sensitive in detecting a pattern of deficit for the rugby forward players relative to the norms. These tests suggest impairments in working memory and visuo-perceptual tracking at speed. Taken together, these studies provide strong evidence for compromised cerebral functioning in rugby forward players, and these deficits reflect the *multiple* mild head injuries sustained in playing the game.

#### 4.2.6.2 Synthesis of Results in relation to Demographic Data

The question arises as to the influence of the demographic data on the current results. As noted in Chapter 2 (see Table 1, section 2.1, p. 36), there were statistical differences between the groups on age, educational level and estimated premorbid IQ. Nevertheless, in clinical terms these differences were negligible except for the difference in range of intellectual functioning for the Hockey Control and Under 21 Rugby (superior and average respectively). If the demographic data were confounding the results in any way, then a global lowering of test scores relative to the norms, would have been expected for the Under 21 players. However, not all the tests fell off relative to the norms, indicating that they tend to be on the same level of intellectual functioning. Similar to the Total Rugby group and Springbok Rugby group, the Under 21 Rugby group tended to fall off relative to the norms on tests which are more sensitive to diffuse brain damage. Moreover, the rugby forwards and backs in the rugby playing groups showed no significant differences on the demographic data (see Table 2, section 2.1, p.36), thus the fact that the backline players hold on the majority of the tests further mediates against the demographic data accounting for the results.

#### 4.2.7 Implications

Overall, these results imply that rugby players were more susceptible to the cognitive effects of *cumulative* mild head injuries as revealed by tests sensitive to diffuse brain damage, than non-contact sport players. The results support previous research which has found cognitive deficit consequent on mild head injury in soccer (Baroff, 1998; Matser et al., 1998; Tysvaer and Lochen, 1991), in American football (Barth et al., 1989), in Australian Rules football players (Cremona-Meteyard & Geffen, 1994; Maddocks and Saling, 1991) and in rugby league players (Hinton-Bayre et al., 1997). The findings also confirm previous research by

Gronwall (1989) and Gronwall and Wrightson (1975) which found that cumulative mild head injury increases the risk of permanent cognitive deficit. In addition, the findings corroborate previous findings that forward players are more susceptible to deficit than backline players (Dickinson, 1998; Shuttleworth-Jordan et al., 1993) and further support Barth et al.'s (1989) finding that players in the offensive line sustain the most head injuries. Moreover, these findings are consistent with neuropsychological studies on mild head injury in general which have found impairments in information processing (Barth et al., 1983; Gronwall, 1989; Leininger et al., 1990), working memory (Raskin et al., 1998) and visuoperceptual tracking at speed (Matser et al., 1998) consequent on mild head injury.

One of the most valuable and interesting implications of the current findings is that they are consistent with pattern of deficit, which emerged in Reid's (1998) results. Whilst the Springbok Rugby players in Reid's (1998) results did not show a pattern of significant difference, relative to the norms, on tests sensitive to the effects of mild head injury, they did show increased variability about the group mean, suggesting a trend towards impaired performance for some individuals within the group. However, in the current study, this effect was immediately reflected in a declining central tendency for the rugby groups relative to the norms. The more immediate presence of difference in overall means in the present study is probably due to the increased numbers of participants in the expanded study. Furthermore, replication of the results of the Springbok Rugby forward and backline players in the Under 21 Rugby forward and backline players implies that results can be more readily generalized to elite rugby players across a broader range of age, educational level and level of general intellectual functioning. Finally, whilst Reid's (1998) results did not show significant differences for the cricket control group relative to the norms, the current study indicates that the Hockey Control group tends to perform within the normal range across the majority of tests and above the norm on specific tests which exhibited impairment for the rugby playing groups. This heightened performance of the hockey players relative to the norms serves to enhance the visibility of the compromised functioning of the rugby players, suggesting that the use of the hockey players as a control group in the current study was an improvement on the cricket players in Reid's (1998) study.

### **4.3 THEORETICAL IMPLICATIONS OF RESULTS**

The abovementioned findings lend support for the Satz (1993) theory of brain reserve capacity and the Shuttle model of variability (Jordan, 1997).

#### **4.3.1 Positional Variability of Effects**

Results confirm the hypothetical indications that differences between the groups in cognitive test performance, relative to the normative data, was influenced by individual differences in levels of brain reserve capacity which served to alter the threshold of vulnerability to, and protection against, the onset of symptoms of cerebral pathology. In particular, it was hypothesized that the aggregate of multiple exposure to mild head injuries in rugby players would serve as a threshold-lowering influence associated with earlier symptom onset. Further, it was expected that playing in a forward position would have an effect on cognitive test performance and lower the critical threshold at which impairment became evident. In the light of the findings of this study, it appears that these hypotheses can be accepted. This is discussed further below.

Brain reserve capacity is said to be indirectly reflected by general intelligence and educational level. The Total Rugby and Under 21 Rugby groups compared to the Hockey Control group differed significantly on the variables of general intelligence and educational level, in that the general intellectual functioning of the Under 21 Rugby group falls in the average range, the Total Rugby group falls in the above average range, and the Hockey Control group falls in the superior range, and Hockey Control has a higher mean educational level than both Total Rugby and Under 21 Rugby (see Table 1, section 2.1, p.36). Nevertheless, in clinical terms the differences between these groups on these variables is not especially significant, except for the difference between the intellectual functioning of the Hockey Control and that of the Under 21 Rugby group. With respect to the latter group (Under 21 Rugby), it is not possible to discount the influence of these variables on results, and assume an equivalent level of functioning and similar premorbid brain reserve capacities. Rather, in terms of BRC theory, it seems likely that differences in results are likely to be a function of the aggregate effects of these factors, in association with the risk factor of head injuries, which serve to raise or lower the brain reserve threshold. Generally, the above average intellectual potential and high educational level of the rugby and hockey players act as protective factors which together with the additional protective factor of a relatively young age, serve to raise the threshold of symptom onset. However, the reduced scores for the full

rugby groups compared to the hockey group, relative to the norms, suggests that the rugby players have succumbed to some neuropsychological impairment. It seems likely that it is the cumulative effects of mild head injury in the rugby playing groups that acts as a vulnerability factor and lowers their critical thresholds such that the onset of cognitive difficulties becomes evident. In addition, it is possible that, in terms of BRC theory, the lower educational level and intelligence of the Under 21 Rugby group, relative to the other groups, in association with the mild head injury effects may have served to enhance their vulnerability to symptom presentation such that they exhibited impairments across more tests than the other groups (see Figure 1, section 3.3, p. 56).

Importantly, the Total Rugby Forwards and Total Rugby Backs, and the Under 21 Rugby Forwards and Under 21 Rugby Backs showed no significant difference on the variables of general intelligence and educational level (see Table 2, section 2.1, p. 36). Thus it can be assumed that their level of functioning is equivalent and that they have similar premorbid brain reserve capacities. The results of this study indicate that the rugby forward players compared to the rugby backline players, relative to the norms, have succumbed to neuropsychological impairment, which implies that the forward player's heightened exposure to mild head injury has lowered their critical thresholds such that they are no longer able to adjust to their deficit and thus manifest cognitive symptoms on tests sensitive to the effects of diffuse brain damage.

The rugby backline scores do not show any apparent impairment as yet, suggesting that despite some exposure to mild head injuries, they still have the capacity to adjust to deficits and to be protected from exhibiting symptoms of functional pathology. Nevertheless, they are at risk for lowering their brain reserve capacity as a result of further exposure to head injuries, in line with research by Gronwall (1989) and Gronwall and Wrightson (1975). Furthermore, secondary stressors may temporarily lower their critical thresholds and expose underlying symptomatology. This would be consistent with previous research which has shown that cognitive deficits in 'recovered' mild head injury patients become evident under hypoxic conditions (Ewing et al., 1980). Furthermore, in the light of Jordan's (1997) research on aging, it seems likely that as the rugby backline players grow older, the aging process may further serve to diminish their brain reserve capacities and increase their vulnerability to symptom onset.

Although, this study did not formally investigate variability data and only examined central trends, it is still possible to consider the implications of the results in this light. As can be seen from the results, TMT Part B revealed a strong tendency of increased variability for the Under 21 Rugby group and the Under 21 Rugby Forwards, although there was no significant difference on the means, relative to the norms. Further, more generally, within the Total Rugby and Under 21 Rugby groups, a bimodal distribution is indicated with the forwards manifesting impairment on the more challenging neuropsychological tests, while the backline players do not. This implies increased variability in scores within the composite rugby groups, relative to the norms, with forward and backline players' scores tending to vary about the group mean. Thus, a shuttle effect occurs, with enhanced variability for the rugby players compared with the non-contact sport controls due to the aggregate of threshold-lowering influences of multiple exposure to mild head injuries (Jordan, 1997). This effect is consistent with Reid's (1998) results which showed increased variability of Springbok Rugby players about the mean, suggesting the onset of a marked decline in ability for some individuals in the group.

#### **4.3.2 Task specific effects**

Furthermore, in terms of BRC theory, it was anticipated that tests less sensitive to head injury effects would present less challenge to brain reserve capacity thresholds, and those tests sensitive to brain damage would present more challenge to brain reserve capacity thresholds, resulting in differential effects for the various tests with some showing more marked differences than others. This was indeed the case, with specific tests such as the SAWAIS Digits Backwards, WMS Visual Reproduction Immediate recall, Digit Symbol Substitution Copy and Trail Making Test Part B tending to fall off relative to the norms, while tests such as SAWAIS Digits Forwards and the Trail Making Test Part A showed relative preservation and held across the groups. It seems likely that the aggregation of the high task challenge associated with the former tests and the lowered brain reserve capacity threshold due to cumulative mild head injury accentuated the risk of functional impairment in the rugby players and in the rugby forward players in particular. Conversely, in spite of the high challenge, the raised brain reserve capacity threshold due to the absence of cumulative mild head injury in the hockey control group reduced the risk of functional impairment and they showed no deficits. In addition, the low task challenge of the latter tests failed to precipitate functional impairment even in the face of the lowered brain reserve capacity of the rugby groups.

#### 4.4 EVALUATION OF THE STUDY

The strengths of this study include the following:

- (1) The study meets five of Satz et al. (1997) essential criteria for methodologically strong research, namely, (1) a control group (2) a clear definition of head injury (3)  $n > 20$  mild head injury cases (4) standardized tests, and (5) control for pre-injury risk factors.
- (2) The use of rugby players as participants provides a convenient 'laboratory' group for understanding the outcome of repeated mild head injuries in general.
- (3) The extensive neuropsychological battery meant that a clear pattern of deficit across several tests became evident. This pattern could then be compared with known patterns associated with diffuse brain damage injury in order to draw conclusions.
- (4) The large cohort of subjects provided a robust data base within which to investigate subsets of participants. Moreover, the larger sample size served to improve on the results from the initial phase of the research in that results were immediately evident in a declining central tendency without having to resort to an examination of variability data. In addition, the larger rugby sample with an IQ range from average to superior increases the generalizability of results to all elite rugby players.
- (5) The use of a normative perspective, together with a comparison with a control group offered an informative rendering of the situation. The normative comparison standard was based on norms drawn from a university population with a relatively similar high level of cognitive functioning to the participants in the research which implied that deficits in functioning could be detected. Should norms derived from the general population have been used, these deficits may not have been as readily apparent.
- (6) The use of the hockey players as the control group was an improvement on that of the cricket players used in the initial phase of the research. Their heightened performance served to enhance visibility of the compromised functioning of the rugby players.
- (7) The location of this study within a theoretical framework meant that the hypotheses were conceptually coherent in terms of the tenets of brain reserve capacity, and the discussion of the results was able to move beyond an empirical plane into more fully articulated and integrated scientific theory.

- (8) The study provides an understanding of the nature of cognitive effects following mild head injury in contact sport and thereby allows sports personnel and health professionals to institute appropriate rules, training procedures and legislation for both amateur and professional players. On a broader level, this study extends and elaborates on current research on mild head injury in general.

This study also embodies several limitations:

- (1) Although, several methodological precautions were taken to minimize the problems associated with group comparisons, it was not possible to control completely in every data set for balanced age ranges, balanced numbers of subjects and matched levels of education and IQ. Where relevant differences occurred, these were taken into account in the interpretation of results. In the main, they were not considered to be of major significance aside from the lower premorbid IQ of Under 21 Rugby group, relative to the Hockey Control group. However, the Under 21 Rugby mean scores were not globally lowered relative to the norms, and the Under 21 Rugby backline mean scores held relative to the norms, suggesting that the effects of the demographic data on results was negligible.
- (2) This study was restricted to an examination of cross-sectional groups with normative data and thus the possibility of pre-selected group differences cannot be entirely ruled out. There may be inherent differences between those who choose to play rugby and those who choose to play hockey that may have affected their neuropsychological test performance and were not captured adequately in the variables controlled. However, the results are consistent with theoretical indications which imply that the differences are due to brain damage, and that pre-selection is highly unlikely to be the case.
- (3) The choice of the norms drawn from a university population for comparison with the Under 21 Rugby group may have been somewhat problematic in that these participants tended to be younger and had not reached tertiary levels of education. Nevertheless, as noted in (1) above, their mean scores were not lowered on all tests relative to the norms, but rather on specific tests sensitive to the effects of diffuse brain damage. In addition, the mean scores of the backline players were not significantly lowered, suggesting that the use of the normative group as a comparison standard was acceptable.
- (4) The findings may not necessarily be representative of the rugby playing population as a

whole, thus, whether or not they can be extrapolated to amateur or lower exposure rugby players remains to be determined by future investigations.

- (5) The hockey players themselves had a history of previous mild head injury which weakened their appropriateness as a comparison group. However, compared with the cricket players from the initial phase of the research, they were much improved in that they enhanced the compromised functioning in the rugby players. It appears that sports playing groups as a whole are predisposed to head injuries, in which case, future research may have to find better alternatives (i.e. comparison groups relatively free from exposure to possible mild head injury).

#### **4.5 RECOMMENDATIONS**

The outcome of this study highlights several routes for future research:

- (1) The data collected in this study may be used as comparative standards in prospective follow-up studies to investigate deterioration of performance over the long-term as a result of further exposure to mild head injuries.
- (2) Additional studies should be carried out in a similar manner using different groups of rugby players such as schoolboy rugby players, older players, amateur players or those who have had less exposure to mild head injuries, in order to supplement the current findings and make them more widely applicable.
- (3) Furthermore, testing participants under differing conditions, for example, using tests of higher task challenge or testing under hypoxic conditions, opens up the possibility of detecting underlying functional impairment or identifying players at risk for future cognitive deficit.
- (4) Further studies using variability data and not only group mean differences should be conducted in order to elicit additional evidence for the Shuttle model of variability and brain reserve capacity theory in relation to mild head injury.
- (5) Finally, a more qualitative analysis of the extent to which the cognitive deficits noted affect the everyday living of the rugby players, should be undertaken.

## 4.6 CONCLUSION

This study set out to investigate the cognitive sequelae consequent on cumulative mild head injuries in rugby. The findings provide strong evidence that elite rugby may be associated with cognitive impairment following the cumulative effects of mild head injury, and it seems likely that these deficits are permanent. The observed impairment in neuropsychological function preferentially involves working memory, information processing and visuoperceptual tracking at speed. Rugby forward players tend to be more vulnerable to cognitive impairment because they are more likely to be involved in tackling and collisions with other players and experience a higher frequency of rugby-related mild head injuries. Furthermore, the current findings are consistent with those from the initial phase of the research by Reid (1998), suggesting that they are sufficiently robust to be taken seriously. Coaches, sports administrators, medical personnel, spectators, and the players themselves, need to be warned about the potential deleterious cognitive effects of cumulative mild head injury in rugby. In addition, these findings call for additional prevention measures, which maximise safety, and for further energetic research, particularly at school level.

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## **APPENDICES**

**I: Consent Forms**

**II: Pre-assessment Questionnaire**

**III: Neuropsychological Test Battery**

**IV: Pro-rated IQ Scores and Level of Education for Rugby and Hockey Players**



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### **NEUROPSYCHOLOGICAL ASSESSMENT RESEARCH: CONSENT FORM**

I hereby consent to undergo a neuropsychological assessment. I understand the following:  
(i) that the assessment takes 1½ to 2 hours per person, and will be conducted by a skilled clinician trained at Rhodes University; (ii) that the assessment involves a series of questions and a variety of intellectual tests which will not be harmful and are usually quite enjoyable for the testee; (iii) that the results will serve as a group data base for comparative purposes between sportsmen who are intensively involved in a contact sport and those who are not; (iv) that individual results will be *totally confidential and remain anonymous*

I further understand that the information gained in my assessment will not be divulged to anyone other than myself on request, and will have no implications with respect to my ability to play sport at the national level.

Name: \_\_\_\_\_

Signed: \_\_\_\_\_

Date: \_\_\_\_\_

**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 \_\_\_\_\_

---

### **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 \_\_\_\_\_
- 

**Injury 4**

- 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 5**

- 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? \_\_\_\_\_

---



---

#### Question 16

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 \_\_\_\_\_

#### 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 \_\_\_\_\_

### 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 \_\_\_\_\_
-

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

SLEUTEL  
 KEY

1	2	3	4	5	6	7	8	9
-	/	□	L	U	O	^	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"	Aantal half korrek	120"	TOTAAL	120"
Number correct	90"	Number half correct	90"	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 ..... Datum .....  
NAME ..... 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)

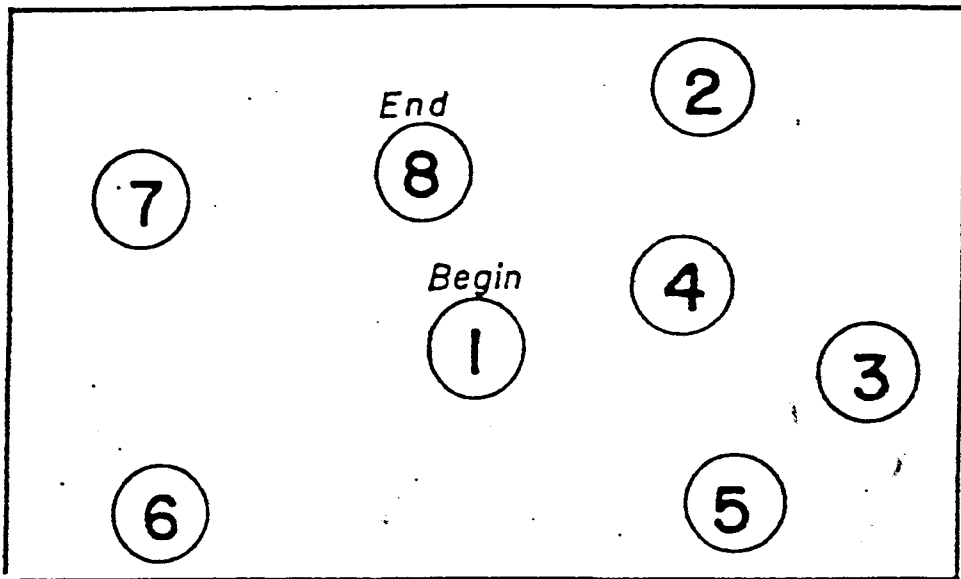
Draw a line to join the circles consecutively by alternating between 1 and A, as fast as you can.

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

# TRAIL MAKING

## Part A

SAMPLE



15

17

21

20

19

16

18

4

22

5

13

6

*Begin*

24

1

7

14

2

8

10

3

9

*End*

25

11

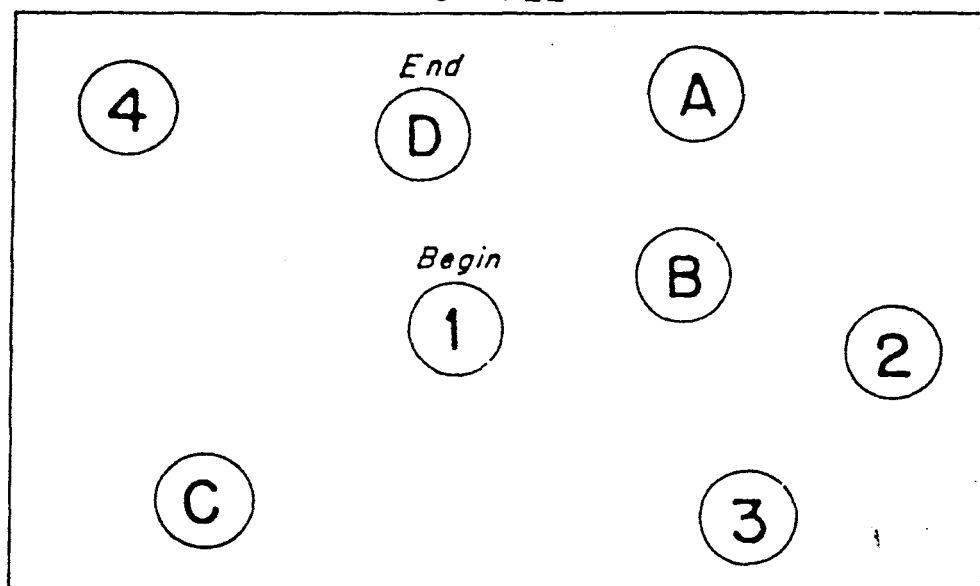
12

23

# TRAIL MAKING

## Part B

SAMPLE



*End*

13

8

9

B

4

I

D

10

3

*Begin*

1

7

H

5

12

C

G

A

J

2

6

L

E

F

11

K

**WORDS-IN-A-MINUTE**

Testee's Name: \_\_\_\_\_

**Requirements:** stop watch

**TIMED**

**Time Limit:** 1 minute

**Instruction:** *The subject can do this test in Afrikaans if that is their first language.*

“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 a person's name or the name of a city. For example, you cannot say Mary or Jane or Grahamstown. You also cannot use different versions on one word. For example, if you say sing, you cannot also say singing, sings or sang. Counting or sentences are also not allowed. In other words I am asking you to say different, unconnected words such as, picture, carpet, music, dog, sky, building, grass and so on. Do you understand? Just keep going, I will tell you to stop after one minute. Go.”

*Instructions 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 ..... Datum .....  
NAME ..... 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 veriang word nie.

L.W.: Moet nooit oorgaan na die volgende vraag voordat seker gemaak is dat die betekenis van eike 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:**

<u>First Recall</u>	<u>Second Recall</u>	<u>Third Recall</u>
TOTAL _____	TOTAL _____	TOTAL _____
<u>Easy:</u> 1. _____	<u>Hard:</u> 1. _____	_____
2. _____	2. _____	_____
3. _____	3. _____	_____
A Total _____	B Total _____	_____
<u>Score:</u> $A/2 + B =$ _____		

Read 1 pair every 2 seconds.

First Presentation

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

Second Presentation

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

Third Presentation

Baby - Cries  
 Obey - Inch  
 North - South  
 School - Grocery  
 Rose - Flower  
 Cabbage - Pen  
 Up - Down  
 Fruit - Apple  
 Crush - Dark  
 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

	<u>Easy</u>	<u>Hard</u>
North	_____	
Fruit	_____	
Obey		_____
Rose	_____	
Baby	_____	
Up	_____	
Cabbage		_____
Metal	_____	
School		_____
Crush		_____
<b>TOTAL</b>	_____	_____

Second Recall

	<u>Easy</u>	<u>Hard</u>
Cabbage		_____
Baby	_____	
Metal	_____	
School		_____
Up	_____	
Rose	_____	
Obey		_____
Fruit	_____	
Crush		_____
North	_____	
<b>TOTAL</b>	_____	_____

Third Recall

	<u>Easy</u>	<u>Hard</u>
Obey		_____
Fruit	_____	
Baby	_____	
Metal	_____	
Crush		_____
School		_____
Rose	_____	
North	_____	
Cabbage		_____
Up		_____
<b>TOTAL</b>	_____	_____

Easy: 1. \_\_\_\_\_  
 2. \_\_\_\_\_  
 3. \_\_\_\_\_  
 A Total \_\_\_\_\_

Hard: 1. \_\_\_\_\_  
 2. \_\_\_\_\_  
 3. \_\_\_\_\_  
 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:**

<u>First Recall</u>	<u>Second Recall</u>	<u>Third Recall</u>
TOTAL _____	TOTAL _____	TOTAL _____

Easy: 1. \_\_\_\_\_  
2. \_\_\_\_\_  
3. \_\_\_\_\_  
A Total \_\_\_\_\_

Hard: 1. \_\_\_\_\_  
2. \_\_\_\_\_  
3. \_\_\_\_\_  
B Total \_\_\_\_\_

Score: A/2 + B = \_\_\_\_\_

Read 1 pair every 2 seconds.

First Presentation

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

Second Presentation

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

Third Presentation

Baba - Huil  
 Luister - Duim  
 Noord - Suid  
 Skool - Winkel  
 Roos - Blom  
 Kool - Pen  
 Op - Af  
 Vrugte - Appel  
 Breek - Donker  
 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

	<u>Easy</u>	<u>Hard</u>
Noord	_____	
Vrugte	_____	
Luister		_____
Roos	_____	
Baba	_____	
Op	_____	
Kool		_____
Metaal	_____	
Skool		_____
Breek		_____

**TOTAL** \_\_\_\_\_

Easy: 1. \_\_\_\_\_  
 2. \_\_\_\_\_  
 3. \_\_\_\_\_  
 A Total \_\_\_\_\_

Second Recall

	<u>Easy</u>	<u>Hard</u>
Kool		_____
Baba	_____	
Metaal	_____	
Skool		_____
Op	_____	
Roos	_____	
Luister		_____
Vrugte	_____	
Breek		_____
Noord	_____	

**TOTAL** \_\_\_\_\_

Hard: 1. \_\_\_\_\_  
 2. \_\_\_\_\_  
 3. \_\_\_\_\_  
 B Total \_\_\_\_\_

Third Recall

	<u>Easy</u>	<u>Hard</u>
Luister	_____	
Vrugte		_____
Baba	_____	
Metaal	_____	
Breek		_____
Skool	_____	
Roos	_____	
Noord	_____	
Kool	_____	
Op		_____

**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 if 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 5<sup>th</sup> trial - they receive a supraspan B score of 5. If they get the 5<sup>th</sup> trial wrong - they would need to get the 6<sup>th</sup> and 7<sup>th</sup> trials correct to get a supraspan B score of 7. Continue until the 10<sup>th</sup> 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."

<u>First Recall</u>	<u>Easy</u>	<u>Hard</u>
North	_____	
Fruit	_____	
Obey		_____
Rose	_____	
Baby	_____	
Up	_____	
Cabbage		_____
Metal	_____	
School		_____
Crush		_____
<b>TOTAL</b>	_____	_____

**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."

<u>First Recall</u>	<u>Easy</u>	<u>Hard</u>
Noord	_____	
Vrugte	_____	
Luister		_____
Roos	_____	
Baba	_____	
Op	_____	
Kool		_____
Metaal	_____	
Skool		_____
Breek		_____
<b>TOTAL</b>	_____	_____

**SCORE:**

Delayed recall = \_\_\_\_\_

## APPENDIX IV

### PRO-RATED IQ SCORES AND LEVEL OF EDUCATION

#### Springbok Rugby (n=26)

Participant No.	Comp (Scaled Scores)	Pic Com	Pro-rated IQ	Educational Level (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 (omitted)	96	15
23 (B)	12,5	15,0	132	15
24 (F)	14,0	14,0	133	16
25 (F)	13,5	12,5	125	12
26 (B)	10,5	8,5	96	12

#### Key:

Comp	- Comprehension
Pic Com	- Picture Completion
(F)	- Forward player
(B)	- Backline player

#### Cricket (Participant No.s: 27-47)

**Under 21 Rugby (n=19)**

Participant No.	Comp (Scaled Scores)	Pic Com	Pro-rated IQ	Educational Level (Years)
48(B)	12,0	8,5	103	12
49(B)	10,0	10,0	100	12
50(F)	10,0	12,5	111	14
51(B)excluded	8,5	6,0	77 (<85)	12
52(F)	14,0	14,5	136	14
53(F)	10,5	9,5	100	13
54(B)	9,5	10,0	98	10
55(F)	9,5	14,5	117	15
56(F)	11,0	12,5	115	12
57(F)	11,5	11,0	111	12
58(B)	12,5	13,0	123	13
59(F)	8,5	10,5	96	11
60(F)	12,0	9,5	107	13
61(F)	13,0	10,5	115	13
62(B)	10,0	12,5	111	14
63(B)	8,0 (omitted)	12,5	121	12
64(F)	10,5	8,5	96	8
65(F)	11,0	14,5	123	12
66(B)	11,0	11,0	108	12
67(B)	8,5	12,5	104	12
68(F)excluded	7,5	7,0	76 (<85)	11

**Hockey (n=21)**

69	14,0	12,5	128	13
70	7,5 (omitted)	12,5	121	12
71	12,0	12,5	119	16
72 excluded	15,5	15,0	144 (>140)	16
73	14,0	14,5	136	15
74	10,0	15,0	121	15
75	13,5	14,5	133	14
76 excluded	16,0	14,5	144 (>140)	15
77	14,0	14,5	136	12
78	15,5	11,0	128	16
79	11,5	14,5	125	14
80	13,5	10,0	115	12
81	13,0	12,5	123	15
82	10,0	12,5	111	16
83	11,5	14,5	125	15
84	13,5	12,5	125	14
85	11,5	11,0	111	15
86	13,0	15,0	133	15
87	11,5	13,5	125	15
88	11,5	10,0	107	14
89	9,5	12,5	108	14
90	12,5	12,5	121	15
91	10,0	12,5	111	14